SPE Conference
Rotary Wheel Extrusion Blowmolding 101

10/23/2023

GRAHAM ENGINEERING

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AMERICANKUHNE

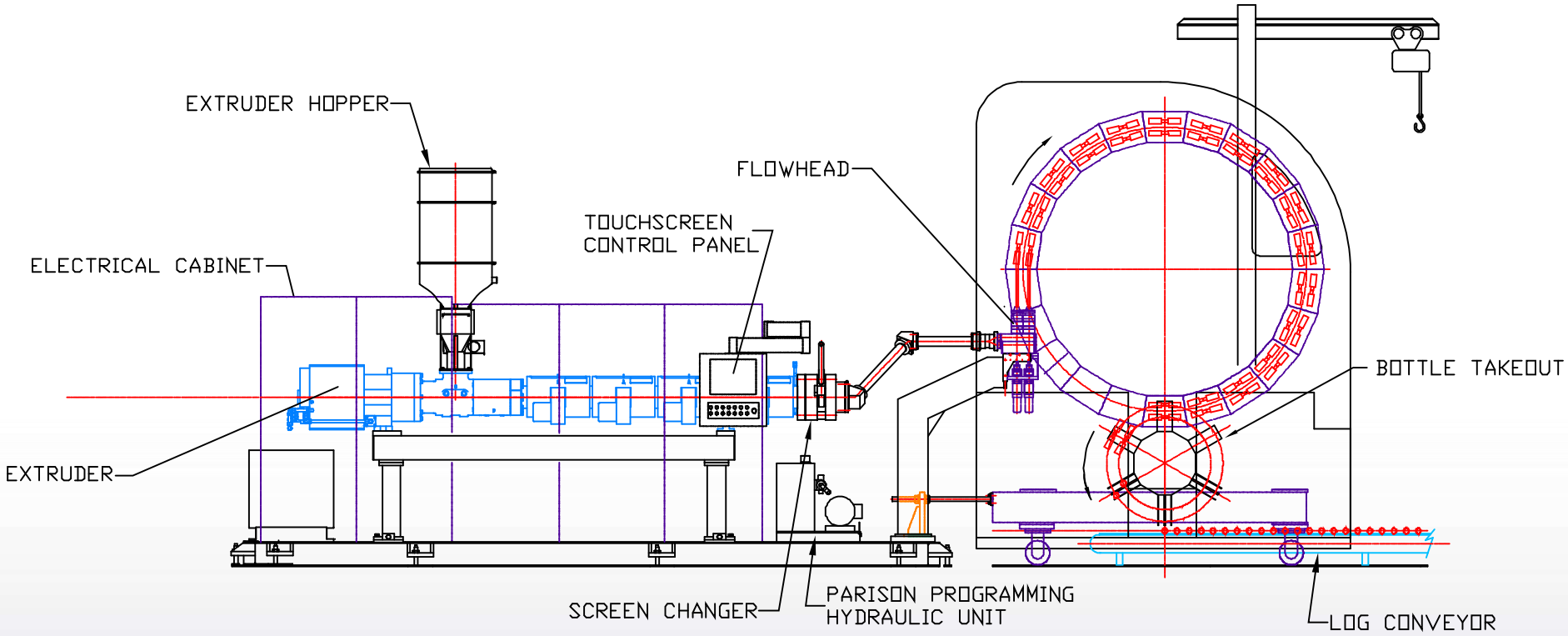
Welex

VERTICAL ROTARY WHEEL UPWARD EXTRUSION

Vertical Wheel – Upward Extrusion

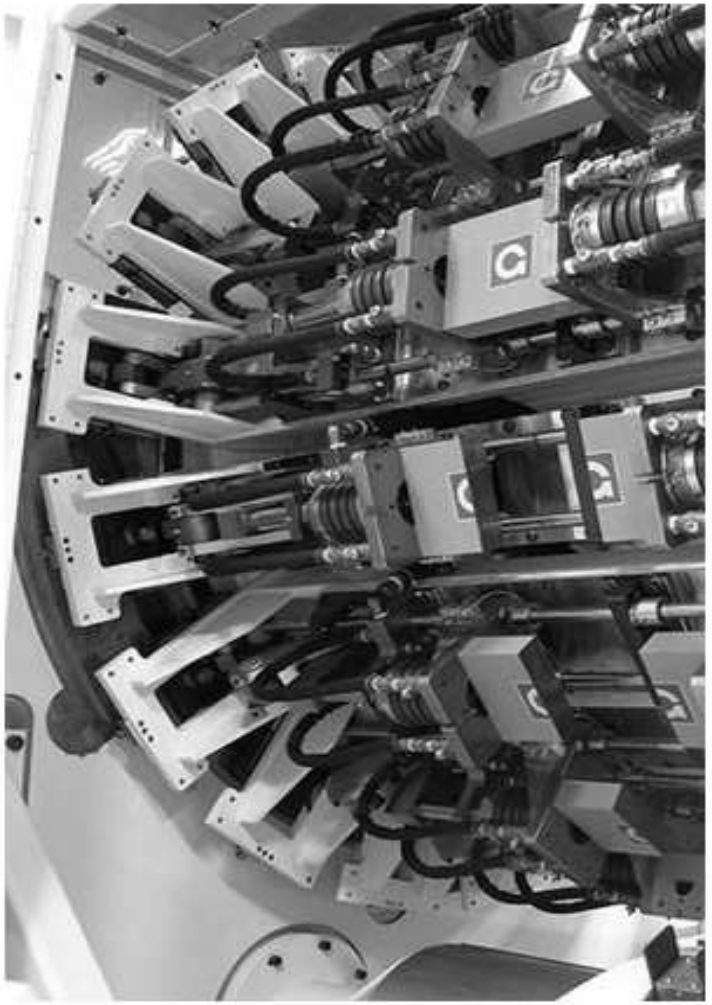
Vertical Rotary Wheel – Upward Extrusion

Characterized by continuous rotary motion, upward extrusion, and bottom takeout.

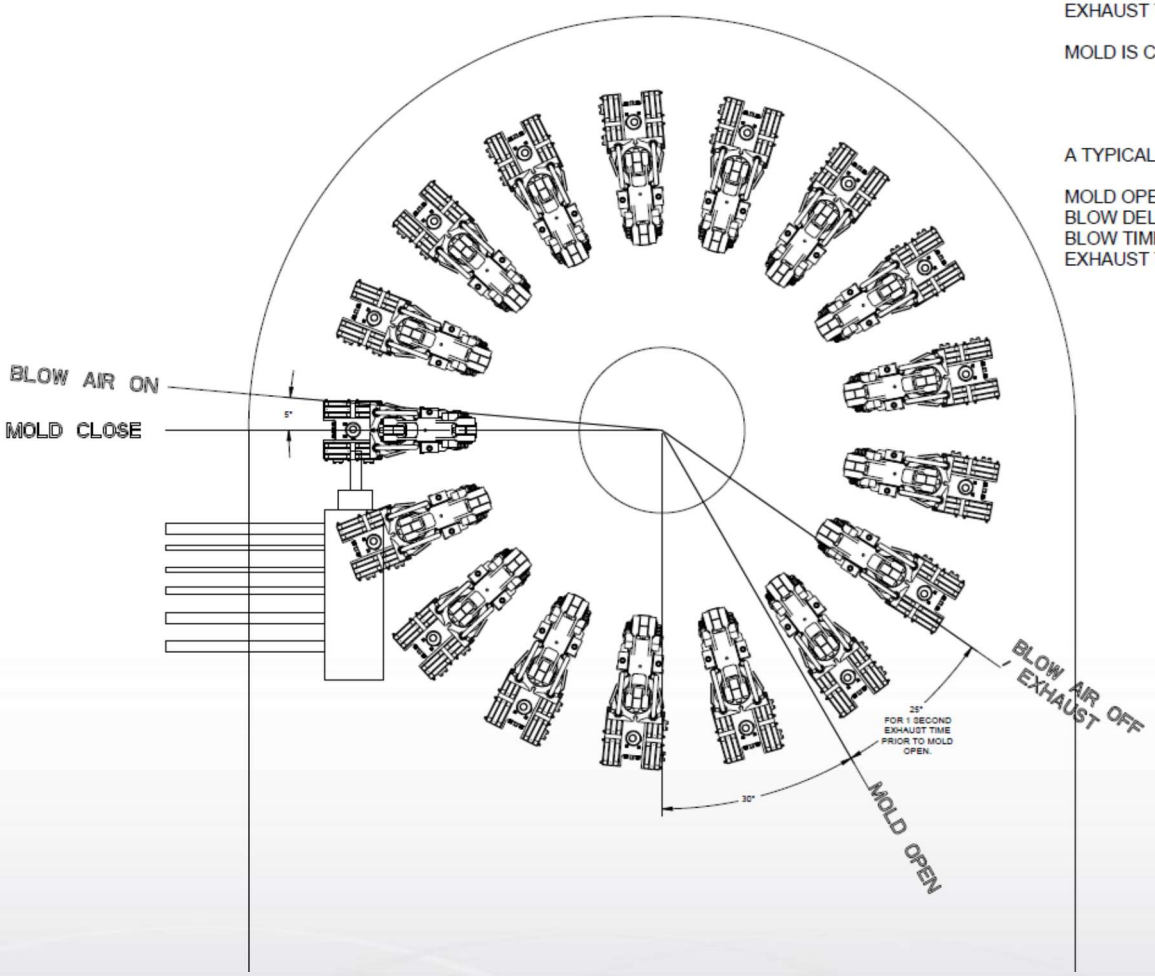


Rotary Wheel
Frame and Cam

Rotary Wheel Construction
Cam and Spool



Vertical Wheel – Upward Extrusion



BLOW AIR TURNED ON WITHIN 5 DEGREES OF MOLD CLOSE.

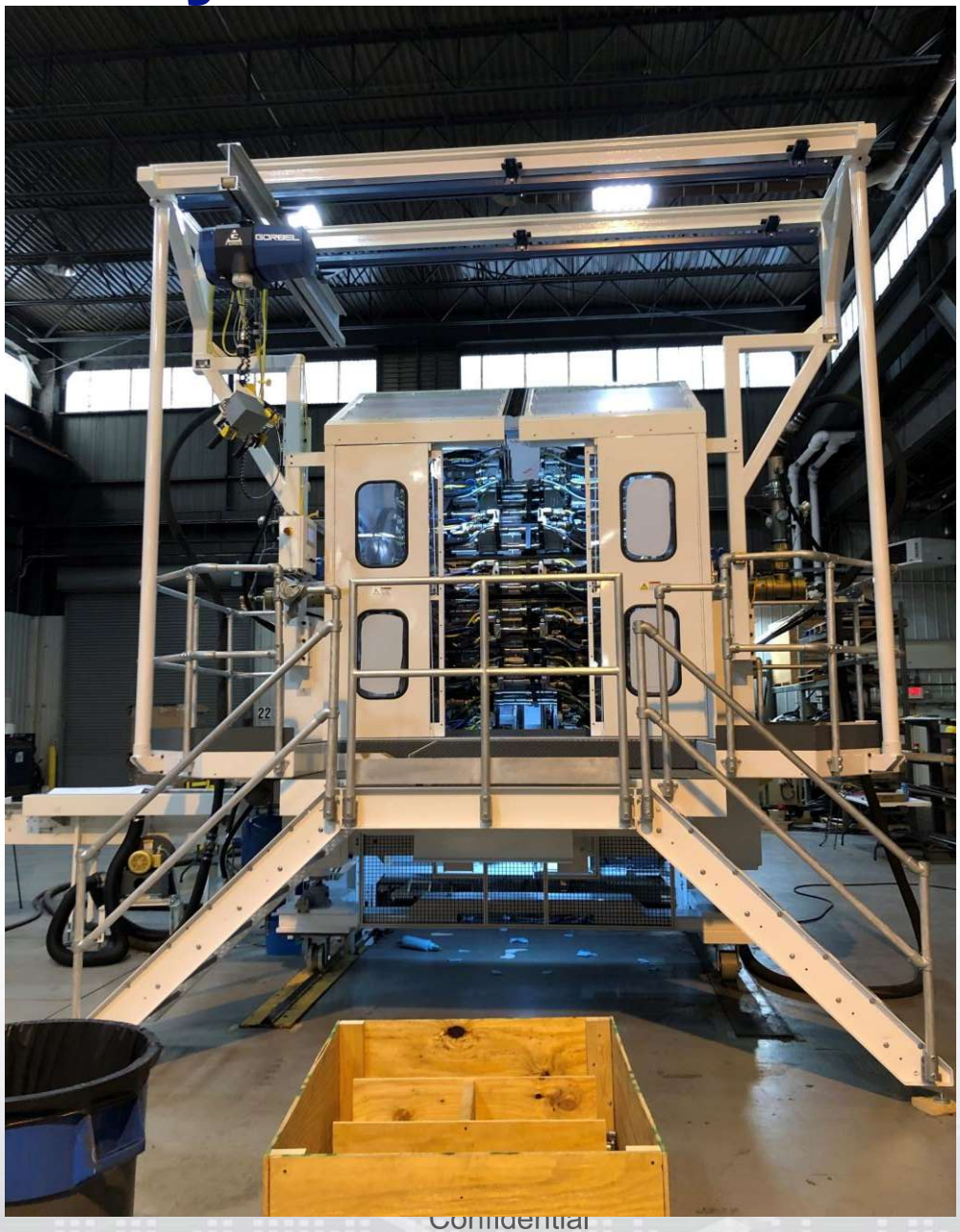
TYPICAL EXHAUST TIME BEFORE MOLD OPEN IS 1 SECOND.
EXHAUST TIME CAN BE REDUCED TO AS LITTLE AS 1/2 SECOND.

MOLD IS CLOSED FOR 240 DEGREES (2/3 OF CYCLE)

A TYPICAL 4.5 RPM (13.35 SECOND) CYCLE IS AS FOLLOWS:

MOLD OPEN (DRY CYCLE) - 4.4 SECONDS
BLOW DELAY - .2 SECONDS
BLOW TIME - 7.75 SECONDS
EXHAUST TIME - 1 SECOND

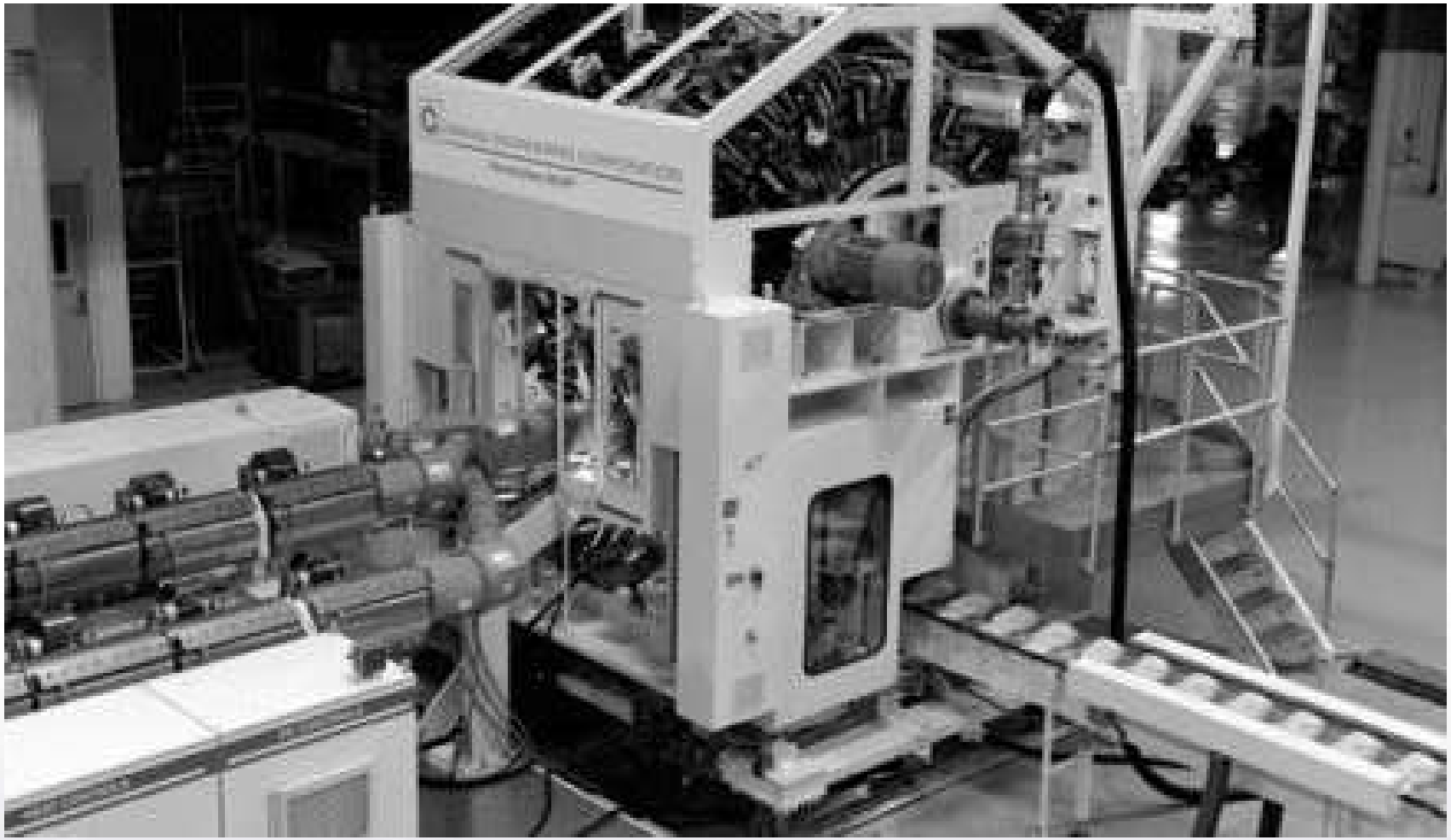
Rotary Wheel Contruction



Rotary Wheel Extrusion System

Trilayer with Viewstripe, single parison
Screen Changer on middle layer

Rotary Wheel: Construction
Complete with side discharge



Ease of Operation

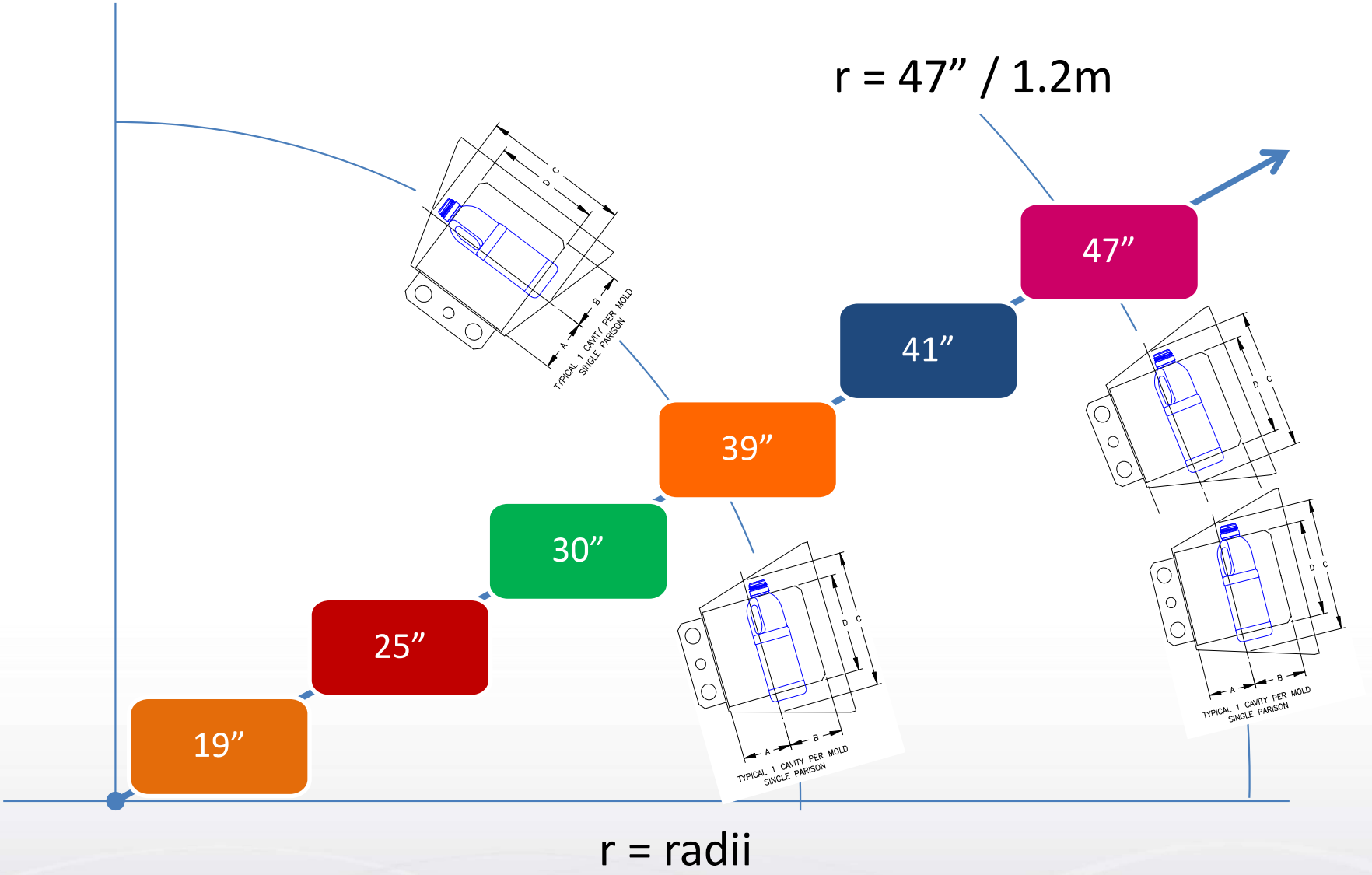
Dual Parison Start-Up

- Parison is suspended by parison air
- Blown bottles within one revolution
- Stabilized process within 4-5 revolutions

Bottle Applications

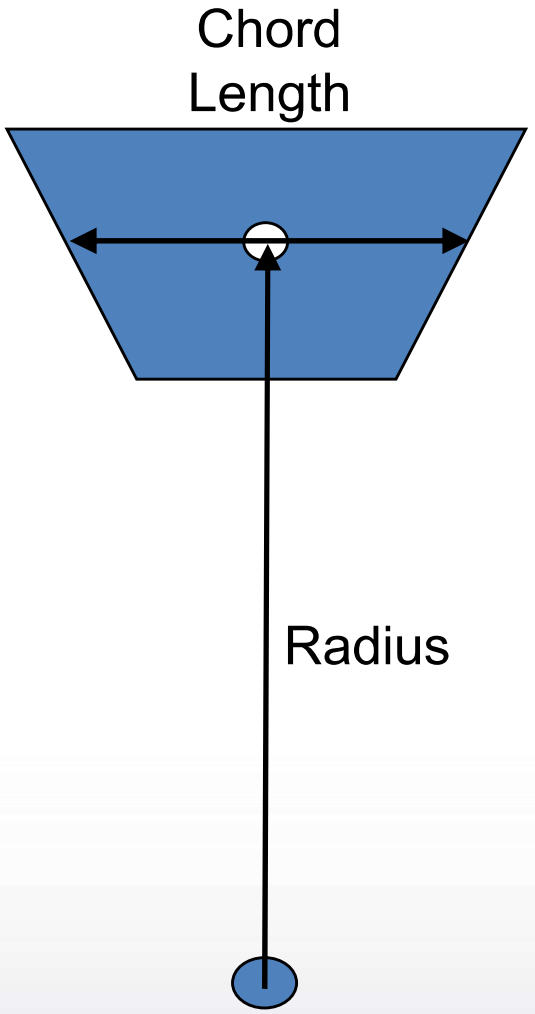
- There are different sizes of wheels and different configurations to process a diverse range of containers on wheel machines.
- Wheel machines are processing containers from 60 ml to 30 liter capacity

The Wheel Portfolio

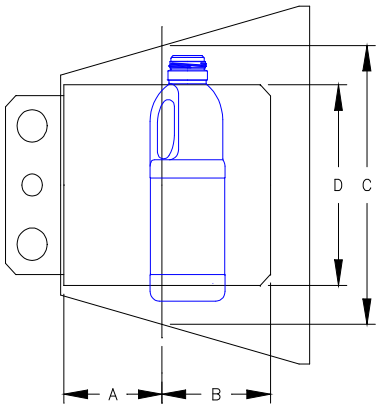


Wheel Radius & Chord Length

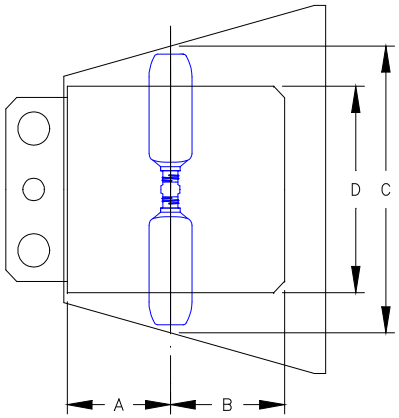
- Wheel molds are trapezoid shaped due to the real estate and rotary nature of the machines.
- The size of the molds, and thus the size of bottles that can be produced, are dictated by two dimensions:
  - The radius of the wheel, to the centerline of force application
  - The chord length is defined by the radius, translated into circumference then divided by the desired number of stations.



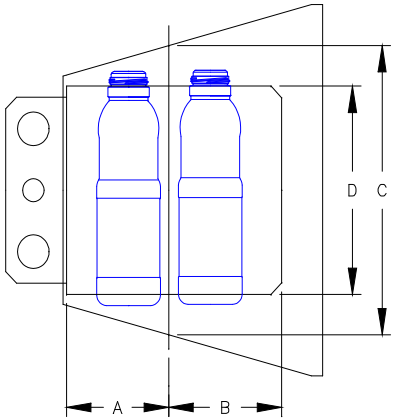
Mold Configurations for Wheels



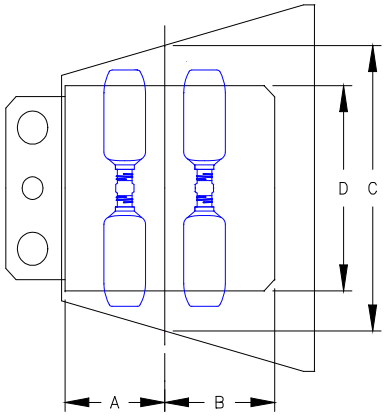
TYPICAL 1 CAVITY PER MOLD
SINGLE PARISON



TYPICAL 2 CAVITY PER MOLD
SINGLE PARISON



TYPICAL 2 CAVITY PER MOLD
DUAL PARISON

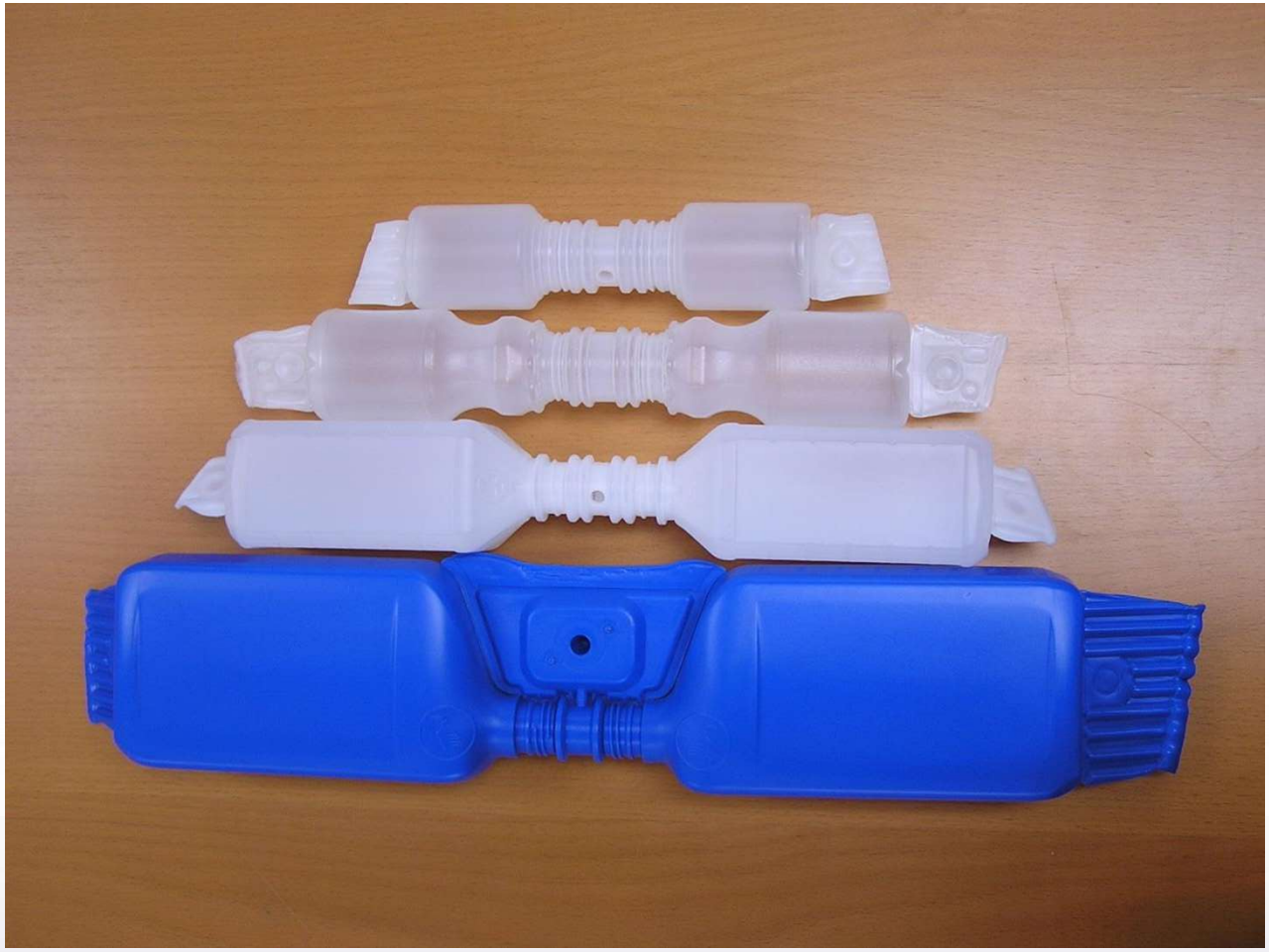


TYPICAL 4 CAVITY PER MOLD
DUAL PARISON

Single PARISON

Dual PARISON

Neck to Neck Wheel Blow Molding



Single Cavity: Tilt for Handle

Optimal fit for the Rotary Wheel

- High Output
- Wide, handleware containers
  - Cavitation is not limited by width of container
  - Up to 18 - 22 cavities
- Small bottles for max cavitation
  - Up to 144 cavities with a triple parison
- IML
- Multilayer
- Wide mouth

ROTARY WHEEL SYSTEMS

Container Take-Out & Spin Trimming

22 stations, Dual Parison, neck to neck

88 cavities running 8.5 RPM=748 BPM or 44,880 BPH

Trim Tops & Tails

Spin Trimming

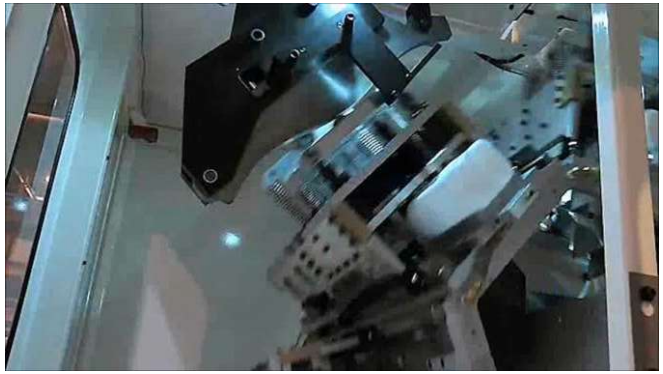
Transfer to Trimmer

Positive Take-Out

Container Take-Out & Deflashing

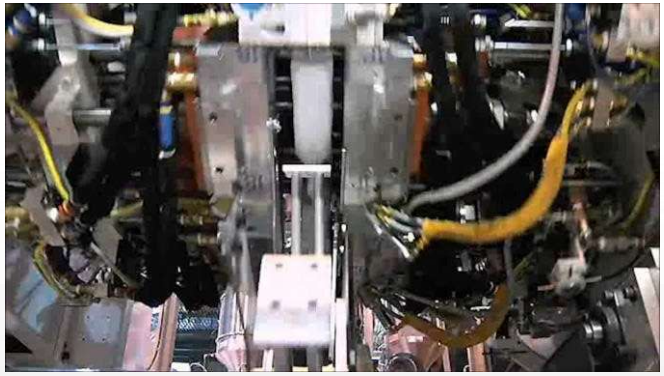
14 station, single parison, trilayer running 7.5 RPM, 105 BPM, 6,300 BPH

Trim Tops & Tails



Deflashing

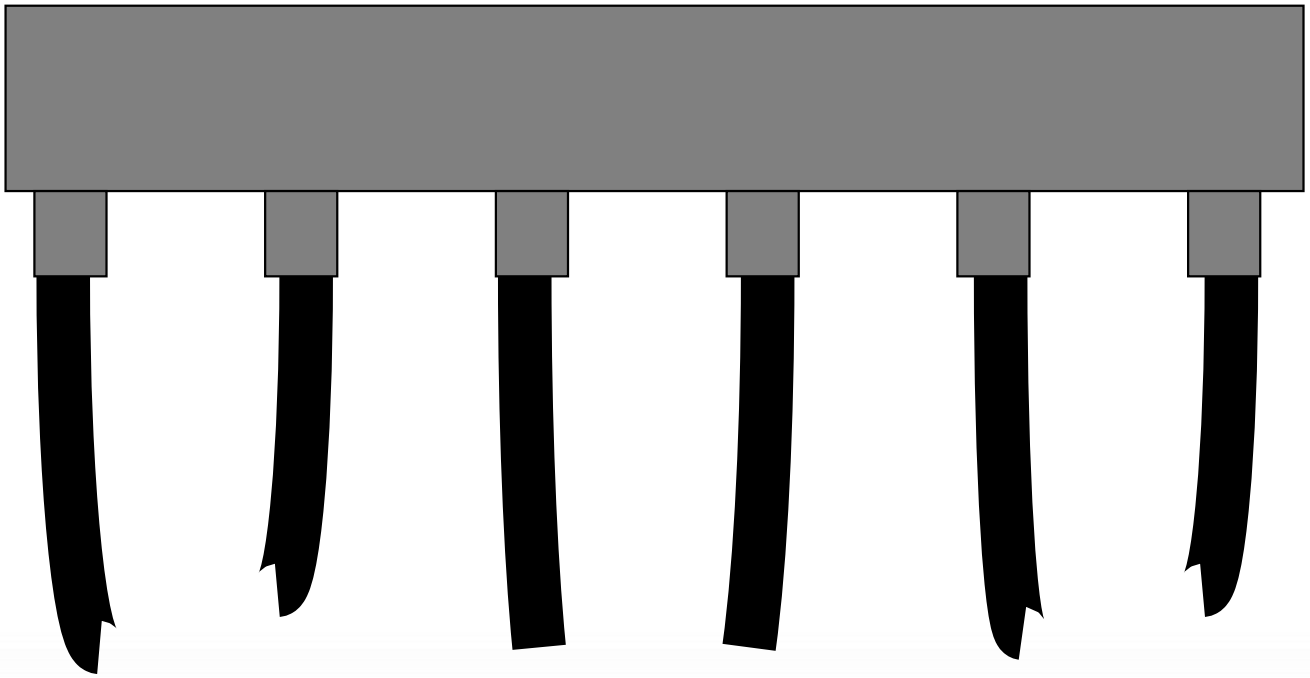
Transfer to Trimmer



Positive Take-Out

TECHNOLOGY COMPARISON
(MULTIPLE PARISON VS. ROTARY WHEEL)

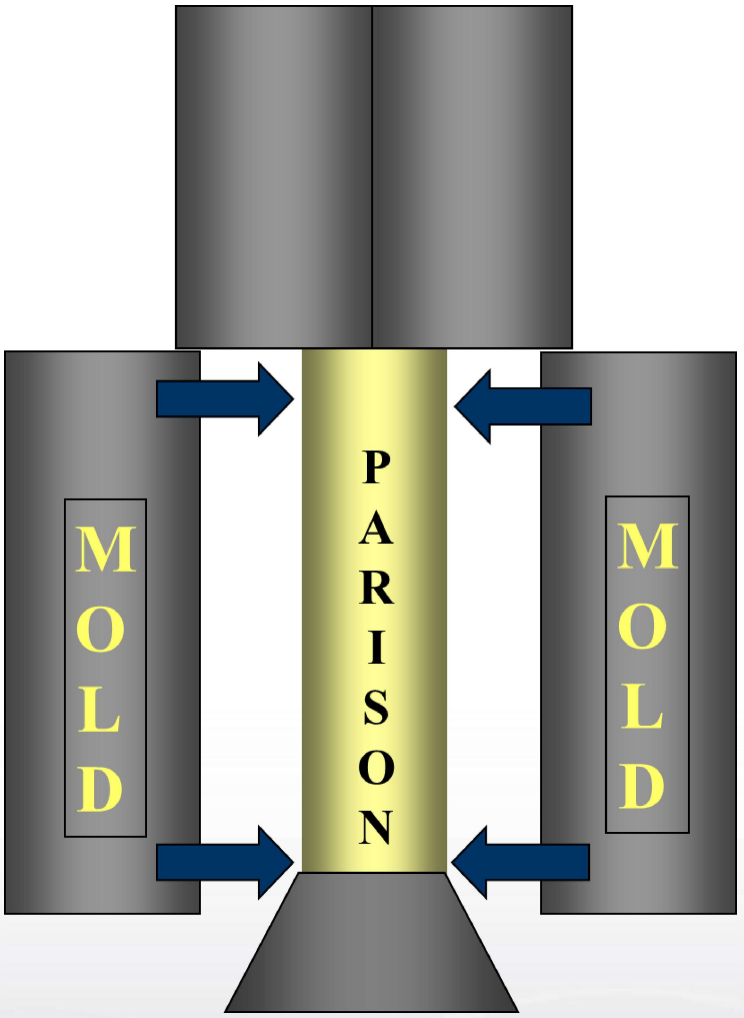
Extrusion Issues



Parison Curling, Static Electricity, Inconsistent Lengths, Weight Control (May require individual programming mechanisms)

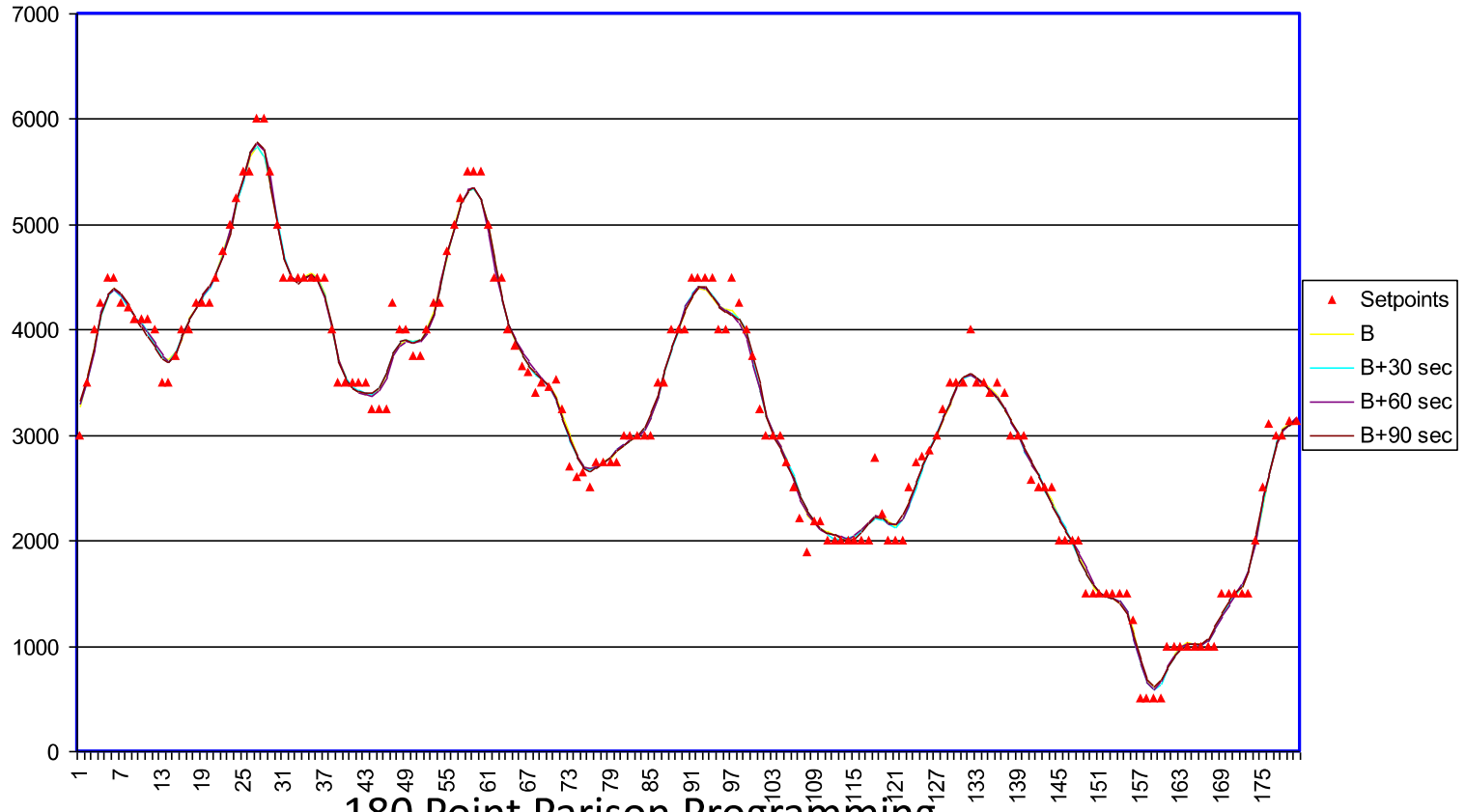
Wheel Bottle Weight Consistency

- On GEC wheel machinery, the parison is captured on each end and is always the same length.
- Because of this, the programming of the parison thickness is very repeatable.
- Resulting in superb bottle weight consistency.

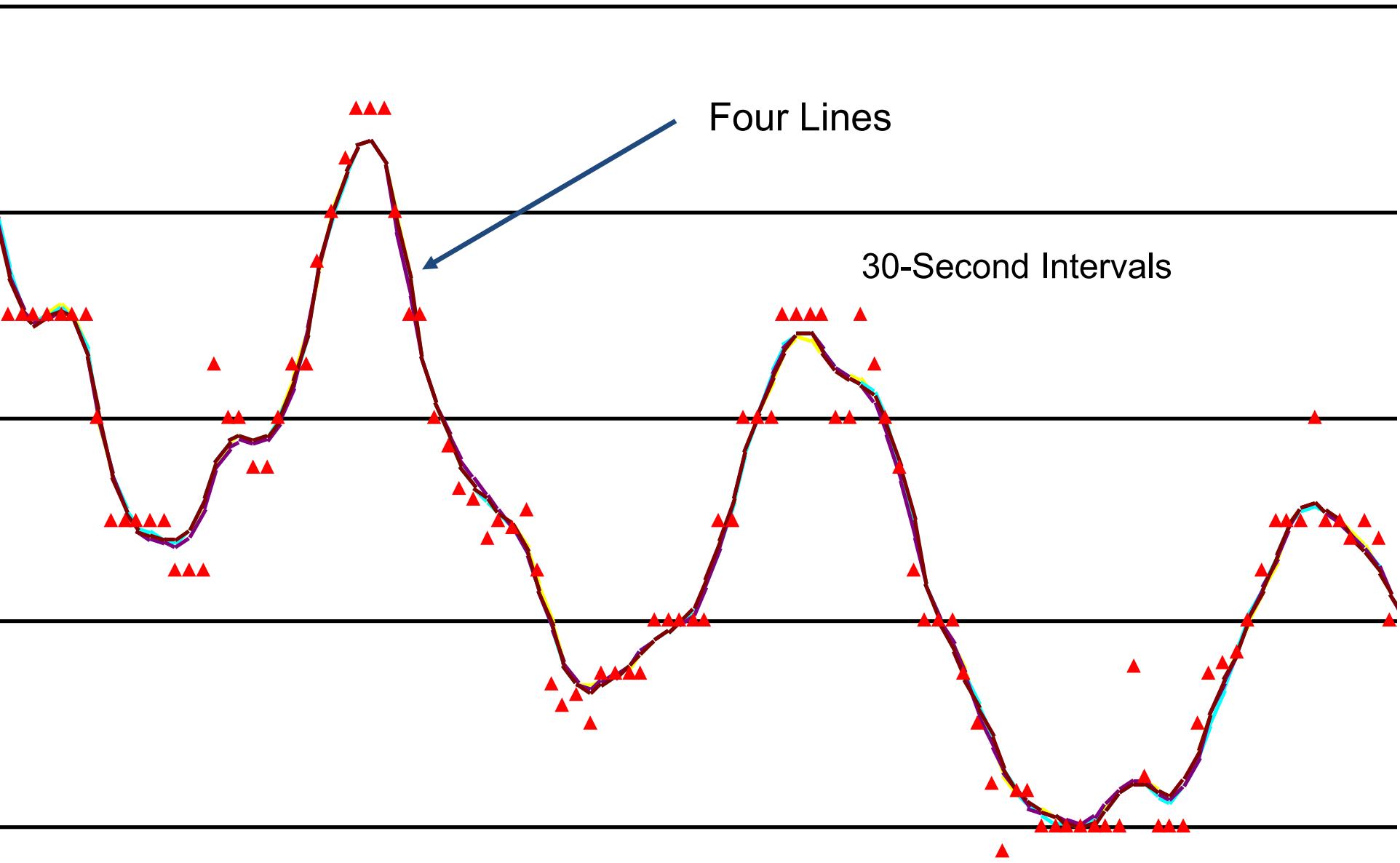


Wheel Parison Repeatability

Composite of 4 Data Sets @ 30 Second Intervals
Running Logs

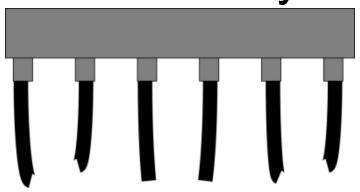


180 Point Parison Programming

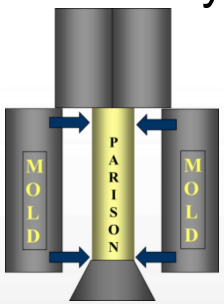

Four Lines
30-Second Intervals

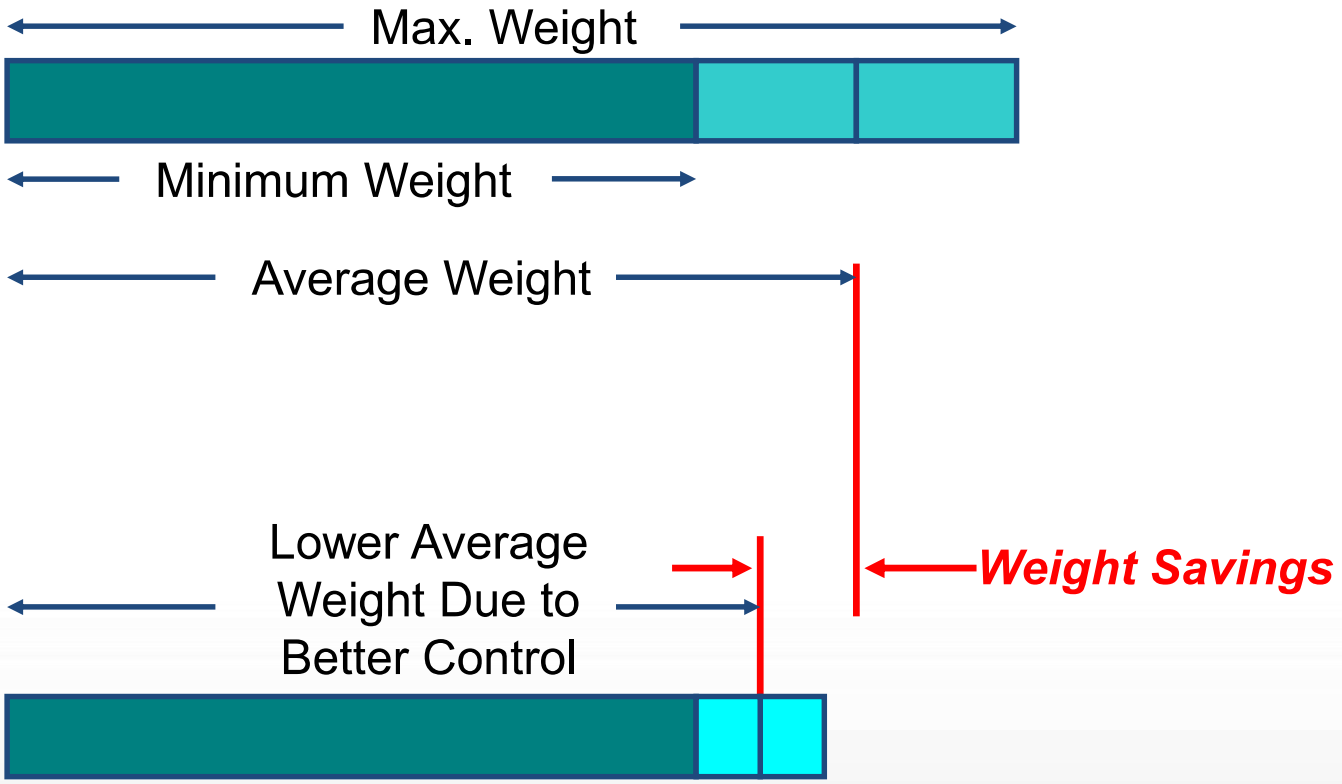
Bottle Weight Consistency

Multiple Parison Machinery



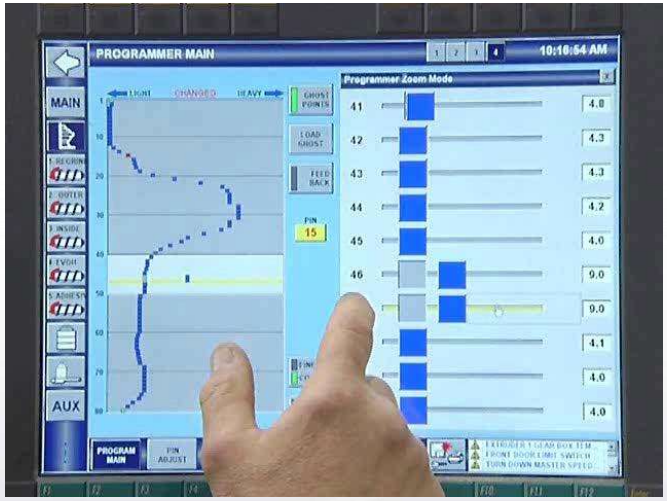
Rotary Wheel Machinery





Wheel Consistency

- Superb bottle weight consistency +/- 2% across all cavities
- Each parison is mechanically captured at each end ensuring no swing and consistent parison lengths.
- The high resolution (up to 180 points) and repeatable profile programming allows operators to optimize their containers through controlled distribution of plastic along the height of the container using a hydraulic servo valve.



IML: IN MOLD LABELING

In Mold Labeling

- GEC IML units may be configured to label as many as 120 cavities per minute.
- No cycle time penalty for label insertion. Other technologies are typically 1.5 -2 second cycle penalty or longer

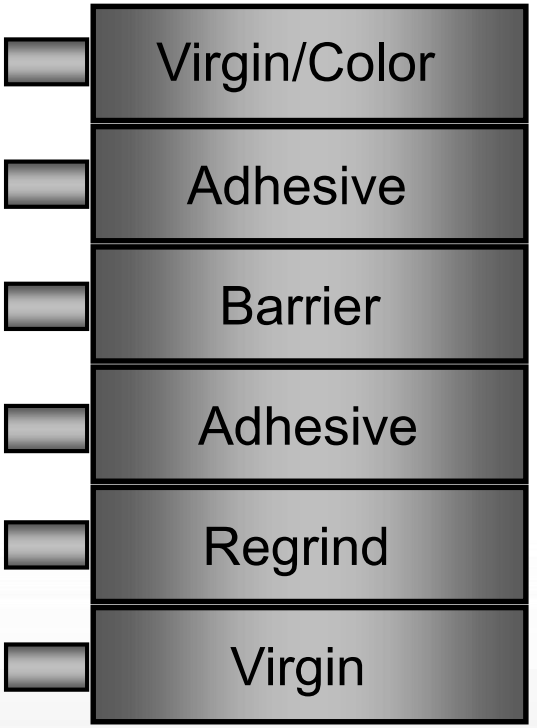
6 Layer Wet Goods Container

EVOH layer consistency

MULTILAYER CONSISTENCY

Typical Layer Configuration

- The layer structures of wet goods container are normally within the following ranges:
  - Inside – Virgin – 15% to 30%
  - Regrind – 45% to 60%
  - Adhesive – 1% to 2.5%
  - EVOH – 1.5% to 3%
  - Adhesive – 1% to 2.5%
  - Outside – Virgin/Gloss – 10% to 20%

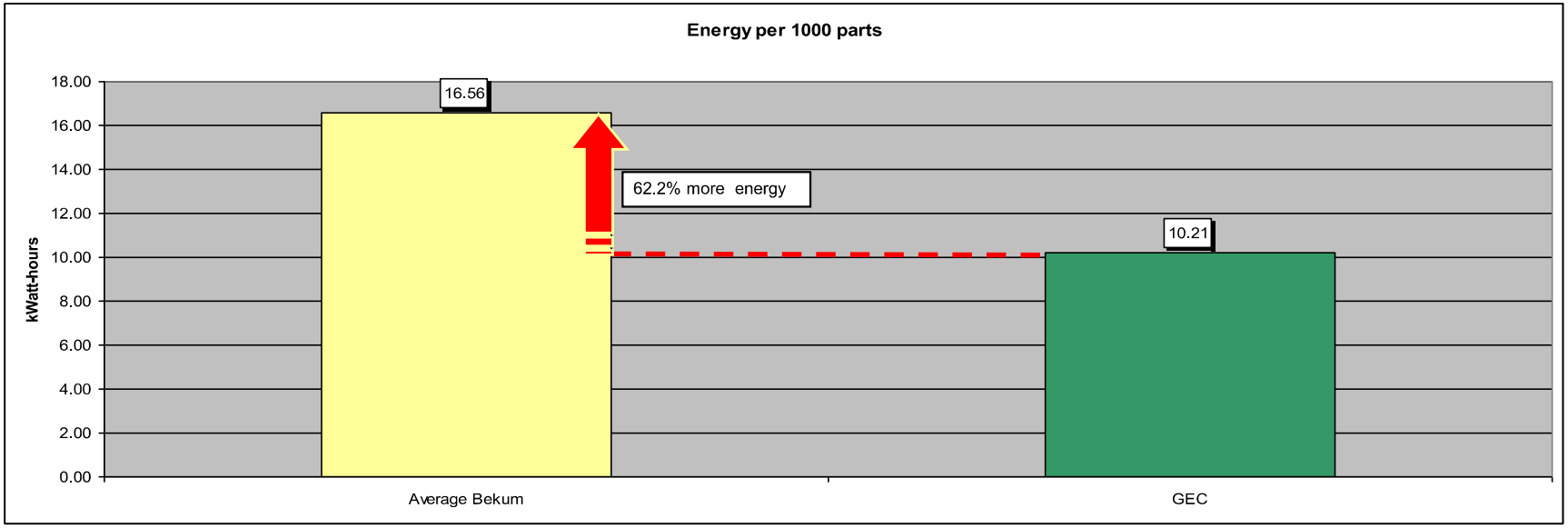


Multilayer Capability

- Multi-layer capability on Rotary wheel machines since the late 1980's.
- Barrier and adhesive layer thickness as low as 0.0002 in. (0.005 mm, 5 microns) or as thick as 0.004 in. (0.1 mm).
- "Average" barrier layer thickness is in the 0.0006 in (0.015 mm) to 0.015 in (0.040 mm) range.

ENERGY ANALYSIS

Energy Usage



Shuttle

- .52 kW/kg

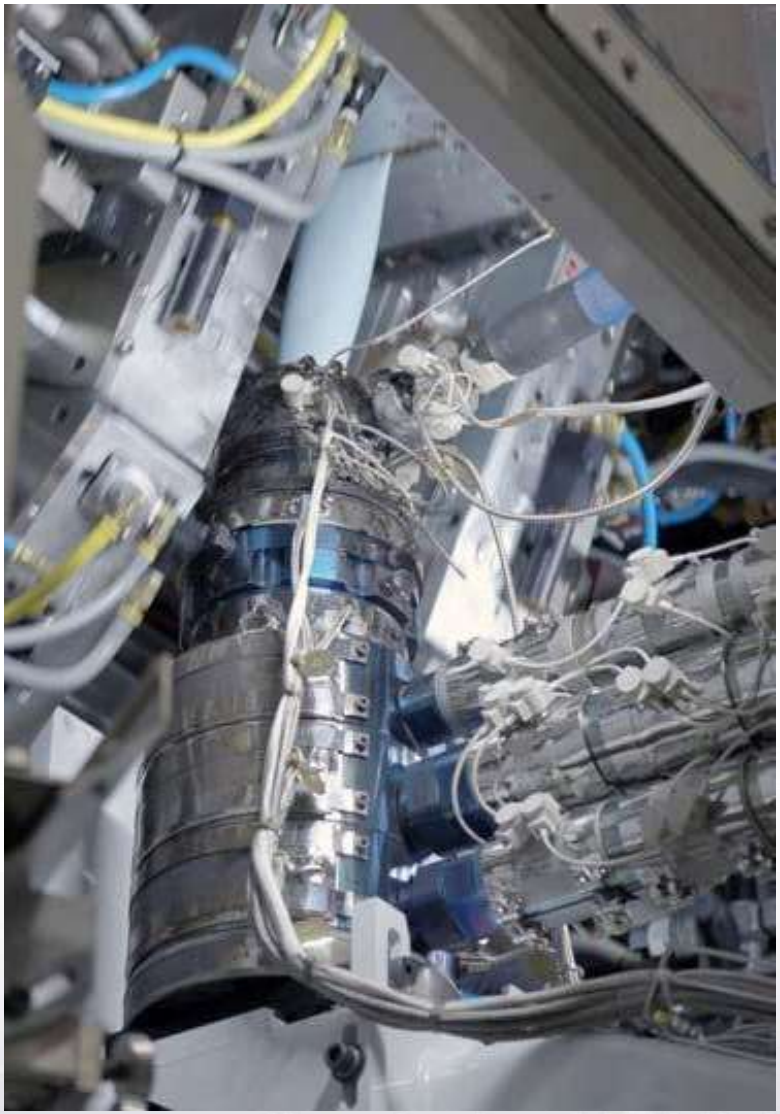
Graham Wheel

- .26-.29 kW/kg

1. Energy (in kWatt-hours) required to produce 1000 parts.
2. Energy values are the actual energy measured over a 1 hour period of continuous operation at typical production rates, assuming 100% efficiency.
3. Average shuttle energy was calculated using the following 3 shuttle machines:
   - Machine 1 - 4-head, double side
   - Machine 2 - 4-head, double side
   - Machine 3 - 3-head, double side

TRILAYER PCR

Trilayer Extrusion and PCR



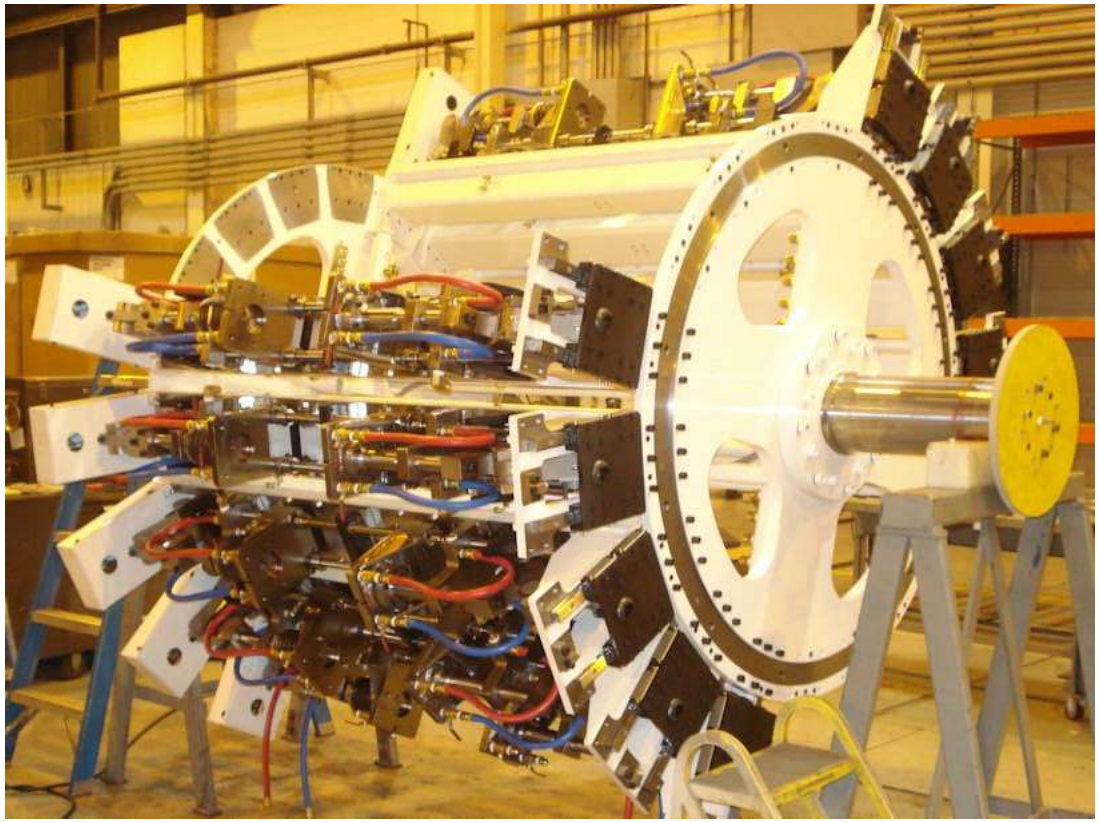
- Two or Three extruder system
- Lowest cost per cavity over other EBM platforms
- Screen changer on middle layer
- Use of melt pump on middle layer for 50% reduction in bottle weight variation

NEW TECHNOLOGY:
REDEPLOYMENT
QUICK MOLD CHANGE
VARIABLE PITCH

Redeployment:
Modular clamp station

Common parts: pre-built clamp stations

Re-deployment of assets



QUICK MOLD CHANGE

Quick Mold Change Video

Quick Mold Change

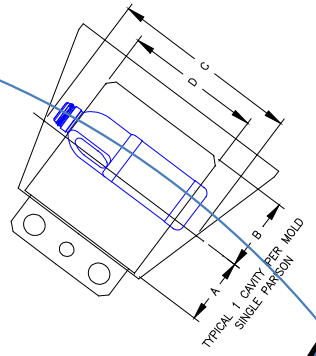
- 5 Minutes per station/mold
- 18 station/18 cavity wheel in 1.5 hours
- 24 station/96 cavity wheel in 4 hours
- 11 station/44 cavity wheel in 4 hours

VARIABLE PITCH/RADIUS

Demo: Variable Pitch

REVOLUTION MVP: OUTPUT OF A ROTARY WHEEL WITH THE FLEXIBILITY OF A SHUTTLE

Revolution MVP



Mega
47” r

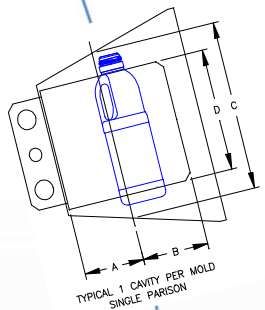
Mighty
44” r

Super
39” r

Regular
30” r

Compact
23” r

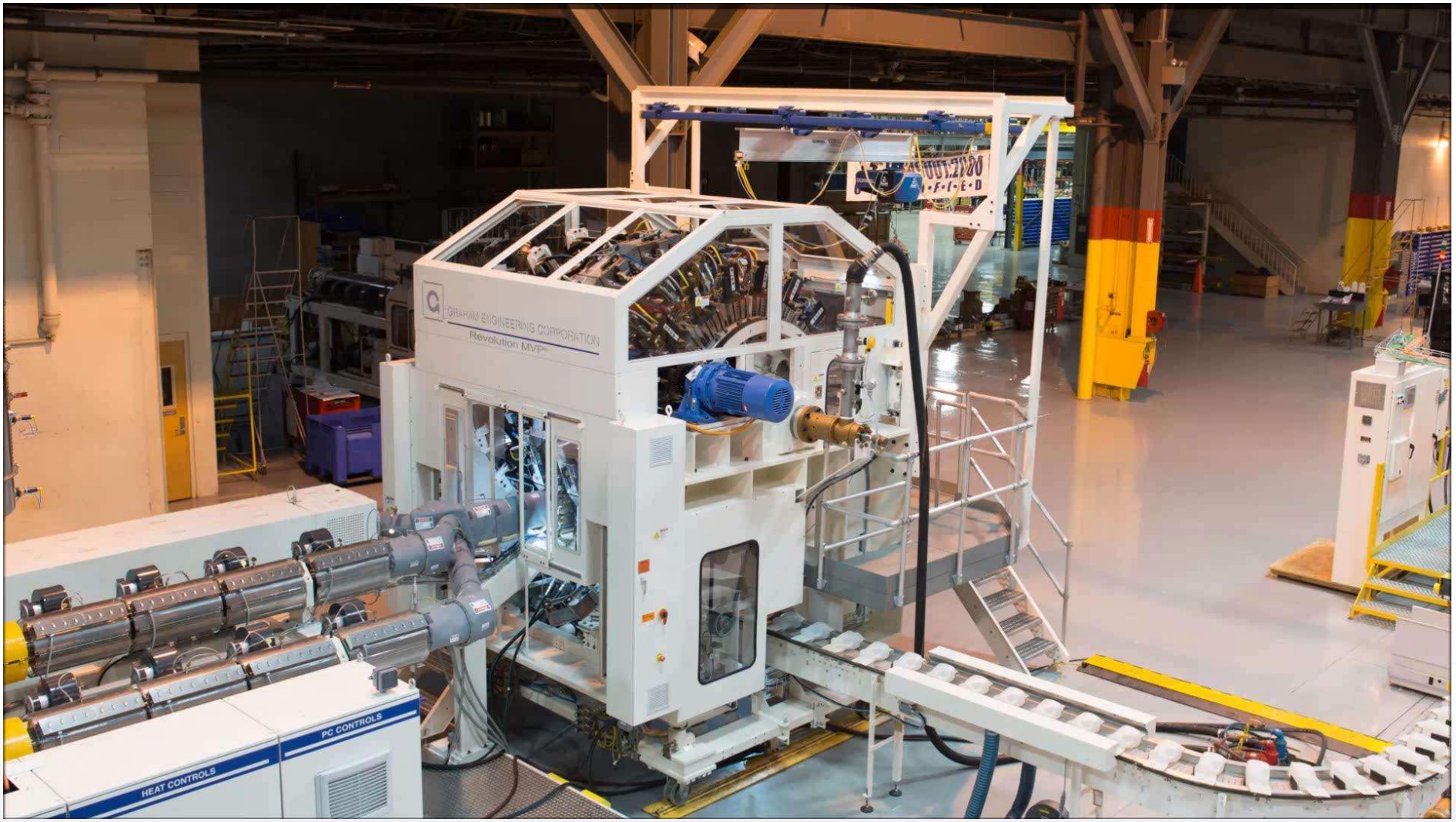
Mini
19” r



- 12-26 Stations
- Radii:39” to 47”
- 6 tons

r = radii

Graham Revolution MVP ®



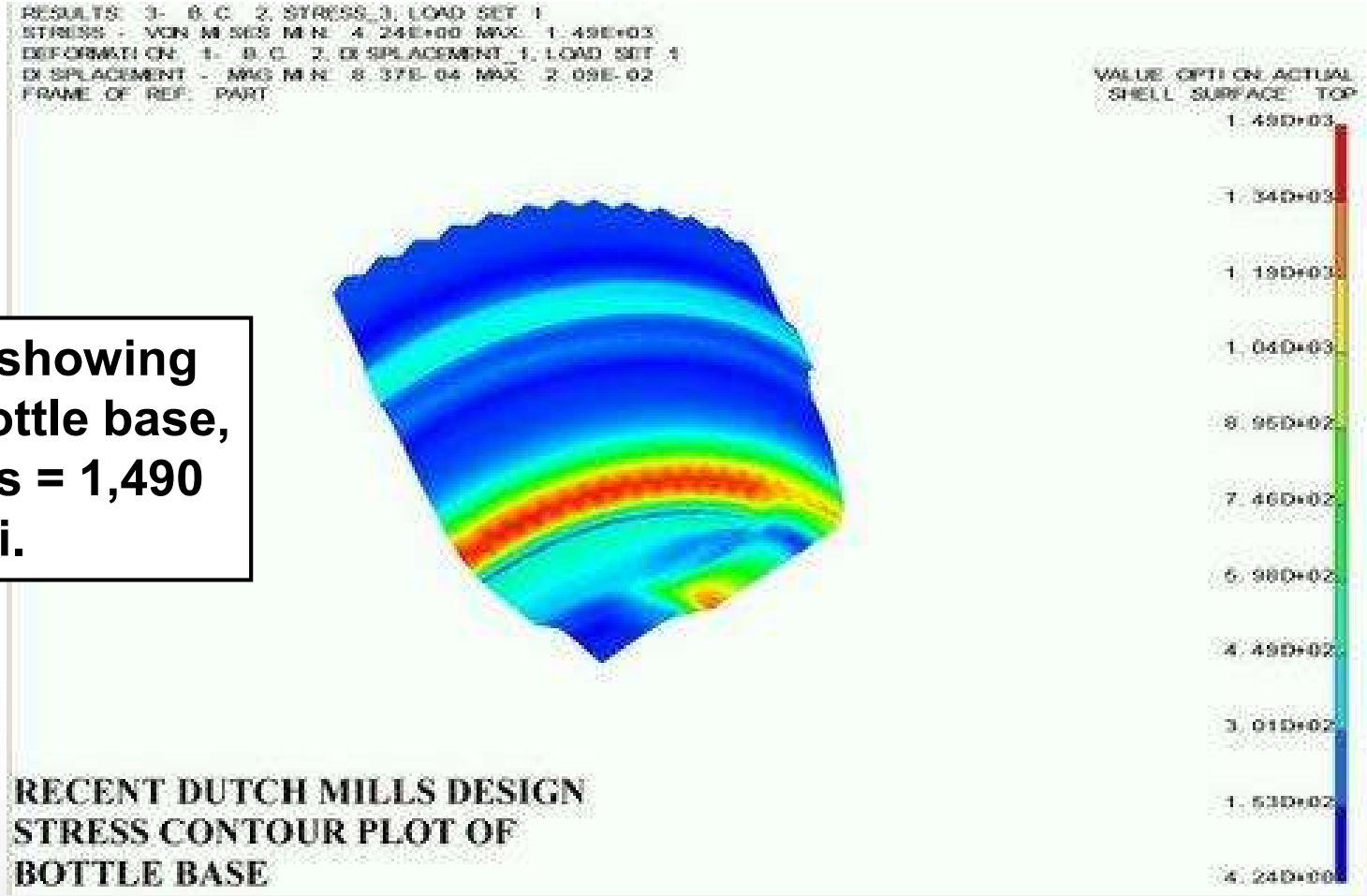
TWO CASE STUDIES

Case Study #1
Dutch Mill Bottle – Light-weighting

HDPE Commercial bottle (Right side) and PP bottle produced in development (left side) – Log shown below.

Case Study #1
Bottle Base Stress

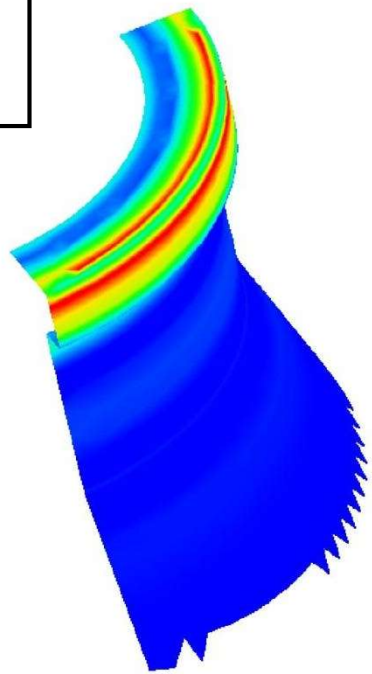
Close-up showing stress in bottle base, max stress = 1,490 psi.



RECENT DUTCH MILLS DESIGN
STRESS CONTOUR PLOT OF
BOTTLE BASE

Case Study #1
Dutch Mill Drinkable Yogurt

Original Design, Close-up of Stress Contours in Neck Area



Case Study #1
Old versus New Design

DUTCH MILLS DESIGN

GEC OPTIMIZED DESIGN

Case Study #1 – GEC Solution

- High-Speed Drinkable Yogurt Application
- Mega 24, 96 Cavity Wheel
- 8 RPM Speed, 7.2 g Bottle reduced from 8.4 g
- At 100% Production Rate:
  - 46,080 bottles per hour
  - 1,105,920 bottles per day
  - Actual production rates in the > 98% range

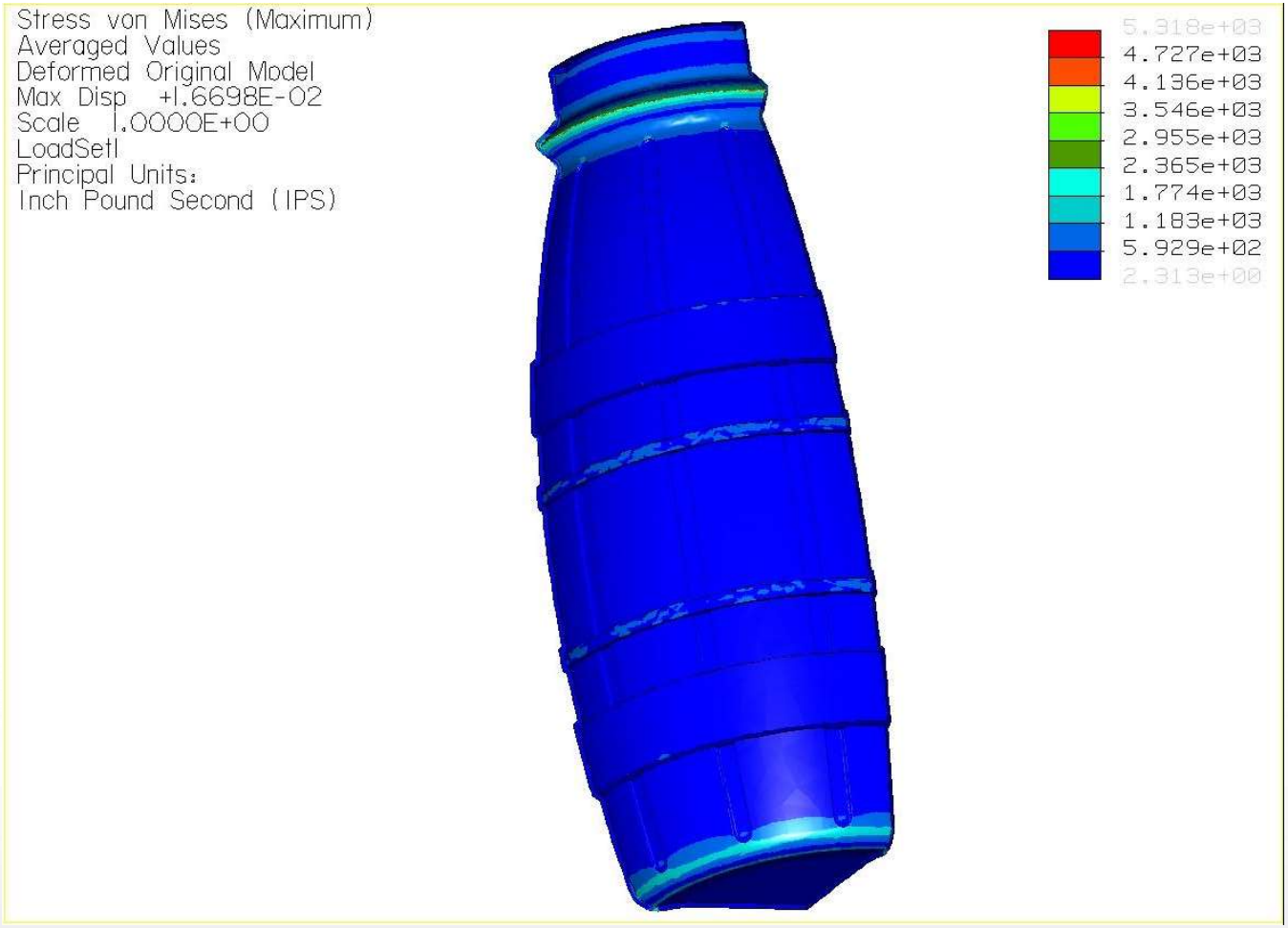
Case Study #2
Juice Bottle – Lightweighting Example

"Little Hug" 8oz Container

Was produced on recip machinery without parison programming at 9.8 grams

Case Study #2: FEA Original Design

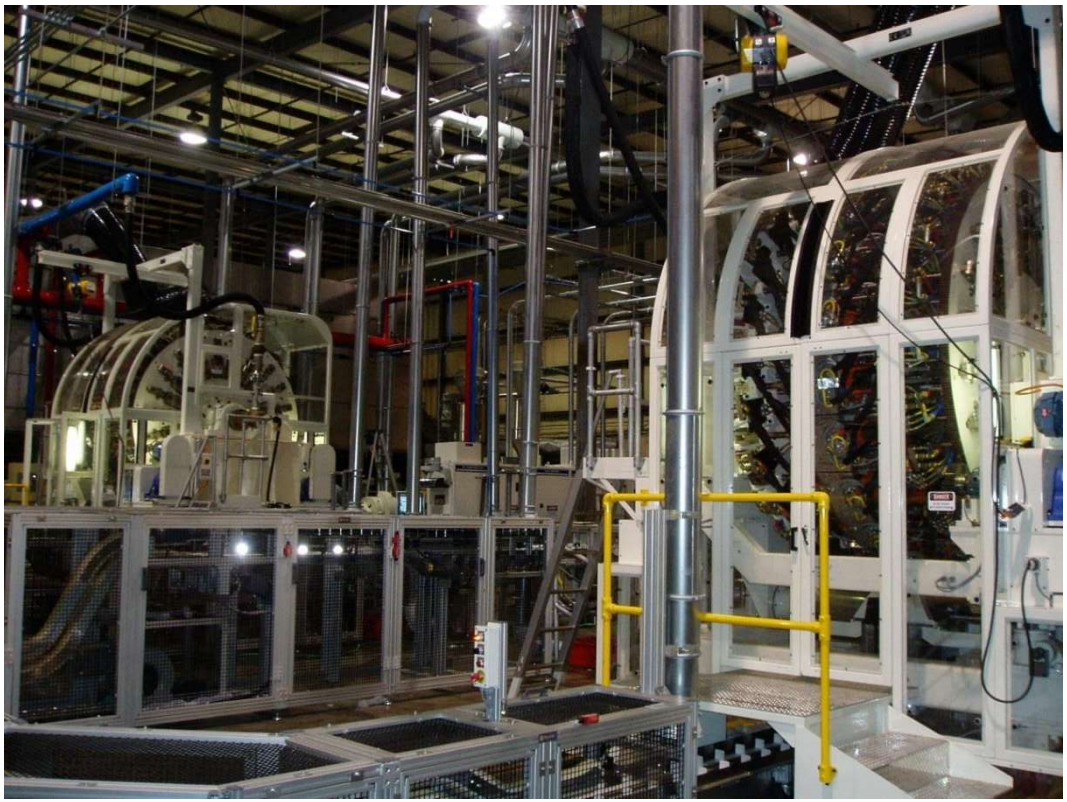
0.635 mm Thick / 12 gram (Stress Under 11.3kg top load)



Case Study #2:
Juice Bottle – Design Optimization

With small design changes and a programmed parison the bottle was reduced in weight **from 9.8 to 8.5 grams**

Case Study #2



Two Mega 22 Wheels, each 88 Cavities replaced 10 reciprocating screw machines.

Case Study #2
Results

- Energy reduced from 6.5 to 3.8 kWh per 1,000, saving 1.35 million kwh of electrical power.
- Saving > 2 million lbs. of HDPE annually.
- The use of two Graham wheels is resulting in an annual savings of nearly $3,000,000.

Rotary Wheel

- Continuous extrusion
- Multi-layer co-extrusion, with one to seven layers of plastic in the finished part
- In some applications, In-mold Labeling (IML) can be integrated with little or no cycle-time penalty
- Parison programming capability, for optimization of wall thickness
- Reduced cycle time on light weight containers, compared to shuttle machinery. Conversely, wheel equipment may suffer cycle time penalties on thick containers
- Easily implemented view stripe capability
- Ability to achieve very high outputs from a single machine - lowest "cost per bottle" when compared to other blow molding equipment
- Higher production efficiencies than most other extrusion blow molding equipment types

THANK YOU!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