

Sentry Fire-Safe: Improvements to the Pre-Fill Work Cell

Team Leader - Nicole Heiges ISE

Craig Adamson- ME

Seth Reightler- ME

Sumeet Gupta- ME

Josephine Ryan- ISE

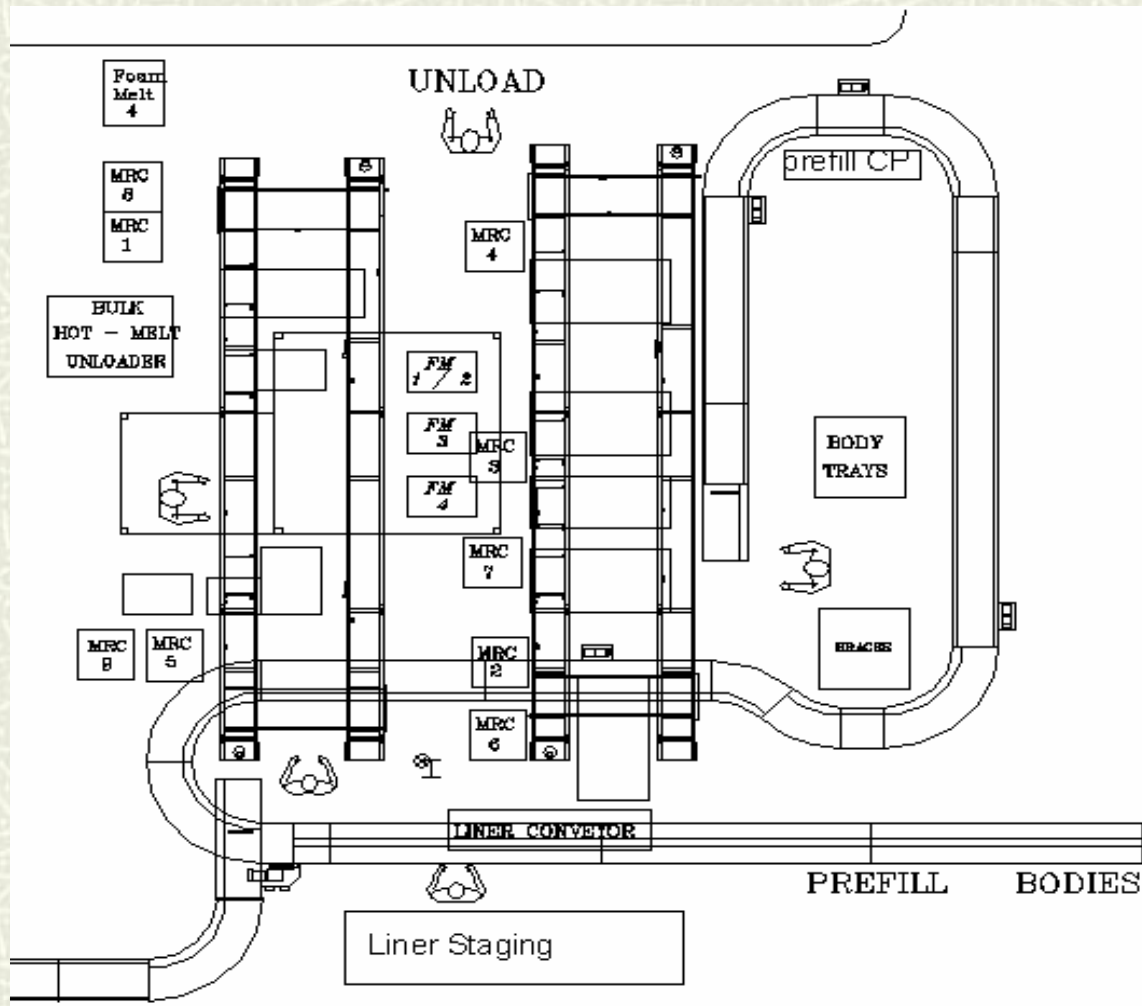
Katie McConky- ISE

Christopher Tiede- ME

Outline

- # How the Pre-Fill Work Cell Operates
- # Needs Assessment
- # Concepts
 - Simulation
- # Feasibility Assessment
- # Specifications
- # Analysis & Synthesis
- # Preliminary Design

Pre-Fill Work Cell Layout



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Overview of Door Assembly



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Overview of Body Assembly



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Needs Assessment

Mission Statement

- Effectively work as a team to review the overall pre-fill work cell operations and make critical improvements to the six areas provided by Sentry.

Six Areas

- Overall Method
- Part Design
- Eliminate Hot-Melt Sealing
- Layout
- Work Content at Each Station
- Ergonomics

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Needs Assessment - Level 3

▣ Budget

- \$200,000 – 300,000 Maximum.

▣ Technology

- Investigate Alternatives to the Use of Hot-Melt.
- Comprehensive Simulation Model.

▣ Performance

- Sentry Should Produce 2,600 Safes/Day Over Two Shifts.
- Reduction in Number of Safes Leaking Concrete.
- Improvements to Flow and Design Should Redeploy One Worker.

Door Concepts

Hot-Melt Removal

- Perimeter
 - Gaskets
- Interior Holes
 - Post-Cure Hole Press Fixture
 - Wax Plug / Four-Pronged Plug Handle

Screw Removal

- Snap-Fit
 - Metal Tab
 - Plastic Extrusion
 - Single-Arm, Double-Arm, and Ball & Socket

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Body Concepts

- # Body Sealing - Improve Hot-Melt
 - Rework Hot-Melt Robot
 - Addition of Rotating Robot
- # Liner / Body Interface
 - Increase Lip Width on Liner
 - Gasket
- # Body Sealing - Eliminate Hot-Melt
 - Liquid Spray
 - Brazing
 - Powder Coating Seams

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Simulation Model

Created Simulation Model

Used for:

- Concept Development
- Feasibility Assessment
- Analysis and Synthesis
 - Layouts and Operator Loading

Operator Concepts

Operator 1

- Standardize Work Methods
- Train Operator in Ergonomics
- Install Rolling Conveyor from Chain to Line

Operator 2

- Standardize Work Methods
- Rearrange Work Station to Eliminate Waste and Improve Ergonomics
- Redesign Set-Screw Process

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Operator Concepts (cont.)

Operator 3

- Standardize Work Methods
- Orient Liners in Same Direction on Pallet / Place a Mark on the Liner.
- Create Stacking Bases
- Install a Pallet Lift, Step, or Turn Table

Operator 4

- Eliminate Wait Time
- Lower the Conveyor Belt
- Use a Pallet Jack to Move Pallets
- Install a Pallet Lift, Step, or Turn Table

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Pre-Fill Concepts

Current Layout

- Central Operators Layout #1
- Central Operators Layout #2

Material Handling

- Install a Conveyor to Return Bases
- Place Visual Markings on the Floor for Cages and Pallets
- Create a Standard Base Storage System

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Feasibility Assessment

Used "Weighted Concepts" Method

Attributes:

- Cost
- Cost Savings
- Operator Time Saved
- Ergonomic Improvement*
- Time Saved
- Outside Vendor Involvement
- Involvement of Moving Robots
- Involvement of Redesign
- Sentry Approval
- Safety*
- Affect on Other Work Areas
- Downtime Prevention

* Used where applicable

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Results of Weighted Concepts: Operator & Pre-Fill

| Task | Rating | Elimination |
|------------------------------------------------------------|--------|------------------------------------------------------------------------------------|
| Train Operators in Ergonomics 1 | 4.05 | |
| Place pallet beside operator 2 | 4.05 | |
| Standardize Work methods 2 | 3.99 | |
| Orient liners all in the same direction on pallet 3 | 3.96 | |
| Visual markings on the floor for cages/ pallets | 3.93 | |
| Standardize work methods 3 | 3.87 | If the bases are stacking (Sentry is already doing) it will eliminate this problem |
| Rearrange work cell to eliminate twisting 2 | 3.81 | |
| Create Standard base storage system 3 | 3.81 | |
| Create Standard base storage system 4 | 3.81 | |
| Create stacking bases 3 | 3.70 | Sentry is implementing this as they create new bases |
| Use a sensor to locate a person/ eliminate finger switch 4 | 3.69 | |
| Standardize Work methods 1 | 3.65 | |
| Manipulate chain speed to reach TAKT 1 | 3.63 | Can not clean large safes fast enough to do this |
| Insert a weight controlled lifting table 3 | 3.61 | |
| Place obvious mark on liner | 3.61 | Upon reinspectin there are clear enough indicators on liners already |
| Install rolling Conveyor from Chain to body conveyor 1 | 3.55 | |
| Add Carts and sensor to locate person 3 | 3.54 | |
| Redesign Cell in "U" shape | 3.40 | |
| Change pallet loading pattern 2 | 3.38 | |
| Operators 3 and 4 close together | 3.22 | |
| Install Pallet Lift | 3.21 | Eliminated by Weighted Concepts |
| Use Pallet lift system | 3.21 | Eliminated by Weighted Concepts |
| Base return conveyor | 3.08 | Eliminated by Weighted Concepts |
| Self Feeding Screw Driver | 3.01 | Eliminated by Weighted Concepts |
| Install a Step | 2.99 | Eliminated by Weighted Concepts |
| Install a turntable | 2.92 | Eliminated by Weighted Concepts |
| Place tote on rotating conveyor | 2.92 | Eliminated by Weighted Concepts |
| Use a pallet jack to move heavy pallets | 2.89 | Eliminated by Weighted Concepts |
| Lower the conveyor | 2.33 | Not Feasible |
| DO NOTHING | 2.89 | Baseline |

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Results of Weighted Concepts: Door & Body

| Task | Rating | Elimination |
|-----------------------------------------|--------|----------------------------------------------------------|
| Single-Arm Snap Fit | 2.46 | |
| Double-Arm Snap Fit | 2.46 | |
| Ball & Socket Snap Fit | 2.46 | Unable to create Snap Fit in mold process |
| Increase Surface Area | 2.15 | |
| Snap Fit Set Screw | 2.07 | Other Snap Fit ideas more feasible |
| Metal Tab Snap Fit | 2.07 | Other Snap Fit ideas more feasible |
| "Garbage Bag" | 2.02 | Tried and Failed by Sentry Safe |
| Liquid Spray Sealant | 2.02 | |
| Gasket (Liner Interface) | 2.00 | |
| Plastic Extrusion Snap Fit | 1.98 | Other Snap Fit ideas more feasible |
| Post-Cure Hole Press Fixture | 1.98 | Too big of a change in production process |
| Rework Current Hot Melt Delivery System | 1.95 | |
| Epoxy Sealant | 1.87 | Too big of a change in production process |
| Wax Plug | 1.84 | Hot Melt is not a problem with holes |
| Change of Hot Melt | 1.82 | Not solving problem of use of hot melt |
| Addition of Rotating Robot | 1.75 | "Harder to move the mountain than the mole" |
| U-Shaped Gasket | 1.70 | Eliminated by Weighted Concepts |
| Slotted Gasket | 1.70 | Eliminated by Weighted Concepts |
| Hot Melt Tape | 1.61 | Eliminated by Weighted Concepts |
| 4-Pronged Plug Handle | 1.49 | Eliminated by Weighted Concepts |
| Resistance Welding along Vertical Seam | 1.48 | Eliminated by Weighted Concepts |
| Brazing | 1.36 | Eliminated by Weighted Concepts/Unable to pass drop test |
| Powdercoated Seams | 1.20 | Eliminated by Weighted Concepts |
| DO NOTHING | 1.70 | Baseline - Eliminated by Purpose of SD |

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Specifications

■ Performance Specifications

- Cost
 - Redeploy an Operator / Robot
 - Reduce Material Costs
 - Reduce Maintenance Costs (~\$100,000 / Year)
- Eliminate Unnecessary Steps in the Pre-Fill Process
- Improve Ergonomics for the Operators
- One Year Return on Investments
- Safe Must Pass Burn / Drop Test

■ Design Specifications

- Final Layouts Drawn in AutoCAD
- Assembly Parts Drawn in Pro-Engineer
- All Units use the English System

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Analysis & Synthesis

- # Operator Balance and Standard Work Instructions
- # Does Orienting Body Liners on Pallet Save Time?
- # Are Operator Workloads in the New Layouts Feasible?
- # Logistics Improvements
- # Ergonomic Concerns
- # Eliminating Hot-Melt
- # Snap-Fit

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Operator Balance & Standard Work Instructions

Analysis

- Time Studies Performed on All Four Operators
- Standardizing Tray Stack Height for Operator 3
- Creating Standard Work Instructions
 - Saves 1.5 Seconds for Operator 1
 - Saves 3.5 Seconds for Operator 2

Known Information

Desired Information

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Does Orienting Body Liners on Pallet Save Time?

■ Analysis

- Operator 3 was timed using current pallet pattern then using the proposed pallet pattern.
- 1.8 seconds per safe was saved with the proposed pallet pattern.

- Known Information
- Pallet Patterns
- Desired Information

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Are Operator Work Loads in the New Layouts Feasible?

Analysis

- Simulation model was used to see if operators could handle work load with new layouts

Known Information

Desired Information

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Logistics Improvements

Analysis

- Room is Available to Place Markings on Floor
- Sentry is already making stacking trays based on our recommendation.

Known Information

Desired Information

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Ergonomic Concerns

Analysis

- Used NIOSH Lifting Equation to Evaluate Lifting Tasks
- No tasks were found to pose an ergonomic risk when completed properly.
 - Some Improper Lifting Techniques Were Being Used
 - Train Operators in Ergonomics and Proper Lifting

Known Information

Desired Information

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Eliminating Hot-Melt From the Body of the Safe

Analysis

■ Spray Sealant

■ Performed Test & Cost Analysis

- One Can Effectively Seals Ten Safes
- Savings of \$137,000 / Year

■ Found to be Cancer Causing

- Searching for Alternative

Known Information

Desired Information

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Eliminating Hot-Melt From the Body of the Safe

- Swivel Hose
- Increase Lip Width on Liner
 - Lip Width = $.0345 * \text{Draft Angle Reduction} + .2302$
 - Minimum Reduction: $>1.15^\circ$
- Gasket

Known Information

Desired Information

Snap-Fit

Analysis

- Part Geometry and Snap Design
- Cost Savings Greater Than \$60,000 Per Year
- Operator / Robot Redeployment

Known Information

Desired Information

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Preliminary Design: Operator & Pre-Fill

■ In Senior Design II:

- Standard Work Instructions
 - For Each Operator
 - Include Proper Ergonomic Instructions
- Orientation of Liners on Pallets
 - Coordinate Changes With Webster Plastic
 - The RIT Packaging Department Will Do a Shipping Test to Ensure the Liners Will Not Break.
- Place Visual Markings for Cages and Pallets on Floor
 - Coordinate With the Maintenance Department at Sentry

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Preliminary Design: Operator & Pre-Fill (cont.)

■ In Senior Design II:

- Create Stackable Cure Trays
 - Door: Currently Being Fabricated by Sentry
 - Body: Coordinate Fabrication With Sentry
- Standardize the Tray Storage System
 - Sentry Has Already Begun Replacing Pallets With Carts
- Redesign the Workstation so Function for Operators 2 and 3 Can Be Combined Due to Snap-Fit
 - Place Pallet Beside Operator 2 to Reduce Waste
 - Place Conveyors Closer Together to Eliminate Wait for Operator 4

Preliminary Design: Body & Door

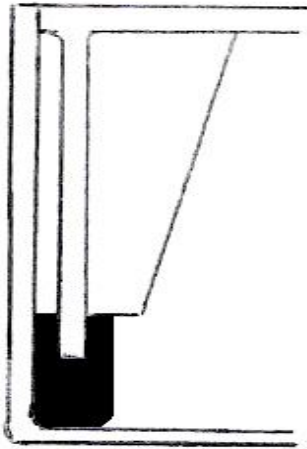
- # Increase the Liner and Body Interface
- # Implement Snap-Fit to Eliminate Screw Operation
- # Continue to Research Spray Sealants to Find a Cost Effective Non-Carcinogen



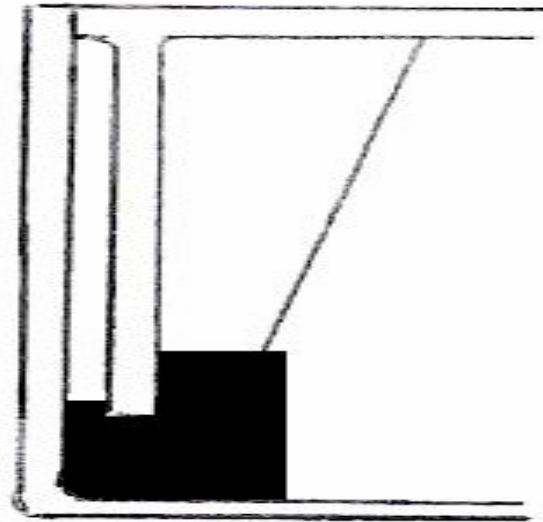
Questions?

Gaskets

U-Shaped Gasket



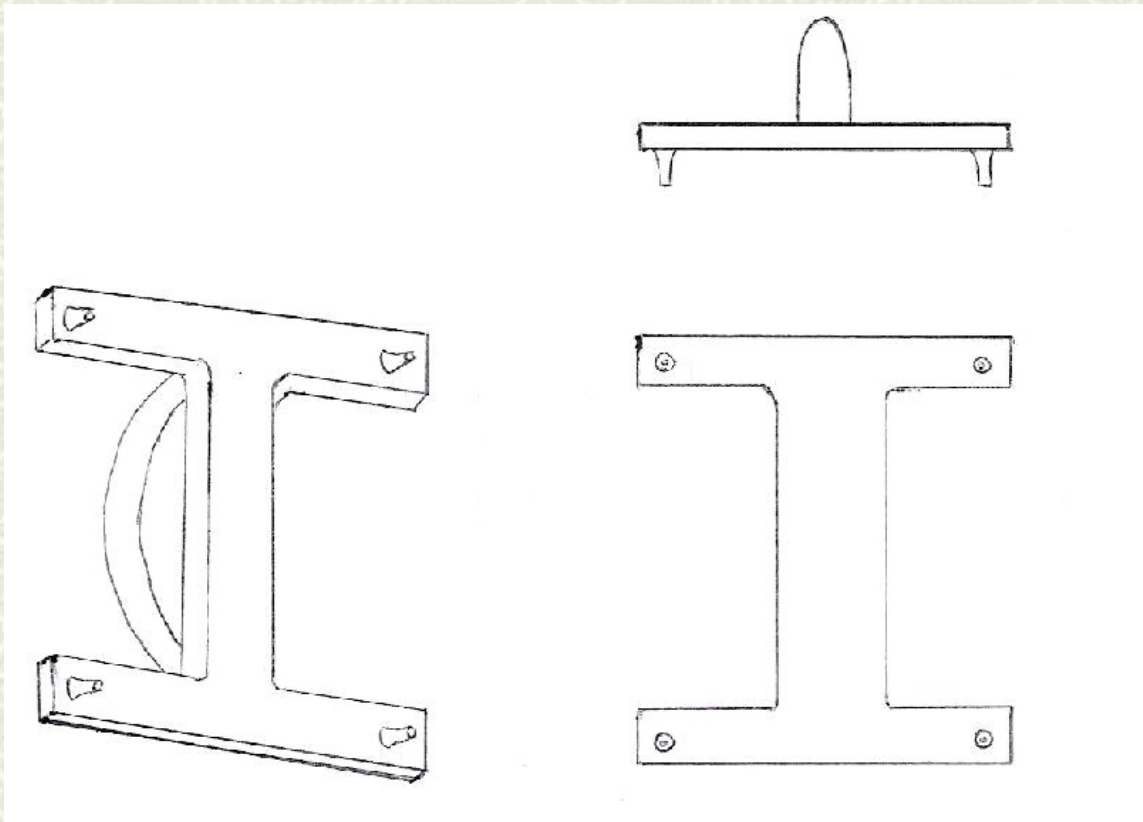
Slotted Gasket



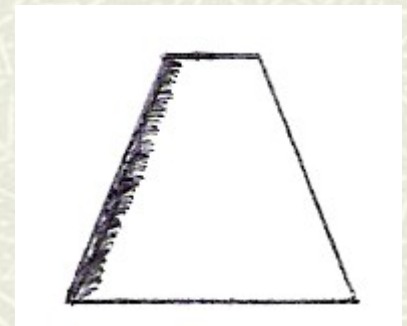
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Plugs

Four-Pronged Plug Handle

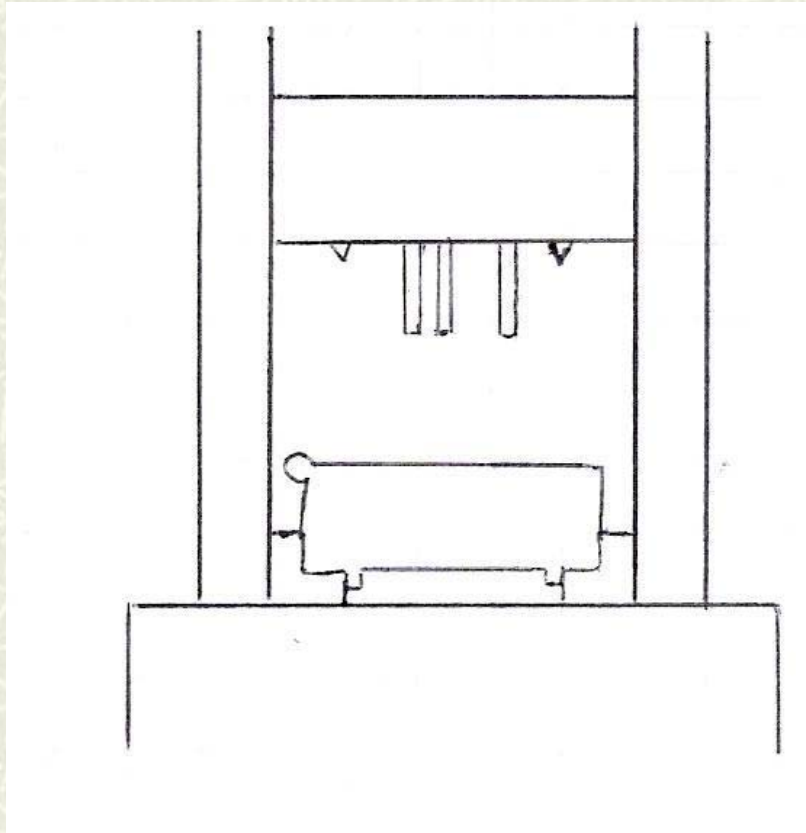


Wax Plug



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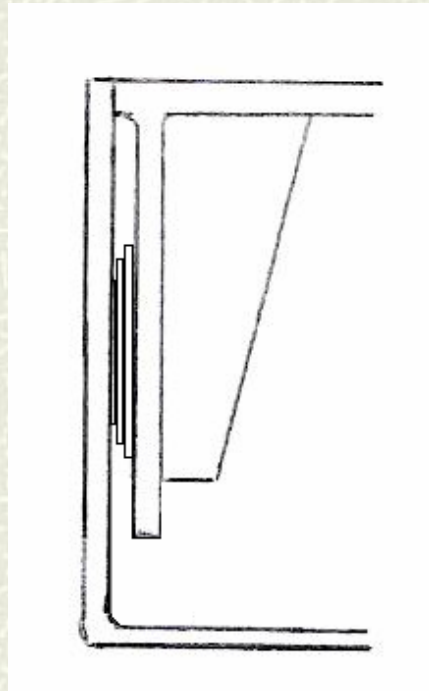
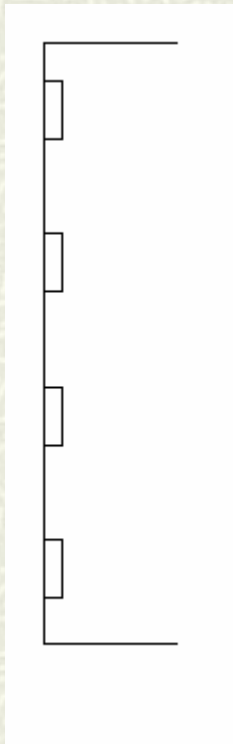
Post-Cure Hole Press Fixture



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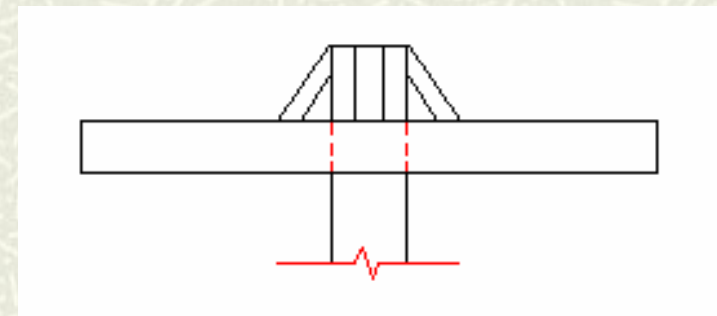
Snap-Fits

Metal Tab



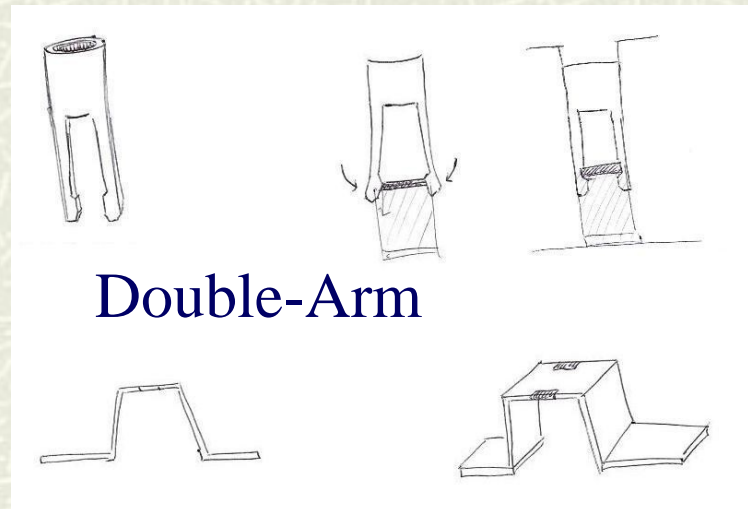
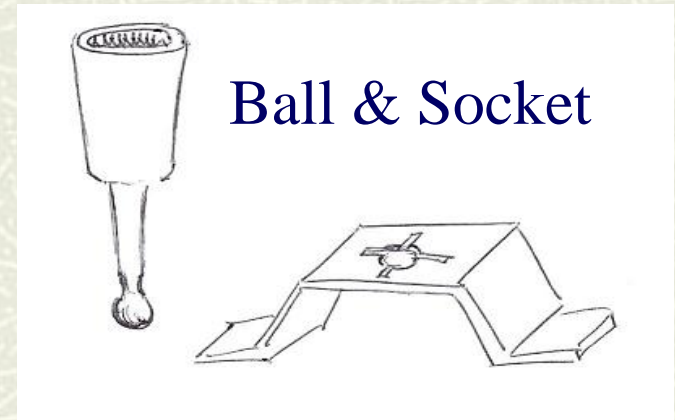
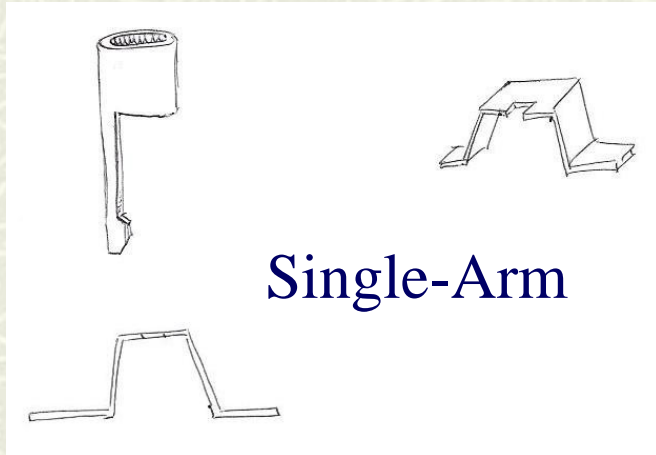
Plastic Extrusion

Snap Fit Set Screw



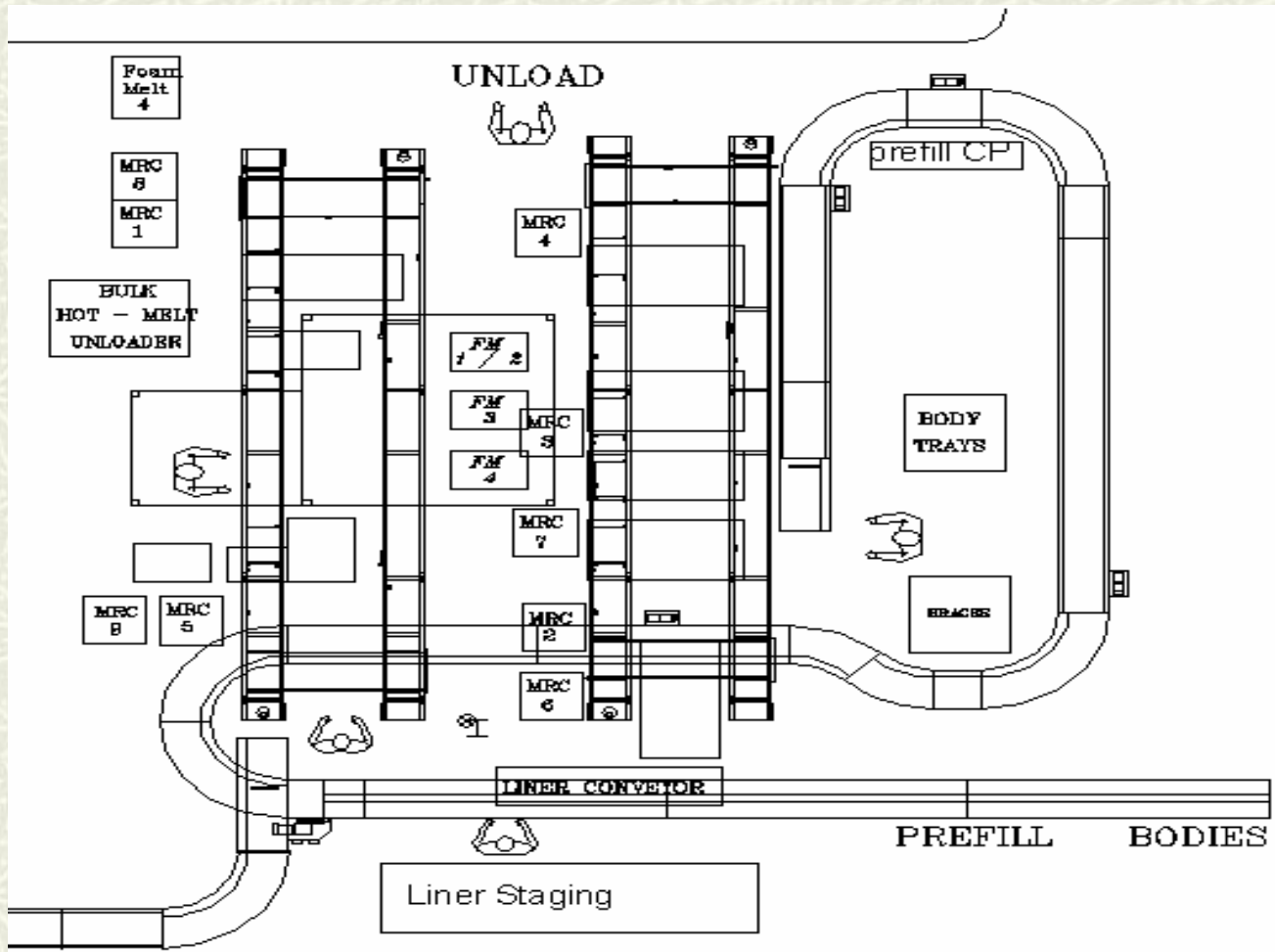
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Snap-Fits



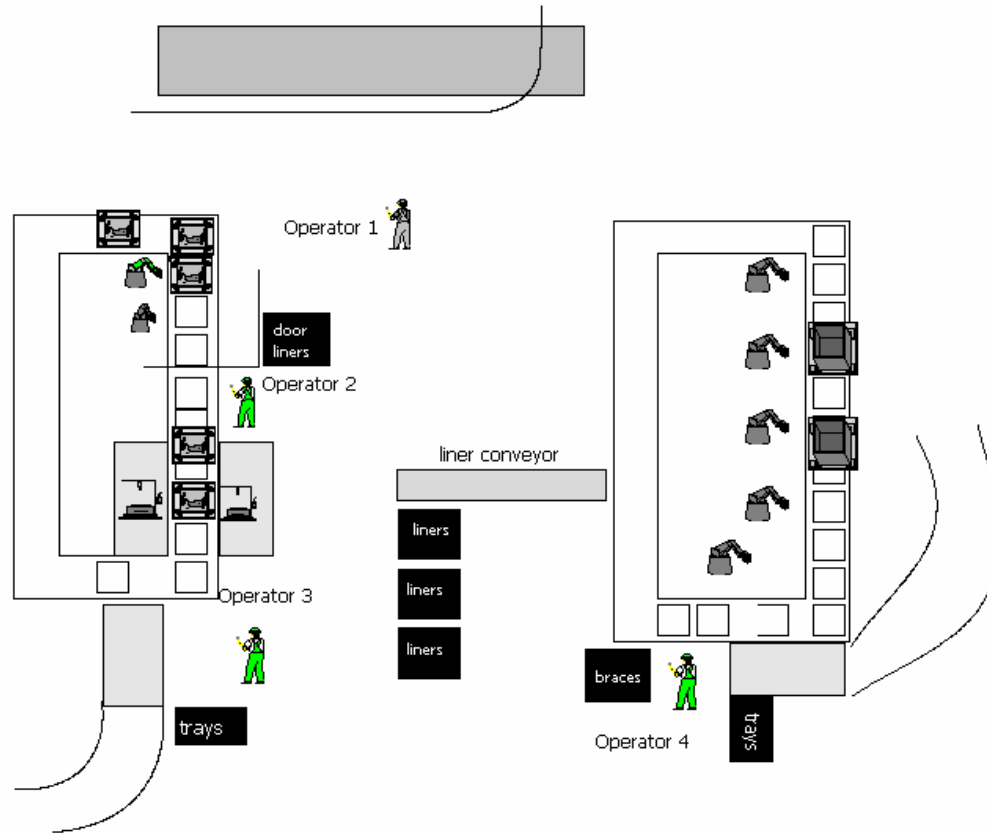
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Current Layout



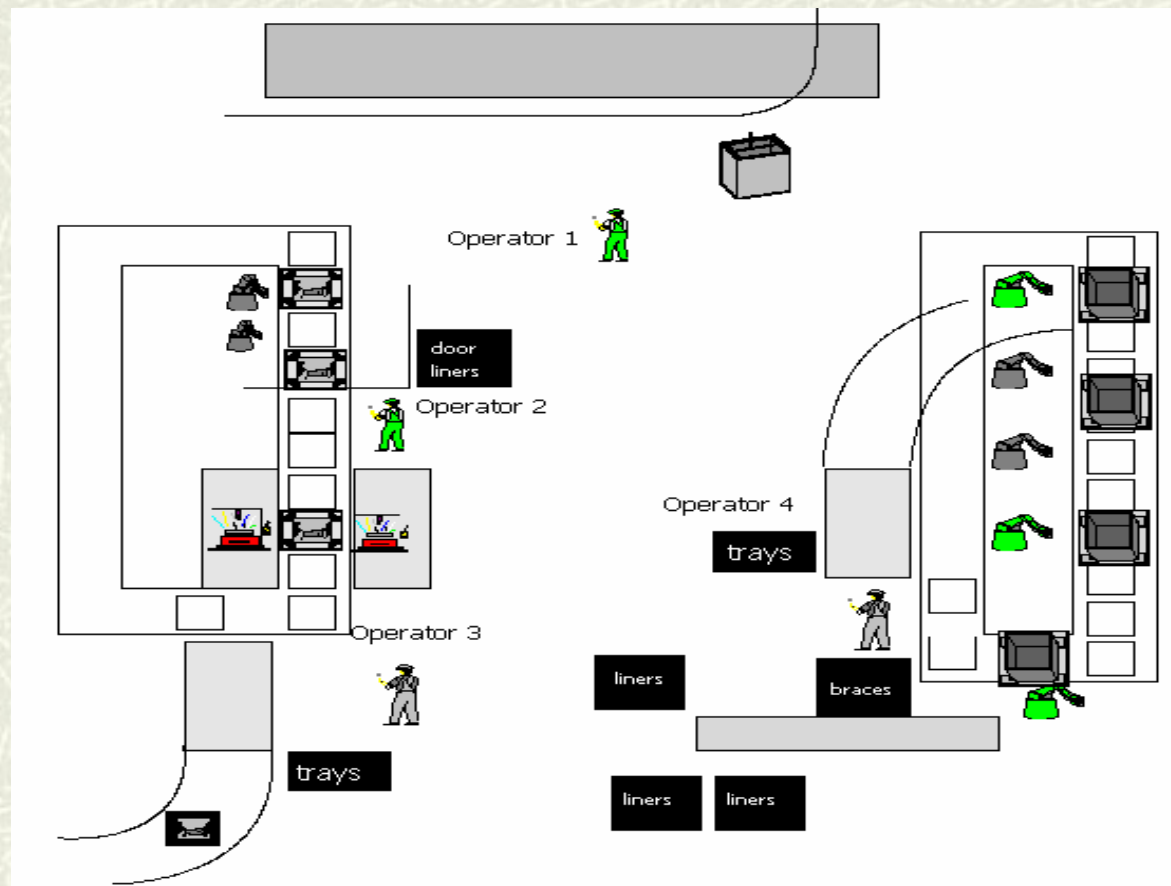
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Central Operators Layout #1



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Central Operators Layout #2



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Operator & Pre-Fill Concepts

Attribute Comparison

| | Cost Savings | Cost | Ergonomic Improvements | Operator Time Saved | Involves another vendor | Involves moving robots | Involves Redesign | Affects other work areas negatively | Prevents Downtime | Safety | Sentry Approved |
|-------------------------------------|--------------|------|------------------------|---------------------|-------------------------|------------------------|-------------------|-------------------------------------|-------------------|--------|-----------------|
| Cost Savings | X | ← | ← | ↖ | ← | ↖ | ← | ↑ | ↖ | ← | ↑ |
| Cost | | X | ← | ↖ | ← | ↖ | ← | ↑ | ↖ | ← | ↑ |
| Ergonomic Improvements | | | X | ↑ | ← | ← | ← | ↖ | ↑ | ↖ | ↑ |
| Operator Time Saved | | | | X | ← | ← | ← | ↖ | ← | ↑ | ↑ |
| Involves another vendor | | | | | X | ↑ | ↖ | ↑ | ↑ | ↑ | ↑ |
| Involves moving robots | | | | | | X | ← | ↑ | ↑ | ↑ | ↑ |
| Involves Redesign | | | | | | | X | ↑ | ↑ | ↑ | ↑ |
| Affects other work areas negatively | | | | | | | | X | ← | ↑ | ↑ |
| Prevents Downtime | | | | | | | | | X | ↖ | ↑ |
| Safety | | | | | | | | | | X | ↑ |
| Sentry Approved | | | | | | | | | | | X |

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Operator & Pre-Fill Concepts

Attribute Weights

| | | |
|--------------------------------------------|-----|-------|
| Sentry Approved | 10 | 0.182 |
| Affects other work areas negatively | 7 | 0.127 |
| Cost Savings | 6.5 | 0.118 |
| Operator Time Saved | 6.5 | 0.118 |
| Safety | 6 | 0.109 |
| Cost | 5.5 | 0.100 |
| Prevents Downtime | 5.5 | 0.100 |
| Ergonomic Improvements | 4 | 0.073 |
| Involves moving robots | 3 | 0.055 |
| Involves another vendor | 0.5 | 0.009 |
| Involves Redesign | 0.5 | 0.009 |

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Door & Body Concepts

Attribute Comparison

| | Cost Savings | Cost | Compatible with Current Process | Process Time Saved | Involves another vendor | Involves removing robots/workers | Affects other work areas negatively | Downtime | Sentry Approved |
|-------------------------------------|--------------|------|---------------------------------|--------------------|-------------------------|----------------------------------|-------------------------------------|----------|-----------------|
| Cost Savings | X | ← | ← | ↖ | ← | ↖ | ↑ | ↖ | ↑ |
| Cost | | X | ← | ↖ | ← | ↖ | ↑ | ↖ | ↑ |
| Compatible with Current Process | | | X | ↖ | ← | ↖ | ↖ | ↑ | ↑ |
| Process Time Saved | | | | X | ← | ↖ | ↖ | ← | ↑ |
| Involves another vendor | | | | | X | ↑ | ↖ | ↑ | ↑ |
| Involves removing robots/workers | | | | | | X | ↑ | ↑ | ↑ |
| Affects other work areas negatively | | | | | | | X | ↖ | ↑ |
| Downtime | | | | | | | | X | ↑ |
| Sentry Approved | | | | | | | | | X |

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Door & Body Concepts

Attribute Weights

| | | |
|--------------------------------------------|-----|-------|
| Sentry Approved | 8 | 0.262 |
| Cost | 4.5 | 0.148 |
| Cost Savings | 4.5 | 0.148 |
| Affects other work areas negatively | 3.5 | 0.115 |
| Downtime | 3 | 0.098 |
| Process Time Saved | 3 | 0.098 |
| Compatible with Current Process | 2.5 | 0.082 |
| Involves removing robots/workers | 1 | 0.033 |
| Involves another vendor | 0.5 | 0.016 |

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Operator & Pre-Fill Concepts

Attribute Rating Scale

| | 1 | 2 | 3 | 4 | 5 |
|--------------------------------------------|--------------------------------------------------|--------------------------------------------------------|----------------------------------------|--------------------------------|--------------------------------------------------|
| Sentry Approved | No | | Maybe | | Yes |
| Affects other work areas negatively | Need to add an operator or change entire process | Need to add a portion of an operator and tweak process | No Impact | Making other areas work easier | Significantly reduces work in another area |
| Cost Savings | None | Minimal | Justifies itself | Saves money | Saves substantial money |
| Operator Time Saved | 0 seconds | 0-1 second | 2-3 seconds | 3-4 seconds | > 4 seconds |
| Safety | Adds a safety Hazard | | No Impact | | Improves Safety |
| Cost | > 10,000 | < 7,000 | < 3,000 | < 500 | No cost |
| Prevents Downtime | Increase downtime | | No change in Downtime | | Prevents Downtime |
| Ergonomic Improvements | Makes worse, adds twisting or increase NIOSH | | No Ergonomic Change | | Improves, eliminates twisting or decreases NIOSH |
| Involves moving robots | All Robots Moved | Most Robots Moved | Some Robots Moved | Few Robots Moved | No Robots Moved |
| Involves another vendor | Involves multiple vendors | | Involves 1 vendor | | Involves no vendors |
| Involves Redesign | Redesign Sentry must complete | | Redesign Senior Design team can handle | | No Redesign |

Baseline = Current set up

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Door & Body Concepts

Attribute Rating Scale

| | 1 | 2 | 3 |
|--------------------------------------------|--------------------------------------------------|----------------------------------------|--------------------------------------------|
| Sentry Approved | No | Maybe | Yes |
| Cost | > 100,000 | < 50,000 | No cost |
| Cost Savings | None | Justifies itself | Saves substantial money |
| Affects other work areas negatively | Need to add an operator or change entire process | No Impact | Significantly reduces work in another area |
| Downtime | Increase downtime | No change in Downtime | Prevents Downtime |
| Process Time Saved | 0-1 second | 2-3 seconds | > 3 seconds |
| Compatible with Current Process | Redesign Sentry must complete | Redesign Senior Design team can handle | No Redesign |
| Involves removing robots/workers | 0 Robots or Workers Removed | 1 Robot or Worker Removed | 2 Robots or Workers Removed |
| Involves another vendor | Involves multiple vendors | Involves 1 vendor | Involves no vendors |

Baseline = Current set up

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Results of Weighted Concepts: Operator & Pre-Fill

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| Gasket (Liner Interface) | 2.00 | |
| Plastic Extrusion Snap Fit | 1.98 | Other Snap Fit ideas more feasible |
| Post-Cure Hole Press Fixture | 1.98 | Too big of a change in production process |
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Burn & Drop Test Specifications

- ⌘ Safe Heated to 1770 °F for 45 Minutes
- ⌘ Safe Dropped From 30 Feet Within Two Minutes
- ⌘ Safe Cooled to Ambient Temperature
- ⌘ Safe Turned Upside-Down and Heated to 1770 °F for 45 Minutes
- ⌘ Safe Cooled to Ambient Temperature
- ⌘ Papers in the Safe Must Be Readable After Test

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Operator Balance & Standard Work Instructions

Known Information

- Different operators have different methods for working at each station.
- Some of the methods take longer than others.
- There is currently no standard method of working at each station.
- There is one optimal method that takes the shortest amount of time and should be made standard.
- Some operators have waiting time in their tasks.
- Changing the operator load may result in an elimination of an operator and cost savings of \$80,000 per year over two shifts.

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Operator Balance & Standard Work Instructions

Desired Information

- Which method is the best and fastest method?
- How much time can be saved if all operators use the fastest method?
- How much time must be eliminated in order to reduce one operator?

Operator Balance Chart

Operator Balance

■ Currently 3.78 Operators Are Needed

Current Set up: Produce 2650 safes per day (chain at 11.2 ft/min)

| | Total Time | Waiting Time | Process Cycle Time | 85% of TAKT |
|-------------|------------|--------------|--------------------|-------------|
| Operator 1: | 12.02 | 1.66 | 16.1 | 13.69 |
| Operator 2: | 13.02 | 0.67 | 16.1 | 13.69 |
| Operator 3: | 12.90 | 0.78 | 16.1 | 13.69 |
| Operator 4: | 13.81 | -0.12 | 16.1 | 13.69 |

TOTAL: 51.75 # of Ops: 3.78
Seconds to eliminate: 5.75

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Time Study Data: Operators One & Two

| Operator 1: | Average Time |
|-------------------------|---------------|
| Grab Doors | 1.77 |
| Walk to Conveyor/Cart | 1.32 |
| Place Doors on Conveyor | 2.51 |
| Walk Back to Chain | 1.4055 |
| Grab Safe | 1.17 |
| Walk to Conveyor | 2.54 |
| Place Safe | 1.04 |
| Hot Melt Check | 0.27 |
| TOTAL TIME | 12.02 |

| Operator 2: | Average Time |
|-------------------------|--------------|
| Grab and Place Plastic | 4.0 |
| Grab and Insert Screw | 6.3 |
| Advance Line | 1.0 |
| Restock/Break Cardboard | 1.75 |
| TOTAL TIME | 13.0 |

| Operator 2: Different Method | Average Time |
|-------------------------------------|--------------|
| Insert Screw | 2.6 |
| Grab and place plastic | 4.1 |
| Advance Line | 1.0 |
| Restock | 1.8 |
| TOTAL TIME | 9.5 |

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Time Study Data: Operators Three & Four

| Operator 3: | Average Time |
|---------------------------|--------------|
| Get Base | 1.40 |
| Get Door | 0.93 |
| Place door on base + push | 3.51 |
| Place liners on conveyor | 4.65 |
| Move Cardboard | 0.15 |
| Unwrap Pallet | 0.42 |
| Get/Remove Cage/Tote | 1.84 |
| TOTAL TIME | 12.90 |

| Operator 4: | Average Time |
|---------------------------|--------------|
| Get Base | 2.5 |
| Place Insert in Safe | 3.6 |
| Wait for safe to advance* | 4.1 |
| Flip and Push Safe | 1.8 |
| Get/Remove Cage/Tote | 1.84 |
| TOTAL TIME | 13.8 |

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Does Orienting Body Liners on Pallet Save Time?

Known Information

- Body liners are made and palletized by Webster Plastics.
- For the 1.2 L safes, body liners are palletized with four layers of nine liners each.
- The liners are not oriented in any specific direction on the pallet.
- Some liners crack during transit from Webster Plastics, and operator 3 must check each liner before placing it on the conveyor.
- Operator 3 spends considerable time orienting and checking liners before placing them on the conveyor.

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Pallet Patterns

Current Pattern



Proposed Pattern



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Does Orienting Body Liners on Pallet Save Time?

Desired Information

- How much time does operator 3 currently spend loading liners?
- How much time would operator 3 spend loading liners if they were oriented properly on the pallet?
- Can the liners fit on the pallet in a different orientation?
- Would more liners be broken during shipment if rearranged? Can we have this test done at RIT?

Are Operator Work Loads in the New Layouts Feasible?

Known Information

- The current layout does not allow operators to share tasks due to the large distance between them.
- Operators can currently handle the work load they are assigned.
- Each operator should be loaded to only 85% of the total safe cycle time, or 13.69 seconds.
- Sentry has approved rearranging the cell layout.

Are Operator Work Loads in the New Layouts Feasible?

Desired Information

- Is operator utilization below 85% for each of the new layouts?
- Is there enough space in the work cell to accommodate the layout?

Simulation Utilization

Central Operators Layout #1

- Operators Share Liner Restocking

| Operator | Utilization |
|----------|-------------|
| 1 | .81 |
| 2 | .83 |
| 3 | .62 |
| 4 | .63 |

Central Operators Layout #2

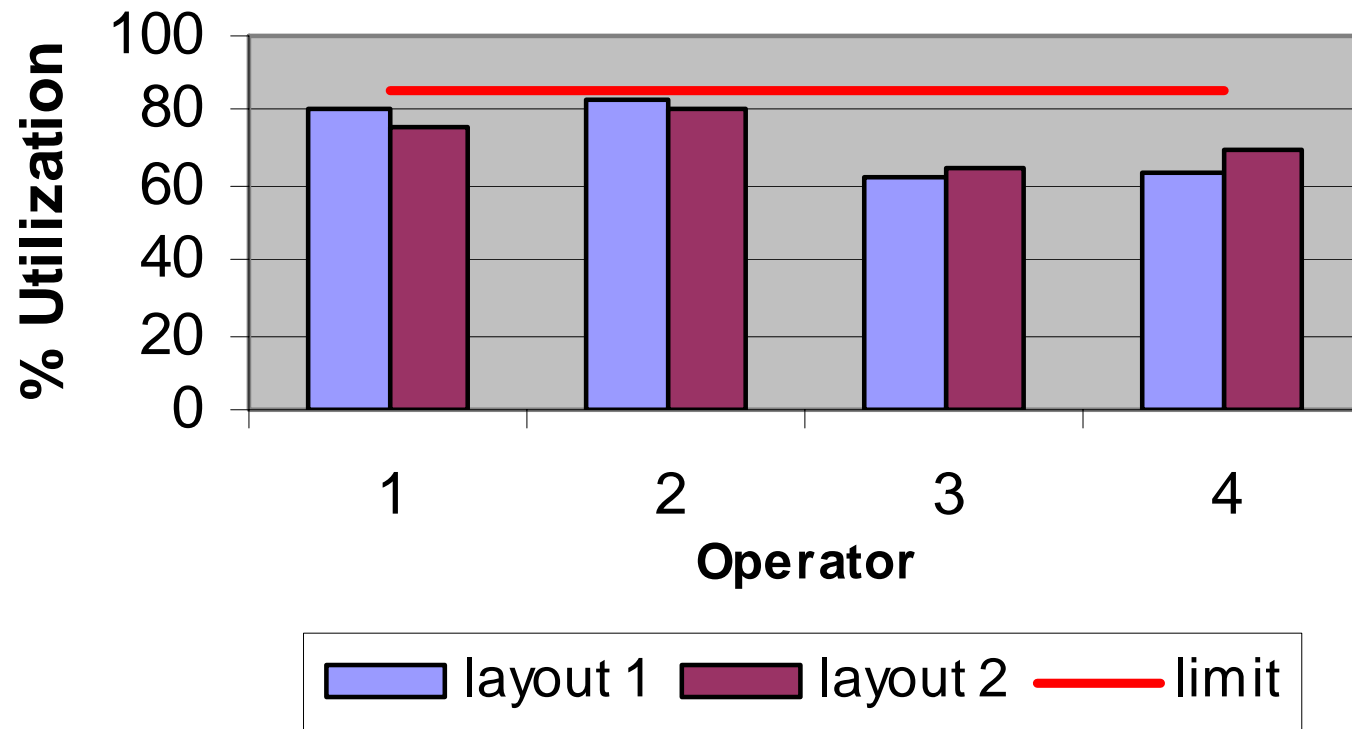
- Operators 3 and 4 Share Liner Restocking

| Operator | Utilization |
|----------|-------------|
| 1 | .76 |
| 2 | .80 |
| 3 | .65 |
| 4 | .69 |

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Simulation Utilization

Operator Utilization vs. Layout



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Logistics Improvements

Known Information

- The trays are oriented in many directions on these carts and pallets.
- The carts and pallets are spread around the Pre-fill workstation in no particular order. A material handler cannot easily see what is needed.
- The trays do not easily stack in the cages, and wobble around on each other.
- In one instance, an operator had to yell at a material handler to alert him to replenish his trays.

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Logistics Improvements

Desired Information

- Is it possible to create stackable cure trays?
- Why do they have pallets in addition to carts?
- Who supplies the cages and pallets to the operators?
- Which storage system (cages or pallets) do the operators prefer?
- Is there space for markings on the floor?
- Will placing markings on the floor improve the Pre-fill area?

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Ergonomic Concerns



Known Information

- Sentry believes operator 1 may be in an ergonomic risk category.
- The 1.2 ft³ Safe weighs 14 lbs.
- The 1.2 ft³ Door weighs 3.5 lbs.
- The trays for the body and door weigh 8.5 and 4.5 lbs respectively.
- The body liner weighs 5 lbs
- The body insert weighs 4 lbs.
- An operator stays at the same position for an 8 hour shift.

Ergonomic Concerns

Desired Information

- Do any of the tasks put the operator in an ergonomic risk category?
- What improvements should be made to reduce the ergonomic risk?

NIOSH Results

Lifting Index Over Three Is Considered Harmful

| Task | Lifting Index |
|-------------------|---------------|
| Operator 4- Tray | 1.48 |
| Operator 1- Door | 0.33 |
| Operator 3- Liner | 0.69 |
| Operator 3- Tray | 0.54 |
| Operator 1- Body | 1 |

Operator 1 Performs the Only Substantial Carry Task

- The Recommended Weight Limit for The Longest Carry Is 39.72 Lbs.
- The Largest Safe Weighs 17.5 Lbs.

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Eliminating Hot-Melt from the Body & Door of the Safe



Known Information

- Cost of hot-melt is \$1.17 per pound.
- Average cost of hot-melt per unit:
 - \$0.10 on the door
 - \$0.45 on the body
 - \$0.02 on the liner interface
- Three robots are used to apply the hot-melt to the safe - two are used on the body, one is used on the door.
- The current hot-melt hoses are purchased from Nordson Hot-Melt Equipment. The part numbers are as follows:
 - 111096A – supply and return hoses
 - 107286C – high flex hose used for the inside sealing of the body
- The plastic parts are made of high-impact polystyrene, which is either blow molded or injection molded.
- The final safe design must pass a burn / drop test.

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Eliminating Hot-Melt from the Body & Door of the Safe

Desired Information

- Can the hot-melt system be redesigned to reduce maintenance costs?
- What type of sealant would be an appropriate replacement for hot-melt on the body seams?
- What option would be an appropriate replacement for hot-melt on the liner interface?

Hot-Melt vs. Spray Cost Analysis

- # \$137,000 in Savings with Material Switch
 - 570,000 Yearly Output of .8 & 1.2 ft³ Safes
 - Estimate Hot-Melt Cost at \$.45 per Safe
 - One 24 oz. Can of Spray Covers 10 Safes
 - Can Purchase 16 Gallons for \$205
 - Estimate Spray Cost at \$.24 per Safe
 - Save 46.6% per Safe – Over \$137,000 per Year!

Spray Sealant

3M™ Underseal™ Rubberized Undercoating 08883

- 24 Oz. Aerosol Can
- Applicable Performance Properties:

| <u>Test</u> | <u>Condition</u> | <u>Effect</u> |
|-------------------|---------------------|-------------------------|
| Water Immersion | 500 Hours @ 75°F | No Corrosion |
| Adhesion to Metal | After 2 Days @ 75°F | Excellent |
| Cure Rate | One Coat @ 75°F | Tack Free in 15 Minutes |

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Spray Sealant

⚠ Unexpected Results

- Carbon Black Is a Carcinogen
- Toluene Has Adverse Effects on the Nervous System

⚠ Continue to Search for Other Options

| <u>Ingredient</u> | <u>C.A.S. No.</u> | <u>% by Wt</u> |
|-----------------------------------------------------|-------------------|----------------|
| SOLVENT NAPHTHA (PETROLEUM), LIGHT ALIPHATIC | 64742-89-8 | 30 - 40 |
| TALC | 14807-96-6 | 10 - 20 |
| PROPANE | 74-98-6 | 10 - 15 |
| ALPHA-METHYLSTYRENE-ISOAMYLENE-PIPERYLENE POLYMER | 62258-49-5 | 5 - 10 |
| ASPHALT BASE | Mixture | 5 - 10 |
| BUTADIENE-STYRENE-META-DIVINYLBENZENE POLYMER | 26471-45-4 | 1 - 5 |
| TOLUENE | 108-88-3 | 1 - 5 |
| DIMETHYL ETHER | 115-10-6 | 1 - 5 |
| SYNTHETIC AMORPHOUS SILICA, FUMED, CRYSTALLINE FREE | 112945-52-5 | <2 |
| CARBON BLACK | 1333-86-4 | <1 |

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Swivel Hose

Automatic Hi-Flex Hoses 240V, 5/16 in. dia.

(Distinguished by a blue nylon thread in the outer braided cover)

| Part Number | RBX Part Number | Hose Length |
|-------------|-----------------|----------------|
| 107285 | X107285 | 1.2 m (4 ft.) |
| 107286 | X107286 | 1.8 m (6 ft.) |
| 107287 | X107287 | 2.4 m (8 ft.) |
| 107289 | X107289 | 3.0 m (10 ft.) |
| 107310 | X107310 | 3.6 m (12 ft.) |
| 104008 | X104008 | 5.0 m (16 ft.) |
| 223838 | X223838 | 6.0 m (20 ft.) |
| 100832 | X100832 | 7.4 m (24 ft.) |

■ Current Hose

■ Diameter of 5/16"

■ Appropriate swivel selected

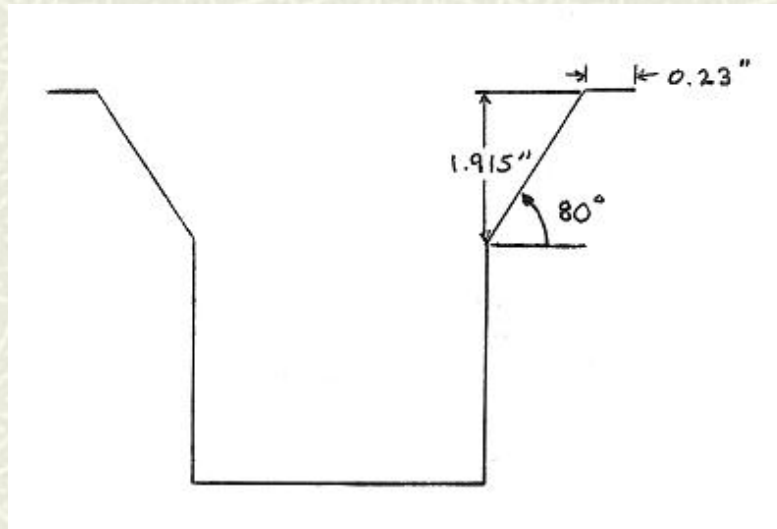
Multi-Plane Swivels (for robotic applications)

| | |
|--------|-----------------------------------------------------|
| 139091 | Hose swivel, SP, SAE 3/16 in. |
| 139093 | Hose swivel, SP, SAE-6/JIC - 6, 5/16 in, straight |
| 139095 | Hose swivel, SP, SAE 3/16 in, 12, 5/16 in, straight |

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Increase in Lip Width

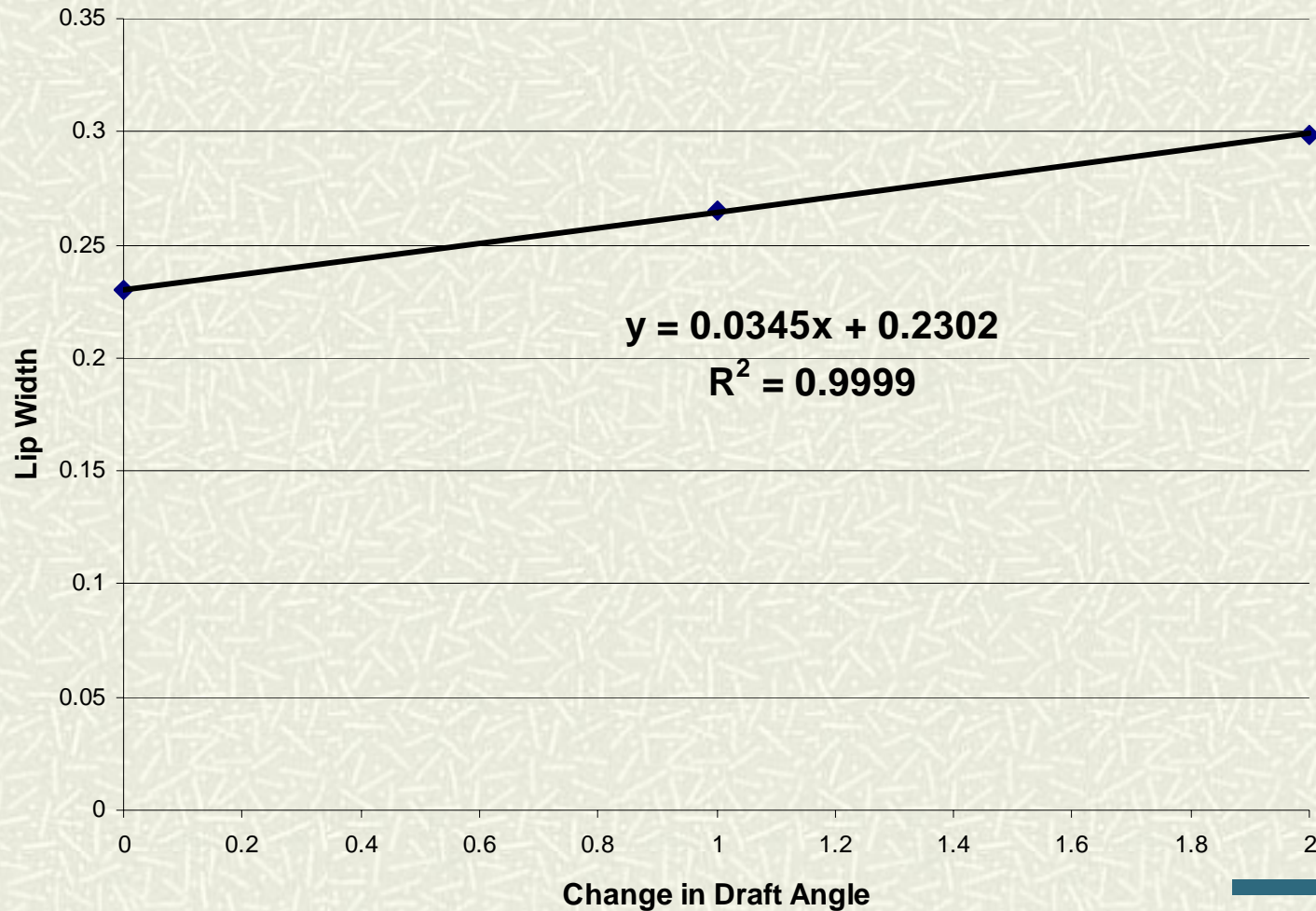
- # Proportionality Between Draft Angle and Liner Interface was Calculated
 - Vertical Height Must Be Kept Constant
 - Graphical Interpretation and Equation of Line



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Increase in Lip Width

Draft Angle vs. Lip Width



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Snap-Fit Cost Analysis

- # \$55,290 in Savings with Screw Elimination
 - 20 Safes / Box of Screws
 - 570,000 Yearly Output of 1.2L and 0.8L Safes
 - 28,500 Boxes of Screws Used Per Year
 - \$1.94/Box of Screws
- # \$5,950 Screw Robot Maintenance Savings

Snap-Fit

Known Information

- Modifications to Door Must Pass Drop Test
- Screws Are From Hewes Industrial Supply at \$1.94 Per Box of 100
- Screw Torque Is Set at 5 to 7 Ft-lbs
- Changes Should Not Decrease Minimal Concrete Door Thickness of 1.5 Inches

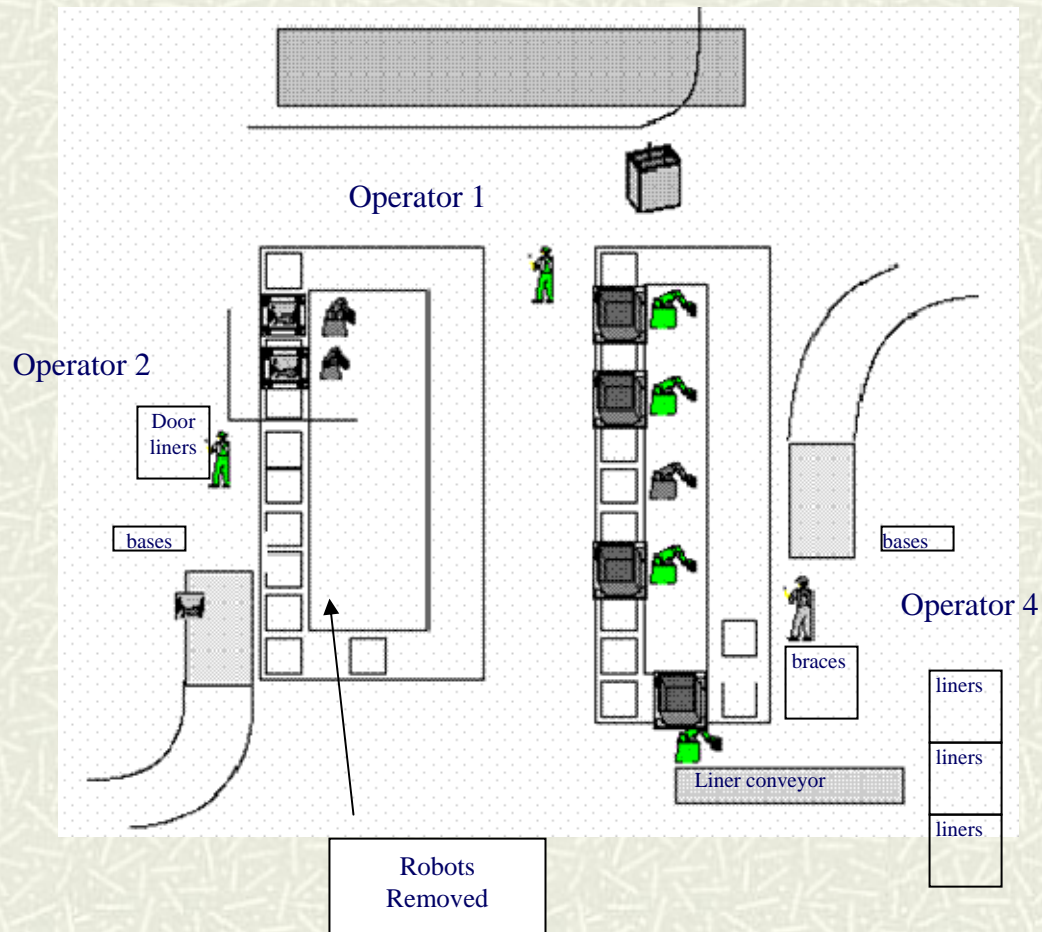
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Snap-Fit

Desired Information

- How Does No Screw Design Perform in Burn / Drop Test?
- What Are the Design Limitations of Injection Molding a Snap Fixture?
- Can a Snap Fit Compensate for the Variations in Door Plate Rigidity?

Snap-Fit Operator & Pre-Fill Layout



Operator Reduction

Snap-Fit

- Operator 2/3 Flips Door Onto Cure Tray
- Operator 4 Restocks Body Liners

Calculation using averages

| Operator 3: | Average Time |
|---------------------------|---------------------|
| Get Base | 1.40 |
| Grab and Place Plastic | 4.0 |
| Restock/Break Cardboard | 1.75 |
| Get/Remove Cage/Tote | 1.84 |
| Place door on base + push | 3.51 |

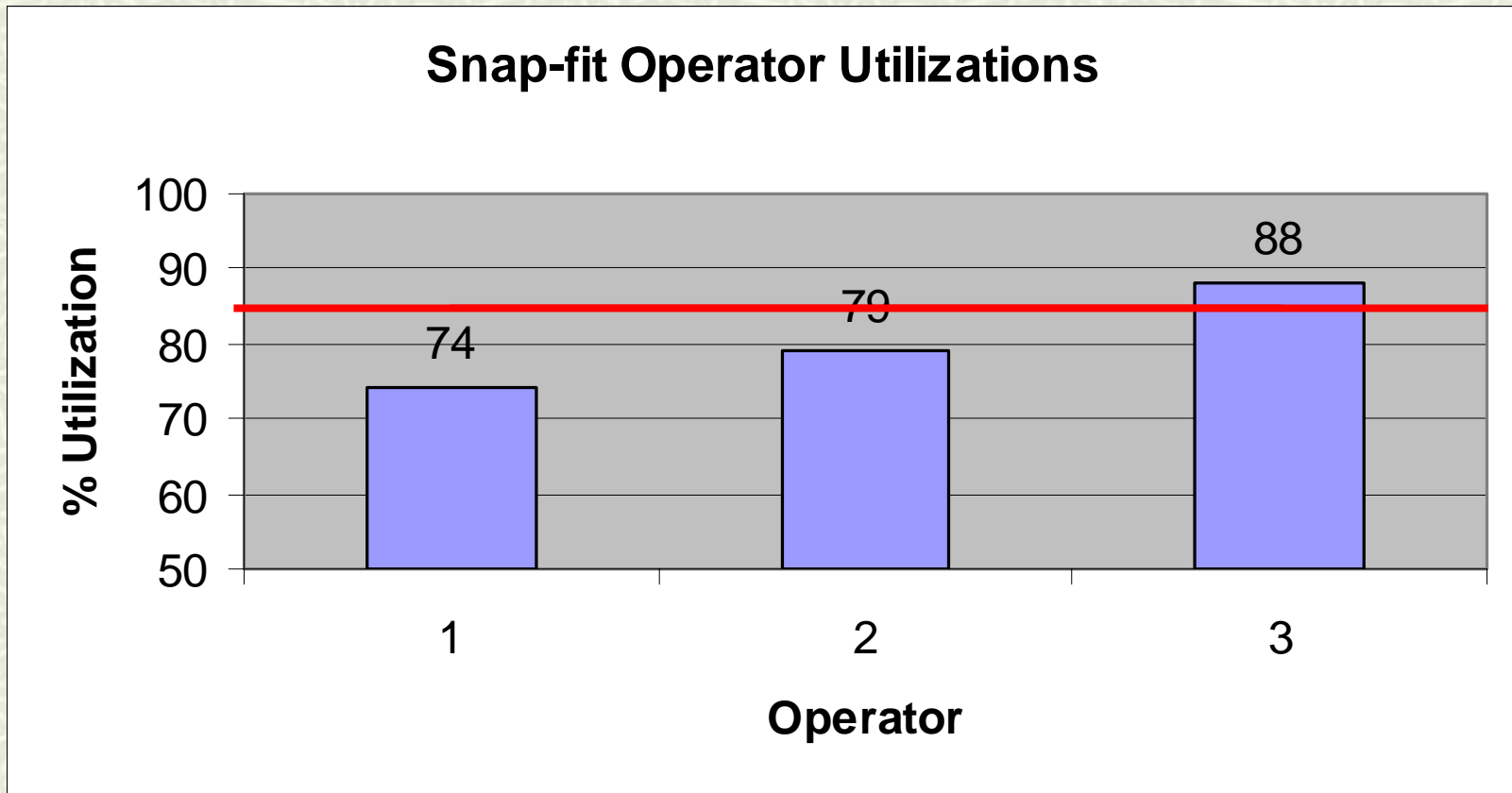
TOTAL TIME 12.50

Utilization from Simulation

| Operator | Utilization |
|-----------------|--------------------|
| 1 | .74 |
| 2 | .79 |
| 4 | .88 |

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Snap-Fit Operator Utilization





SD I Gantt Chart



SD II Gantt Chart

Weighted Concepts Example

Operator / Pre-Fill Concepts

- Orient Liners in Same Direction on Pallet
- Baseline = 2.87 (Out of 5.00)

| Cost Savings | Cost | Ergonomic Improvements | Operator Time Saved | Involves another vendor | Involves moving robots | Involves Redesign | Affects other work areas negatively | Prevents Downtime | Safety | Sentry Approved | Weighted Total |
|--------------|------|------------------------|---------------------|-------------------------|------------------------|-------------------|-------------------------------------|-------------------|--------|-----------------|----------------|
| 3 | 5 | 4 | 3 | 2 | 5 | 5 | 3 | 4 | 4 | 5 | 3.96 |

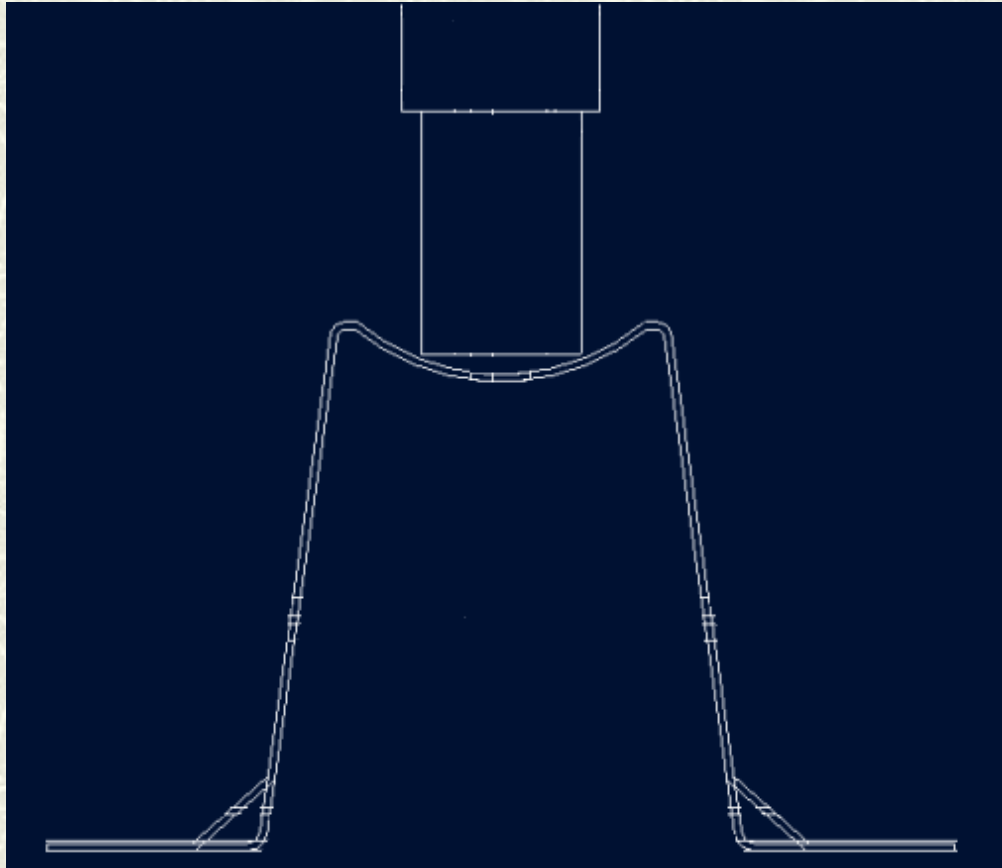
Door / Body Concepts

- Liquid Spray Sealant
- Baseline = 1.70 (Out of 3.00)

| Sentry Approved | Cost | Cost Savings | Affects other work areas negatively | Downtime | Process Time Saved | Compatible with Current Process | Involves removing robots/workers | Involves another vendor | Weighted Total |
|-----------------|------|--------------|-------------------------------------|----------|--------------------|---------------------------------|----------------------------------|-------------------------|----------------|
| 2 | 2 | 3 | 2 | 2 | 1 | 2 | 1 | 2 | 2.02 |

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Part Geometry



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Snap Analysis

$$y = \frac{2}{3} \frac{\epsilon \ell^2}{h}$$

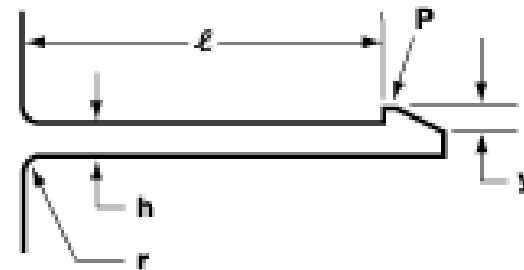
Where:

y = maximum deflection
 ϵ = maximum fiber strain
 ℓ = length of beam
 h = thickness

High Impact Polystyrene

Permissible strain = 0.7

Cantilever Snap-Fit Design



ℓ = length
 h = thickness
 r = radius corner
 y = deflection of cantilever and
height of undercut
 P = deflection force

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