# SHUTTLE BLOW MOLDING TECHNOLOGY 101

**Presented by: Joe Slenk**
**Manager, Applications and Process Development**

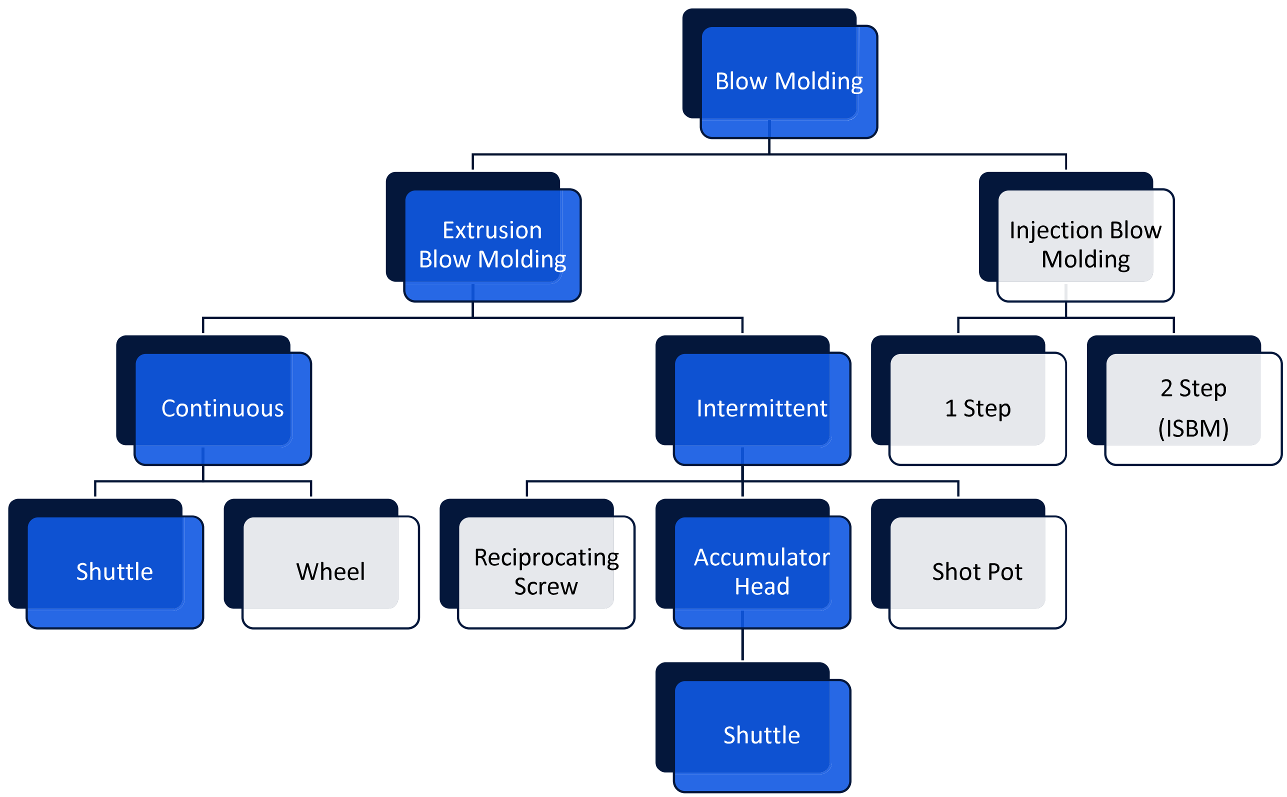
BLOW MOLDING

Annual Blow Molding Conference, September 8-10, 2025

# PRESENTATION CONTENT

- Shuttle Blow Molding Overview
- Parison Formation
- Machine Movements
- Automation Options

# BLOW MOLDING CATEGORIES

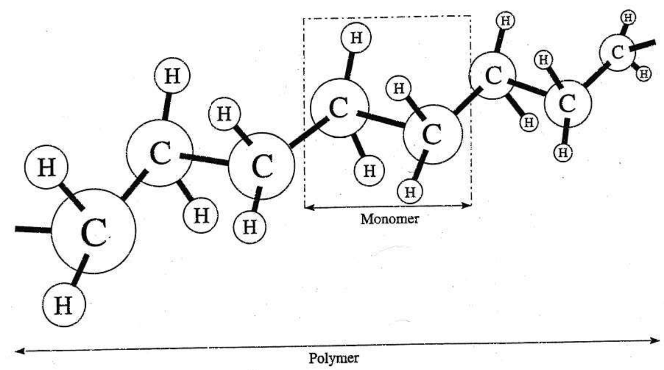


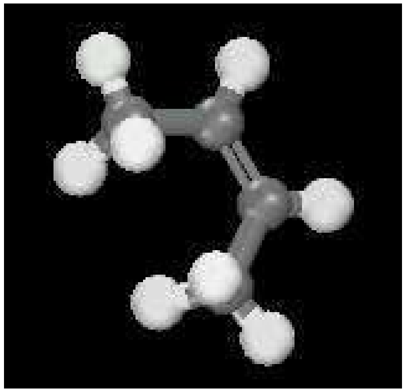
# TYPICAL SHUTTEL APPLICATIONS

- Food & Beverage
- Dairy
- Personal Care
- Household Chemical
- Automotive
- Medical
- Technical Parts


# TYPICAL MATERIALS

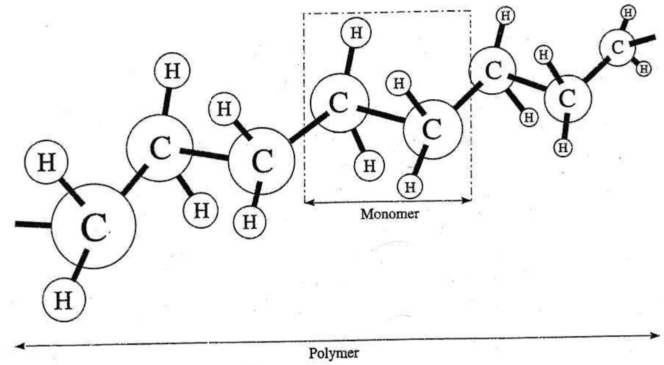
- HDPE- High Density Polyethylene
    - Bottles, cases, drums, tanks
- LDPE - Low Density Polyethylene
    - Flexible bottles
- PP-  Polypropylene
    - Hot fill / Higher temp bottles
- PVC- Poly Vinyl Chloride
    - Clear bottles (chemical resistance)

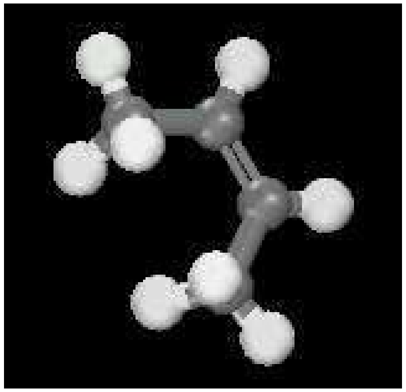


# TYPICAL MATERIALS

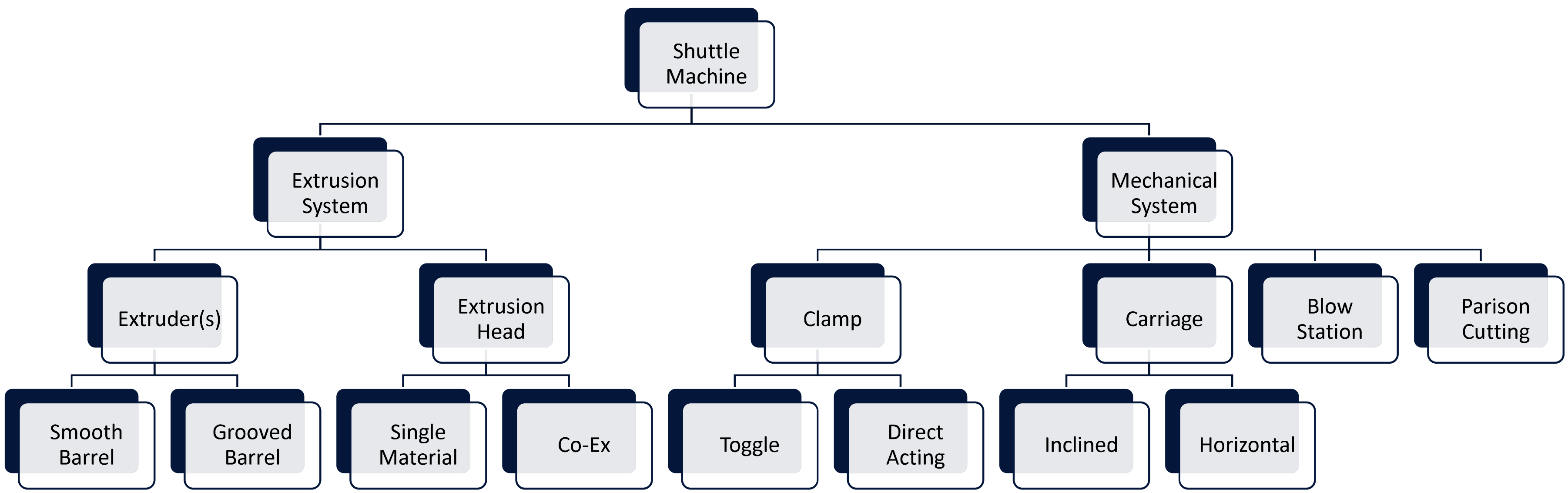
- PET – Polyethylene Terephthalate
  - Clear Bottles (handleware/recyclable)
- PC – Polycarbonate
  - Rigid housings / Bottles
- PA – Polyamide (Nylon)
  - Automotive parts
- CO-EXTRUSION – EVOH Or Nylon Barrier Layer
  - Permeation barrier (oxygen / hydrocarbon)



# SHUTTLE MACHINE SYSTEMS

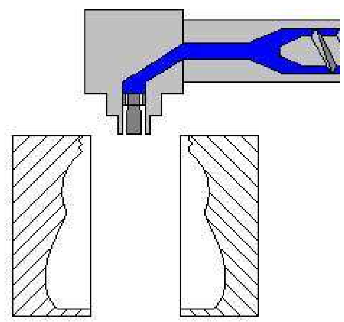




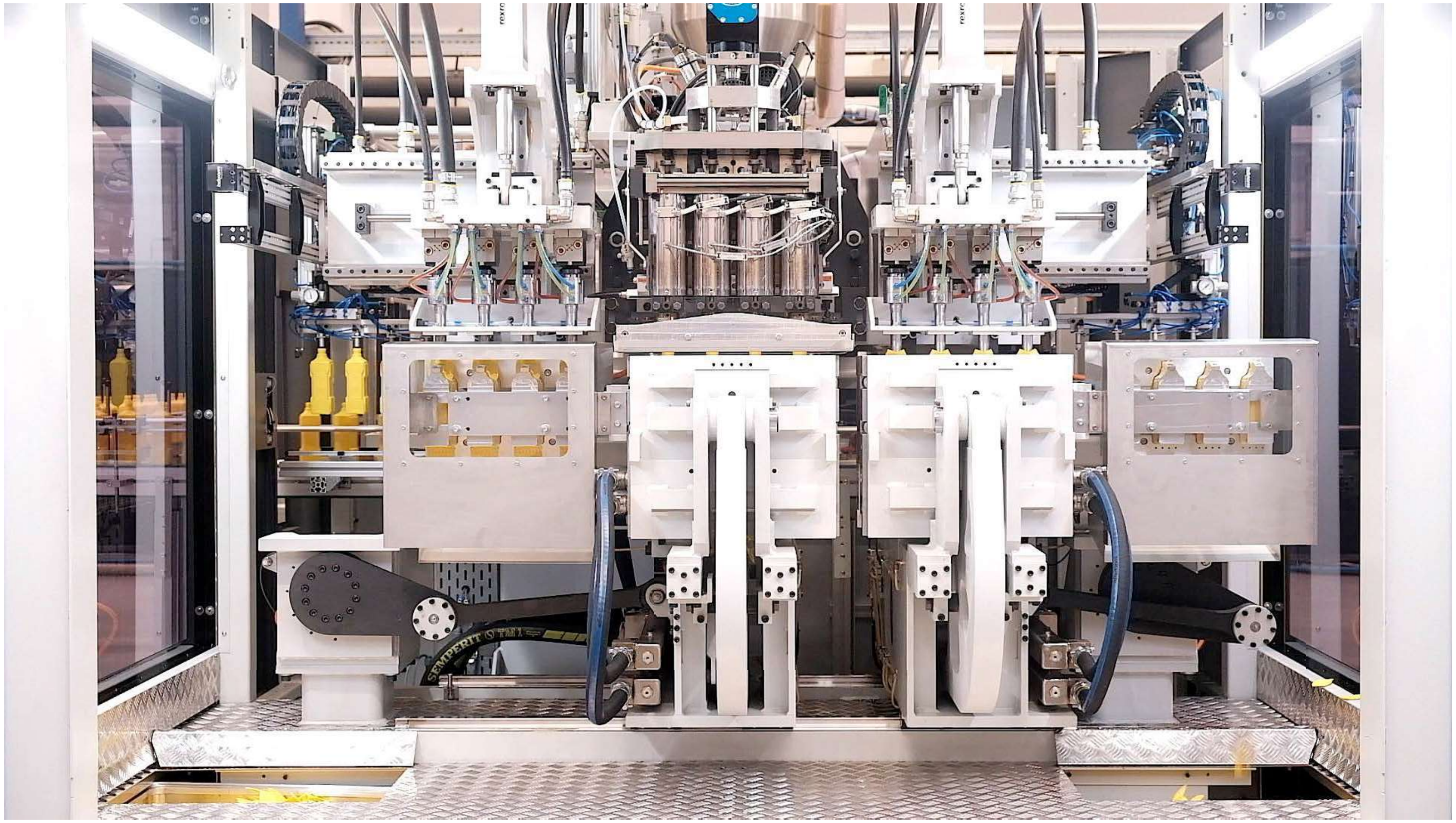
# SHUTTLE PROCESS



- Parison Formation (extrusion system)
- Carriage shuttles clamp to parison
- Clamp closes mold on parison
- Knife cuts parison
- Carriage retracts to blowing station
- Calibration station lowers and blows part
- Part cools while under blowing pressure against cooled mold
- Clamp opens and releases part



# SHUTTLE PROCESS



# PARISON FORMATION

- Shuttle Blow Molding Overview
- **Parison Formation**
- Machine Movements
- Automation Options

# EXTRUDER



## Purpose / Function

- Feed, Melt and convey material
- Provide homogenous melt to extrusion head
  - No degradation of material
  - No un-melts/gels
  - Material at acceptable stock temperature
- Provide sufficient and constant output for required production
  - No surging

# EXTRUDER



## Extrusion Process

1. Material is introduced into extruder via hopper
2. Material is conveyed forward by feedscrew
3. Material is compressed and heated until melted
4. Melted material flows into the extrusion head
5. Material flows through extrusion head tooling and forms the parison

# PARISON FORMATION

# EXTRUDER



## Extruder Types

- Smooth barrel
  - Screw performs the material feeding
- Grooved barrel
  - Grooved Feed housing boosts material feed

## EXTRUDER

### Smooth Barrel Extruders

- **Advantages**
  - More screw design options
    - Barrier screw
    - Special screws for specific materials
  - Can process a wide variety of materials
    - PE, PP, PET, PC, PVC, PA6, TPO, etc.
- **Disadvantages**
  - Lower material throughput vs. similar sized grooved barrel extruder

# EXTRUDER



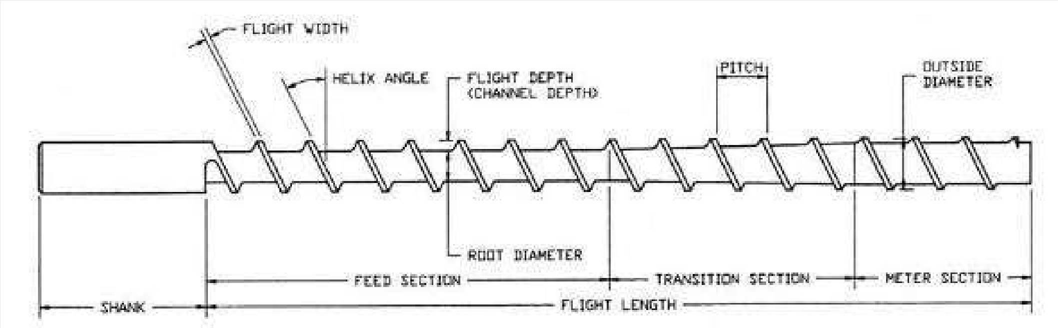
## Extrusion Screws

Screws are designed for the type of material being processed with an overall length (O.L.), overall diameter (O.D.), length to diameter ratio (L/D) and compression ratio.

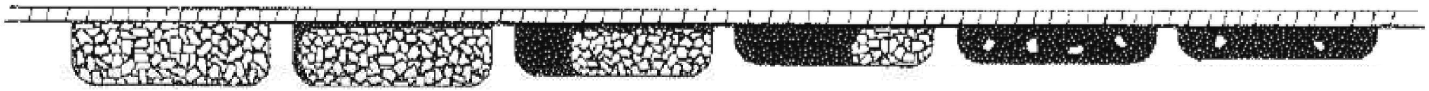
- **Diameter:** Overall outside diameter of flights, measured in inches or millimeters.

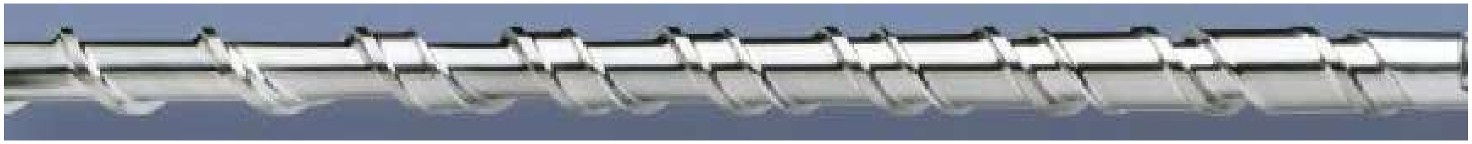
- **L/D Ratio:** Ratio of flight length to diameter. An 80 mm diameter 24:1 screw would have an effective flight length of 1,920 mm. L/Ds for blow molding machines range from 20:1 to 30:1.

- **Compression Ratio:** The ratio of the flight depth in the feed zone to the flight depth in the metering zone. Typical compression ratios range from 1.5:1 to 4.5:1 (except for grooved barrels which are zero compression 1:1).



## Extrusion Screws





## Grooved Barrel Extruders

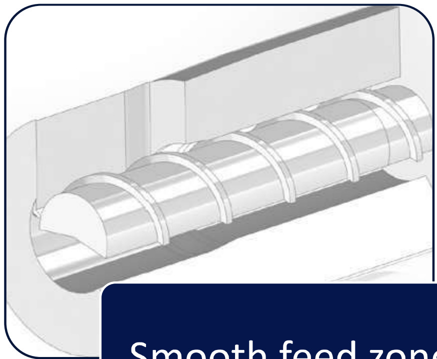
- **Advantages**
  - More material throughput for similar sized extruder
    Example: 90mm Grooved = 525lbs/hr
    90mm Smooth = 450lbs/hr HDPE
  - Lower stock temperature for similar output
- **Disadvantages**
  - Material waste on start up / shut down
    - Must starve feed to start up
    - Must clear grooved section to shut down
  - Proper start up and shut down procedures must be maintained
  - Limited material applications
    - Mainly used for PE and PP

## Grooved Barrel Extruders

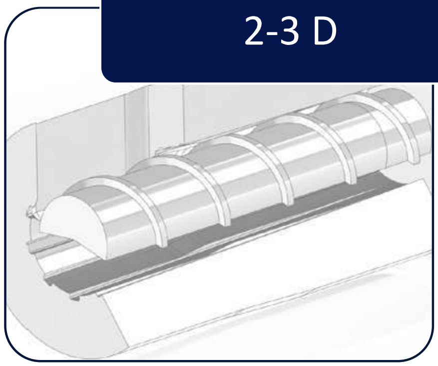
Front view of grooved feed

Top view of grooved feed

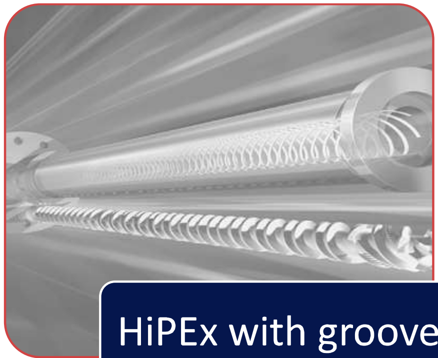
# NEXT STEP: BEKUM HIGH PERFORMANCE EXTRUDER -HiPEx



Smooth feed zone



Grooved feed zone
2-3 D



HiPEx with grooved barrels 36D

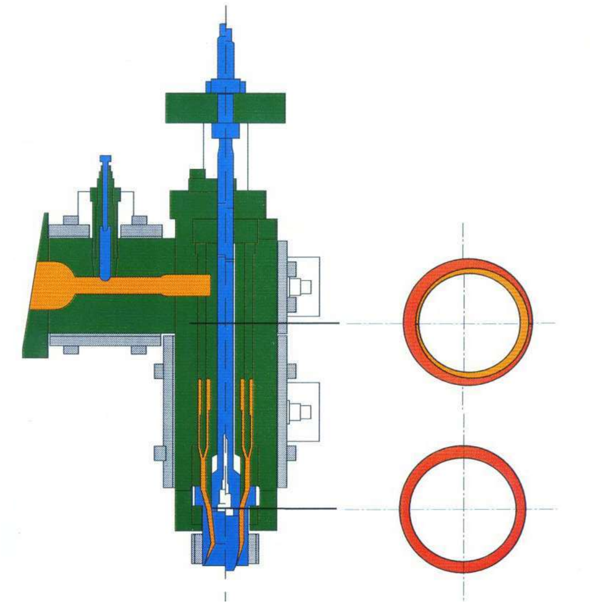
# EXTRUSION HEAD



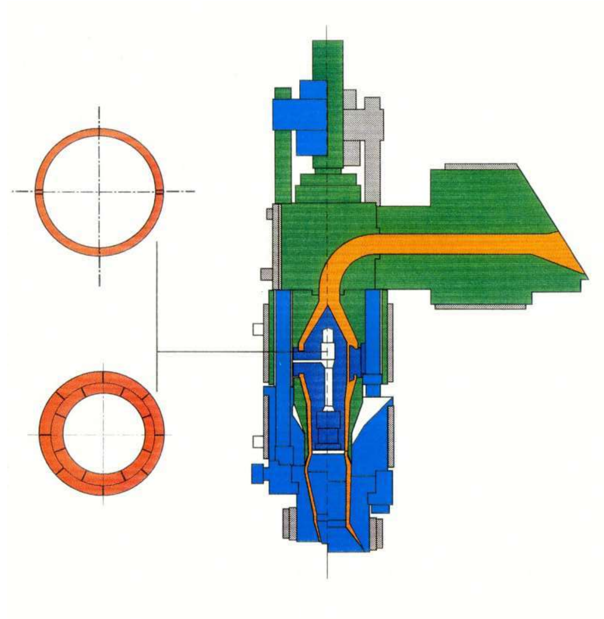
## Purpose / Function

- **Form the parison**
  - Take horizontal melt stream and turn it 90° to form a vertical parison
  - Flow around a core to form a hollow tube
    - Provide proper material re-knit
    - Uniform melt temperature
  - Flow through a die and pin to establish proper parison size
    - Uniform circumferential parison thickness
- **Program parison thickness**
  - Change die gap to influence parison thickness
- **Introduce support air into the parison**
- **Adjust parison alignment for best wall thickness distribution**

## Extrusion Head Variations



Mandrel Style Head



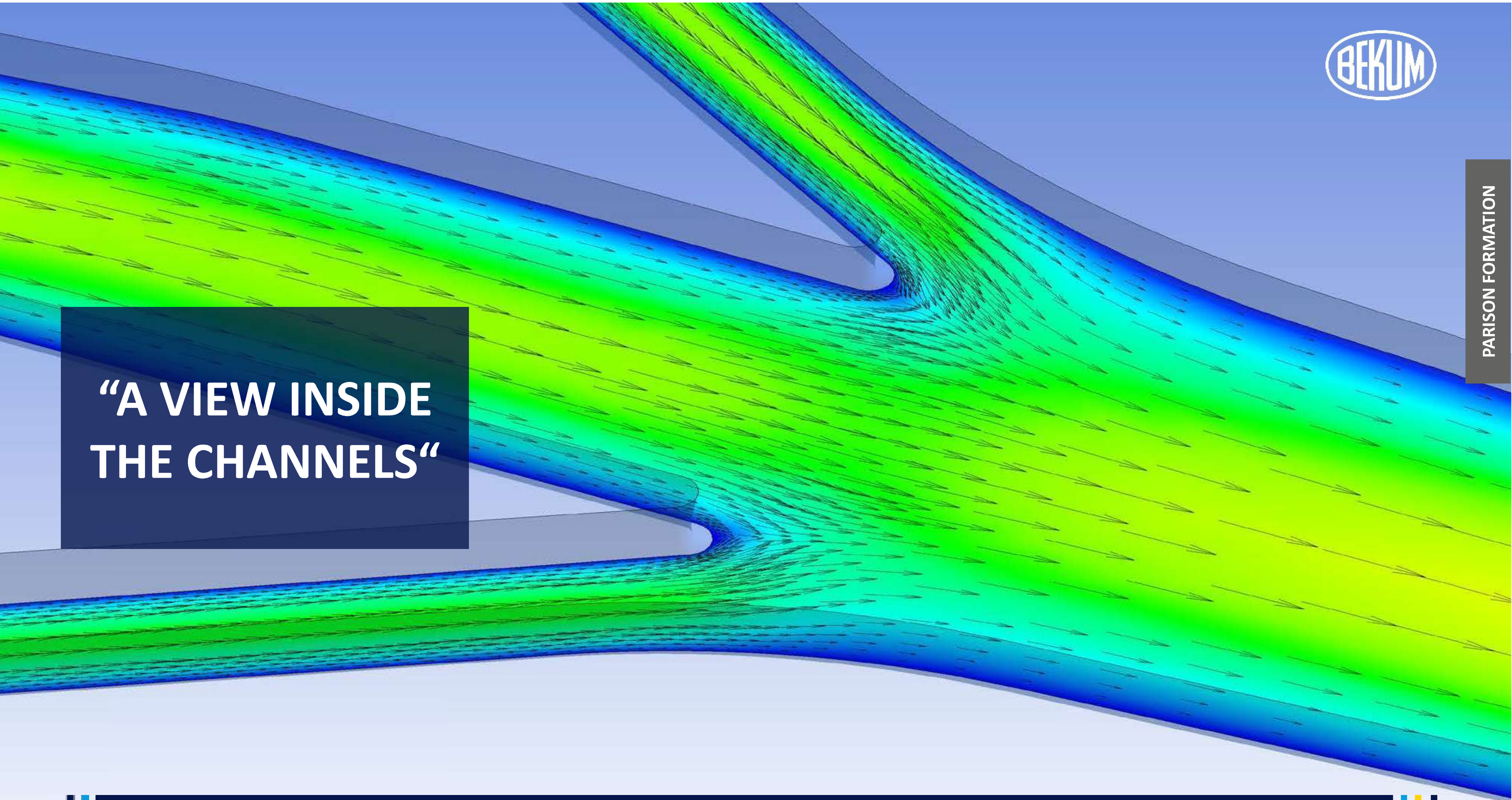
Center-flow Head

## Extrusion Head Variations

Mandrel Style Head

Center-flow Head

# EXTRUSION HEAD

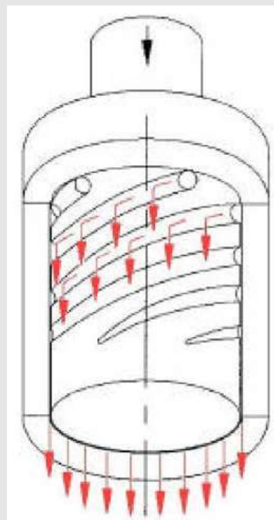


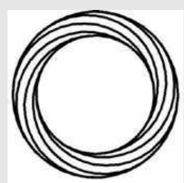
# “A VIEW INSIDE THE CHANNELS“

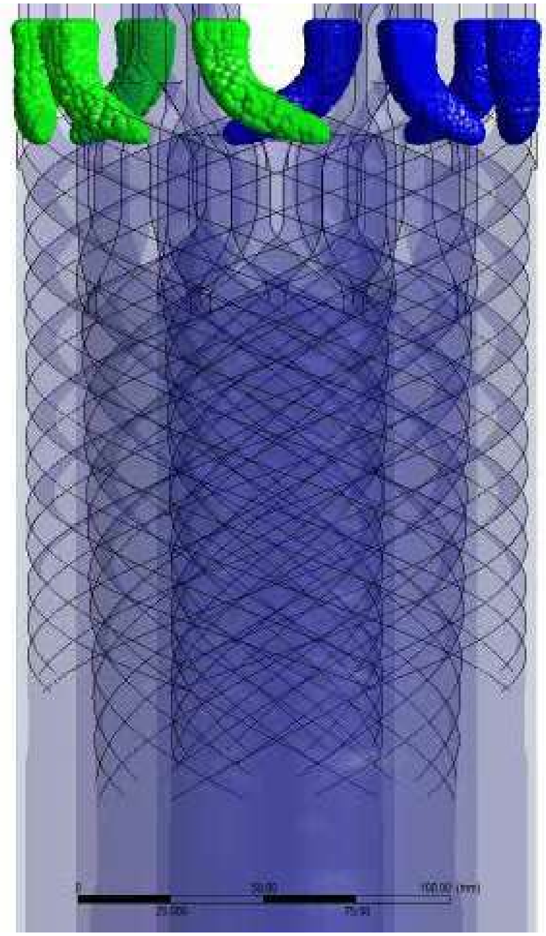
## HOW DOES A SPIRAL MANDREL PINOLA WORK?

### Spiral flow is overlapping the axial flow

- No lines
- Very good circumferential distribution
- Very good coverage of PCR layer

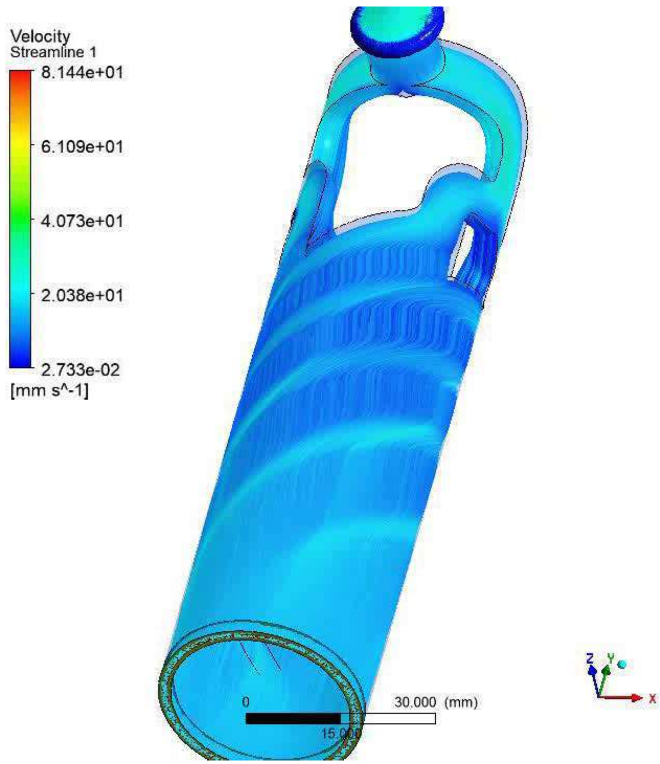


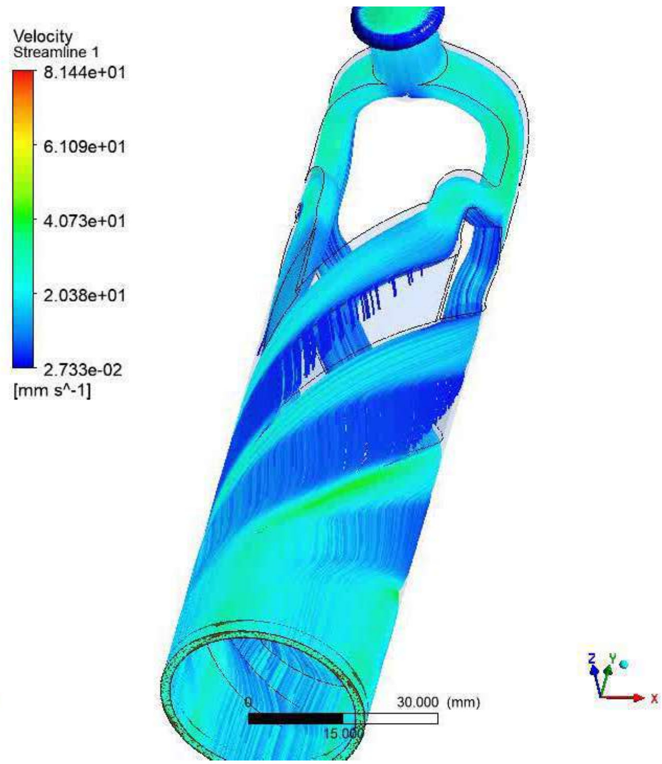




# IMPROVEMENT OF MATERIAL FLOW

NEW:
With CFD



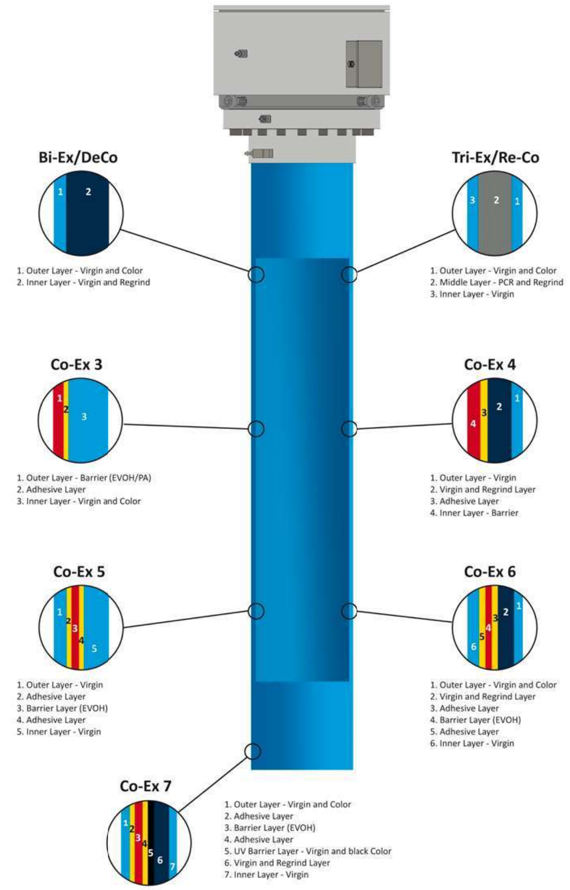




OLD:
Without
CFD

# CO-EXTRUSION

## Heads can be manufactured for two to seven layers for:

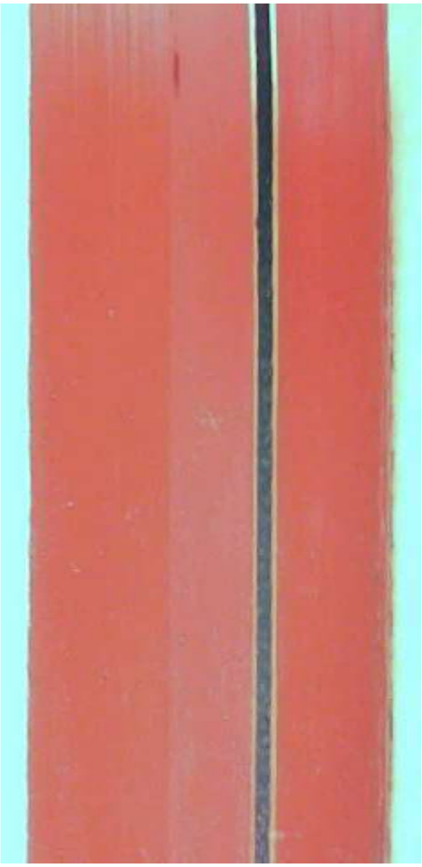
- Oxygen Barrier
- Hydrocarbon Barrier
- UV Barrier
- Recycled Scrap




PARISON FORMATION

## CO-EXTRUSION

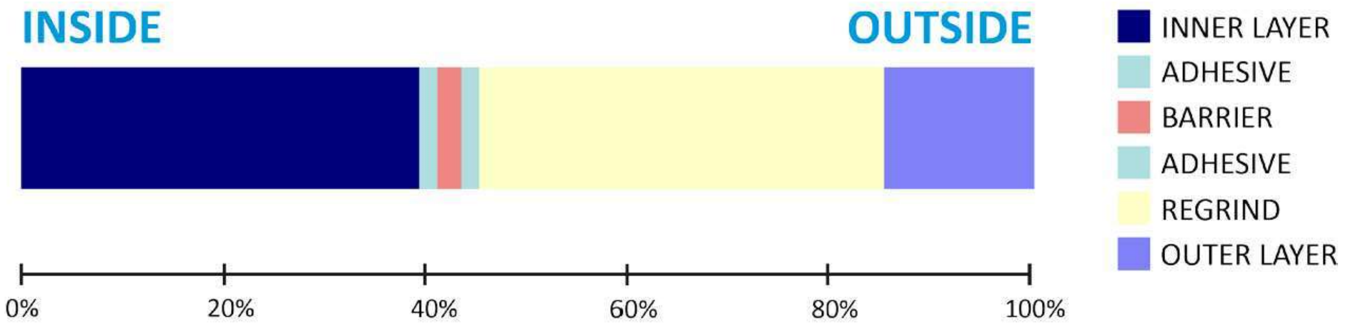
**CARB compliant 6-layer, 2-gallon gasoline can with EVOH barrier (stained black with iodine)**

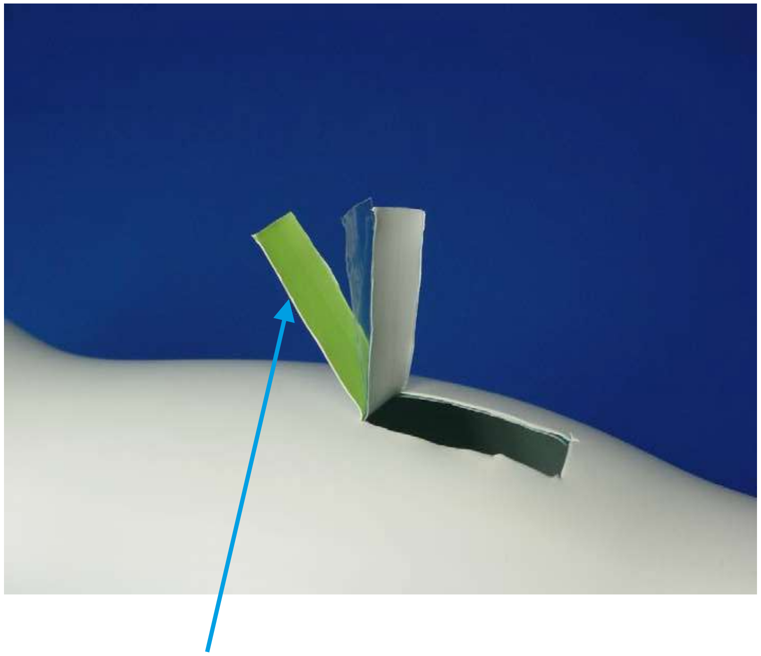
# CO-EXTRUSION

## 6-Layer Co-Ex-Plastic Automotive Fuel Tank
## Typical Ranges of Layer

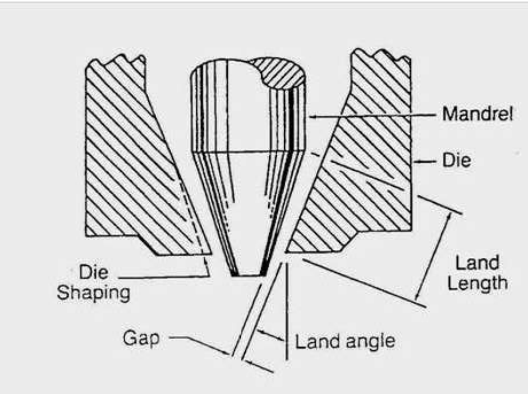
- Outer Layer (> 15 %)
- Regrind (30 - 50 %)
- Adhesive (1 - 3 %)
- Barrier (1 - 3 %)
- Adhesive (1 - 3 %)
- Inner Layer (30 - 50 % )



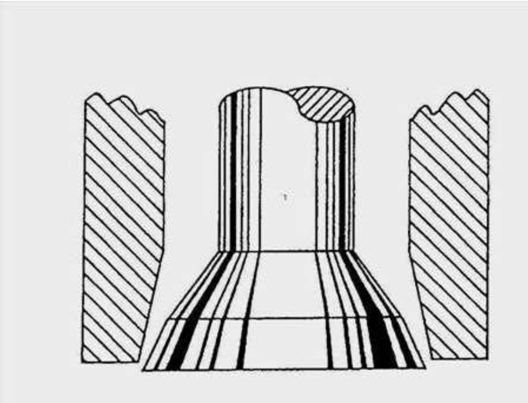
## Barrier for Food Applications

## Head Tooling Variations




Together, the die (bushing) and pin (mandrel) are referred to as the "head tooling". The die and pin determine the wall thickness and the diameter of the parison.



The pin or mandrel determines the inside geometry of the parison, while the die or bushing defines the outside geometry. Head tooling is classified as either converging or diverging.

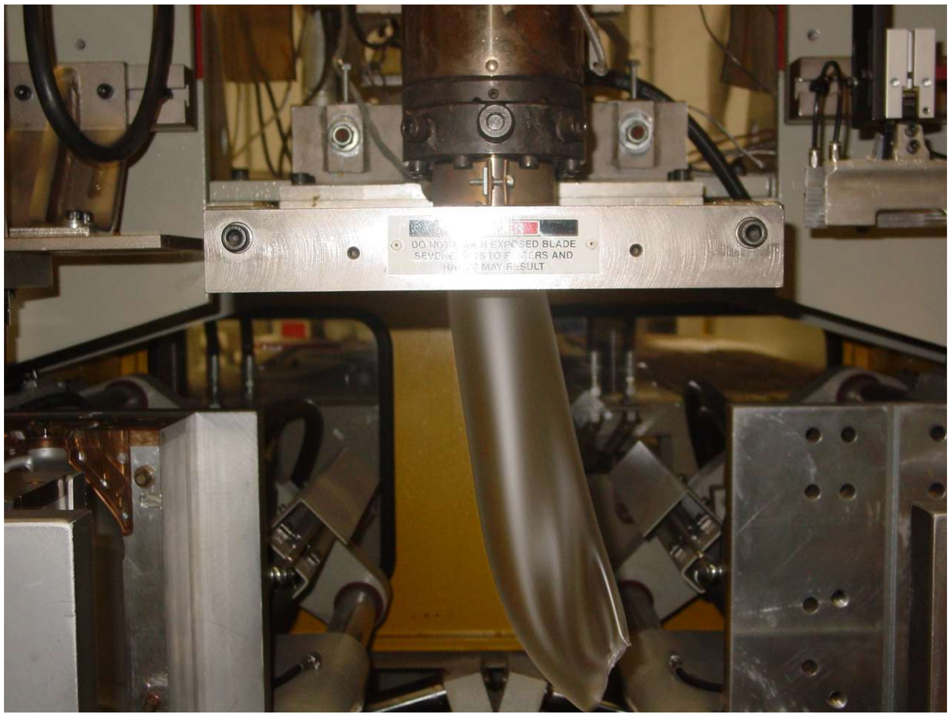
## Head Tooling Variations

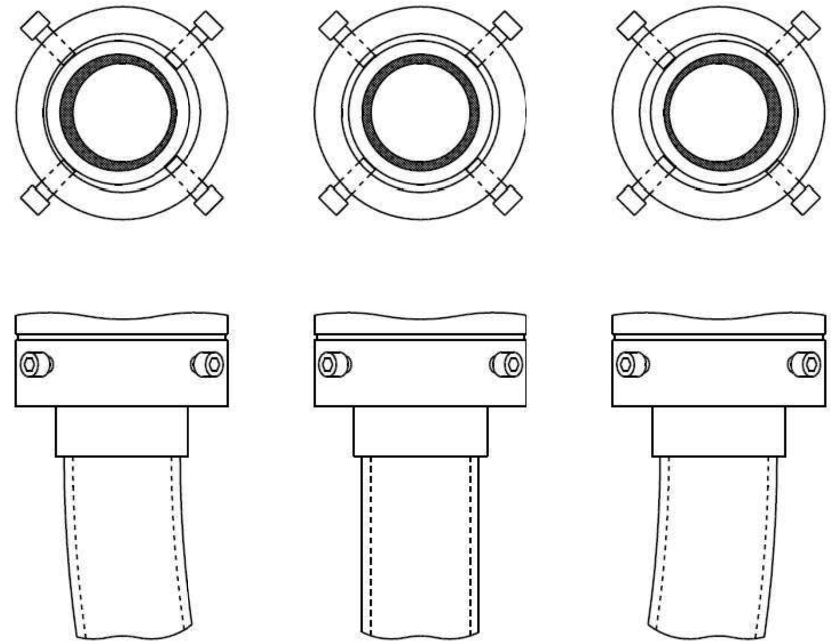
**CONVERGING TOOLING:**
Converging tooling uses a conical shaped pin or mandrel, with a corresponding die or bushing shape.

**DIVERGING TOOLING:**
Diverging tooling uses a bell shaped pin or mandrel with a correspondingly shaped die or bushing.

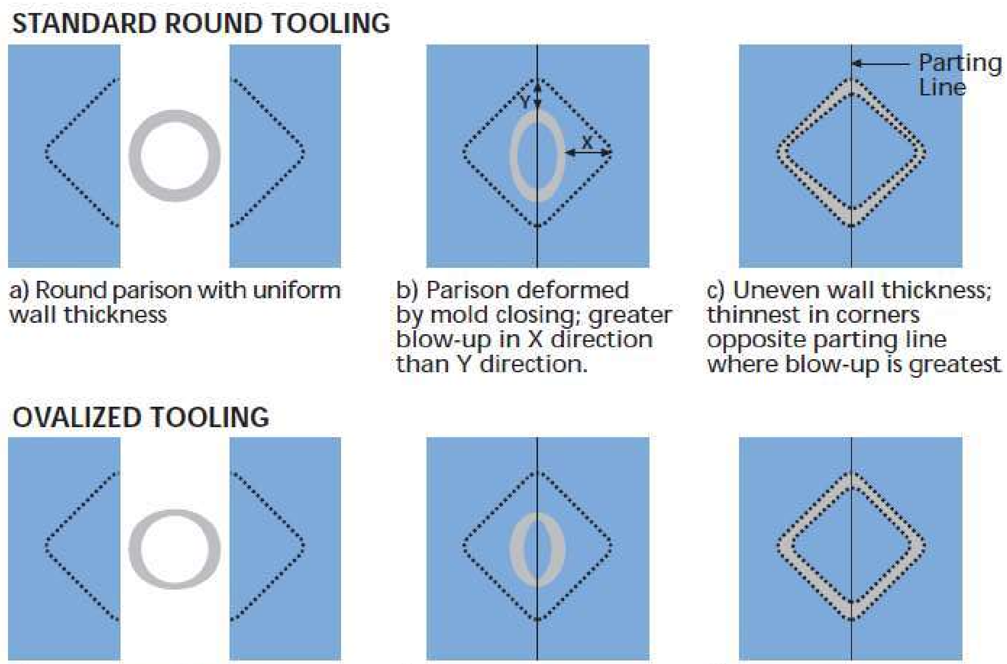
*Head size vs. parison size dictates the tooling type

## Parison Alignment





## Ovalized Head Tooling




a) Round parison with uniform wall thickness

b) Parison deformed by mold closing; greater blow-up in X direction than Y direction.

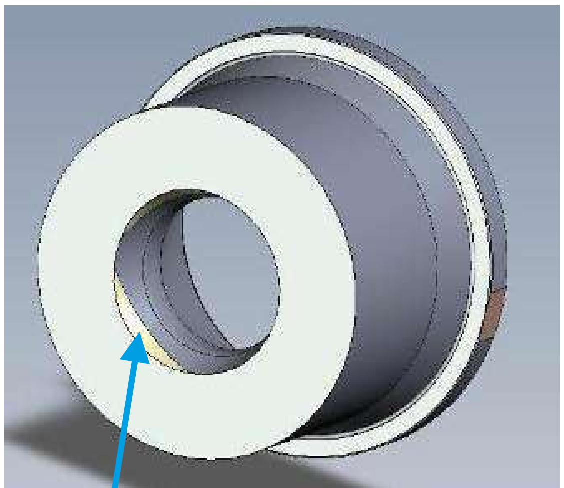
c) Uneven wall thickness; thinnest in corners opposite parting line where blow-up is greatest

d) Shaped die distributes more polymer to greater blow-up areas

e) Added polymer opposite parting line compensates for effects of mold closing

f) More uniform wall thickness; with additional polymer in corners opposite parting line

## Extrusion Head Variations



Ovalization

**OVALIZED TOOLING:**
Ovalization allows the shaping or contouring of the parison wall thickness around the diameter of the parison. This contouring makes more material available for those areas of the article being blown with a larger blow-up ratio. Ovalization can be added to either the pin or the die.

**ATTENTION:**
When mounting ovalized tooling, pay attention to the orientation.

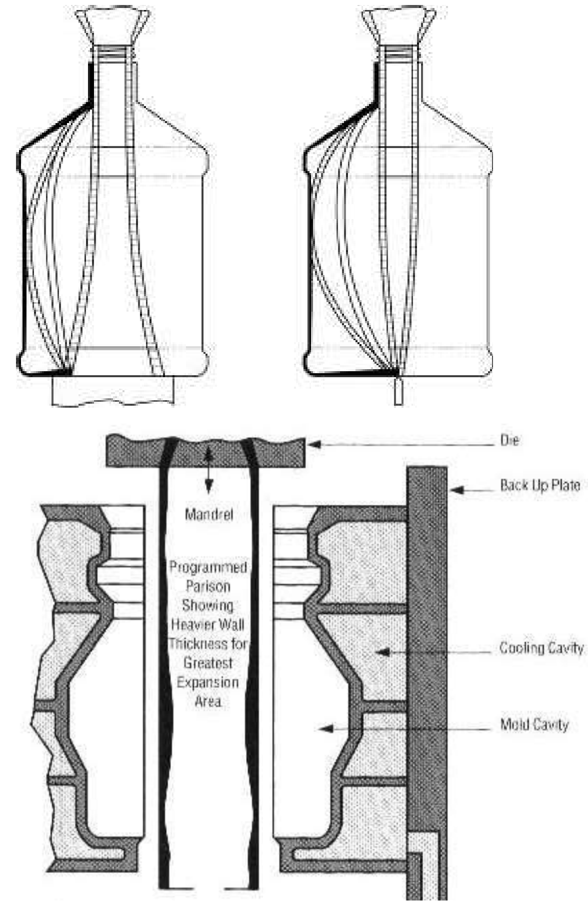
# PARISON PROGRAMMING



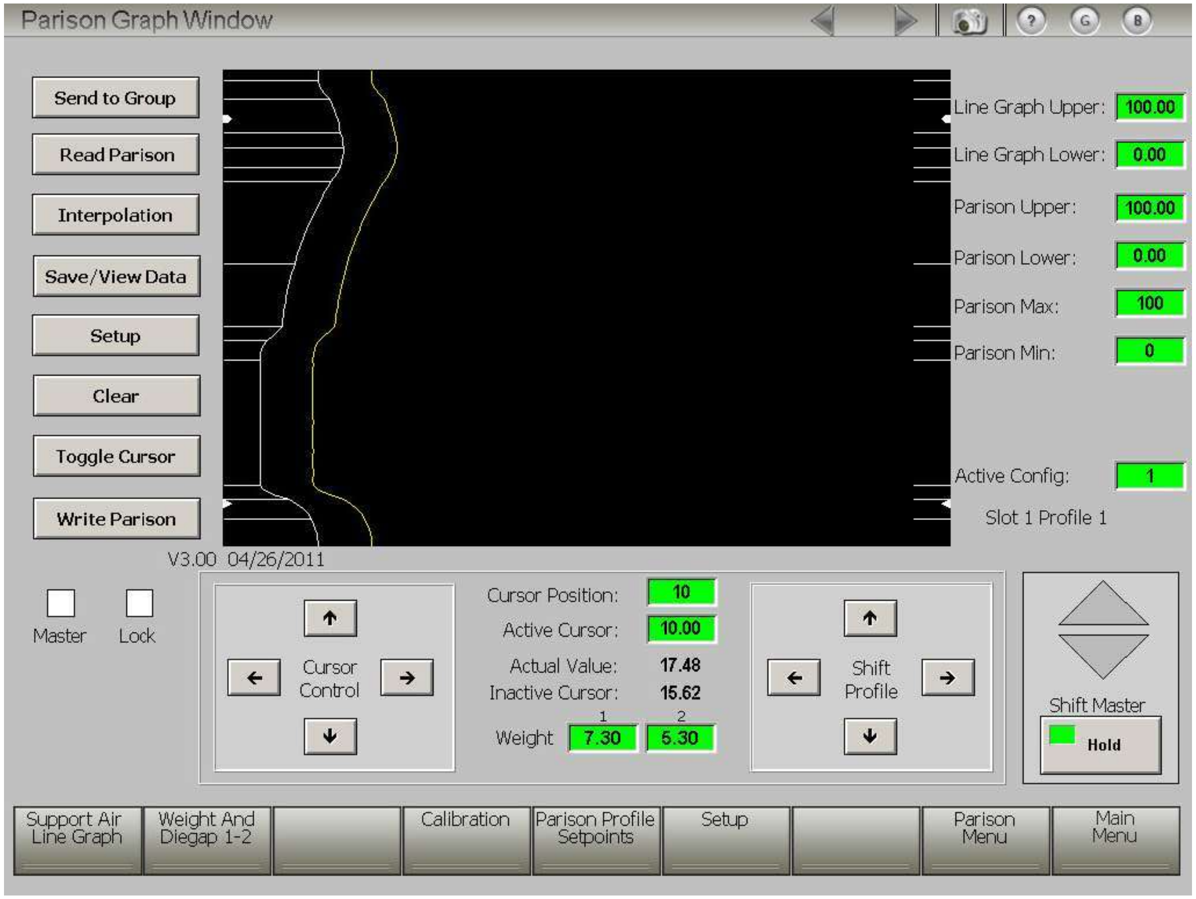
## Parison Programming

- The more a parison is inflated, the thinner it becomes
  - This translates into a part's wall thickness
- We can compensate for this using parison programming
- Using programming, we can change the die gap
  - Increased die gap for larger blow ratio
  - Decreased die gap for smaller blow ratio
  - We can also target specific areas of a part depending on performance criteria
- This is very useful for weight reductio

The picture shows a parison programmed to fit a particular mold configuration.

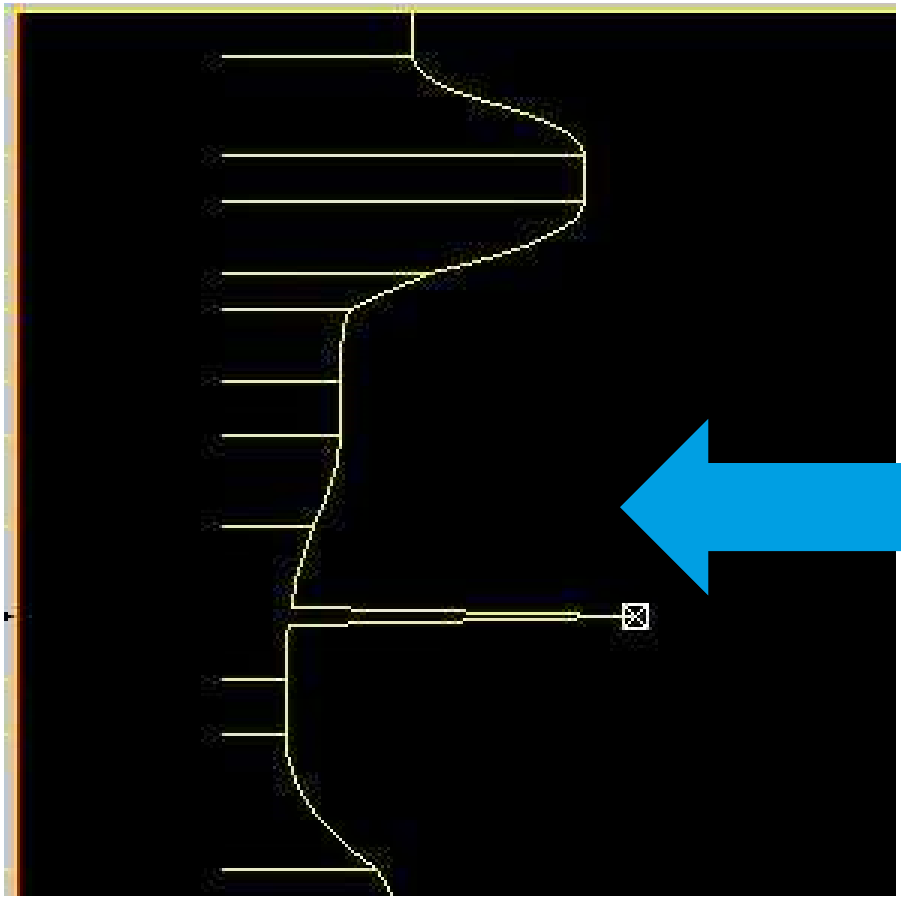


# PARISON PROGRAMMING

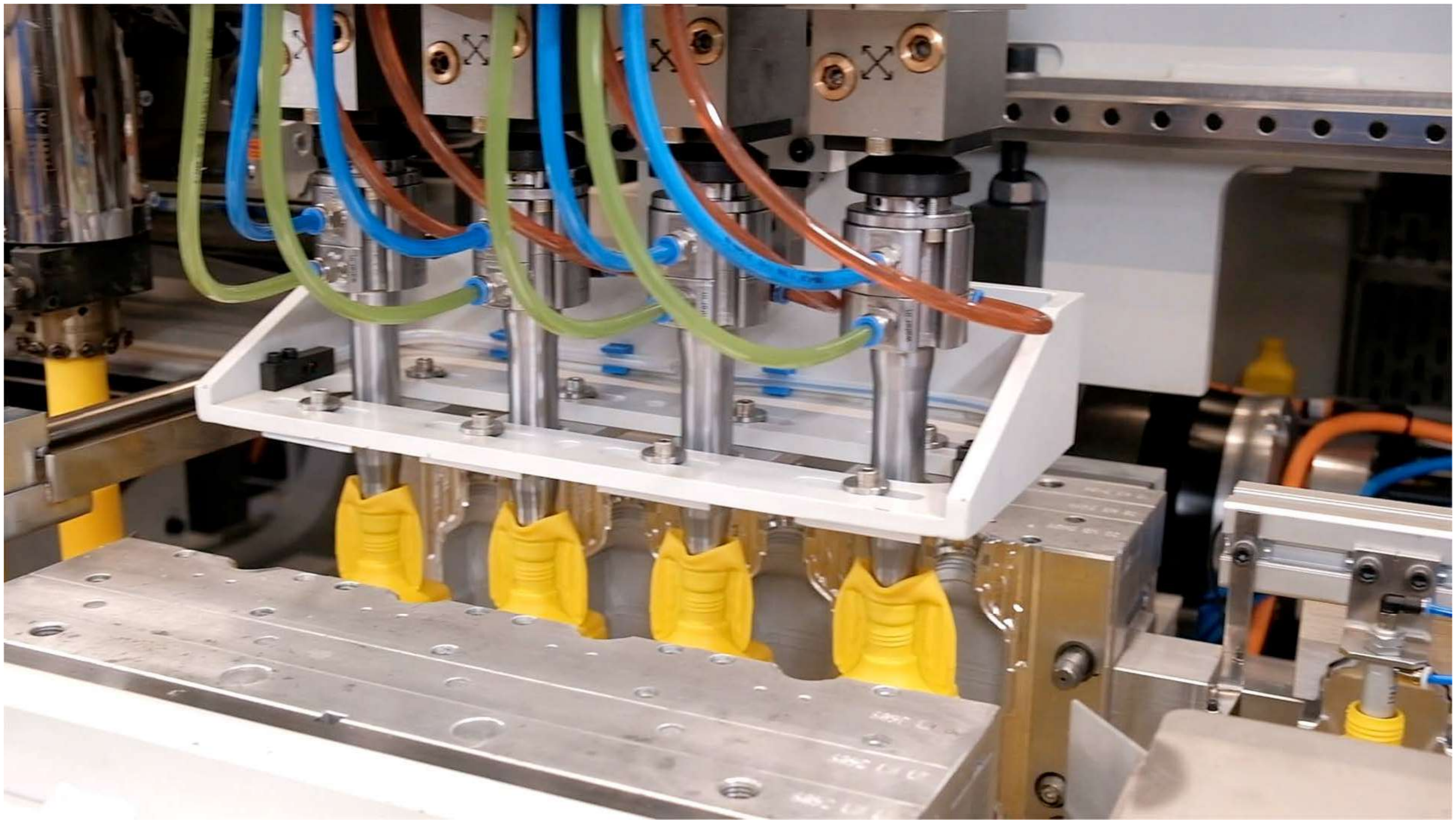



PARISON FORMATION

# PARISON PROGRAMMING



## PARISON PROGRAMMING

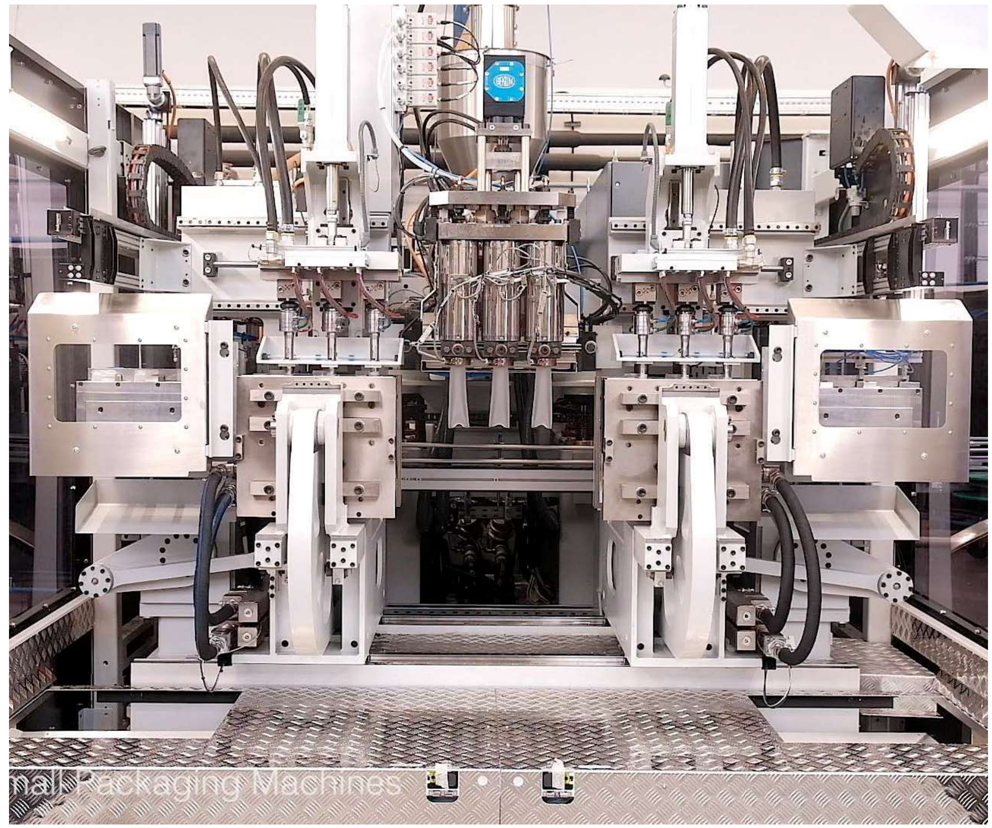


SHUTTLE BLOW MOLDING 101

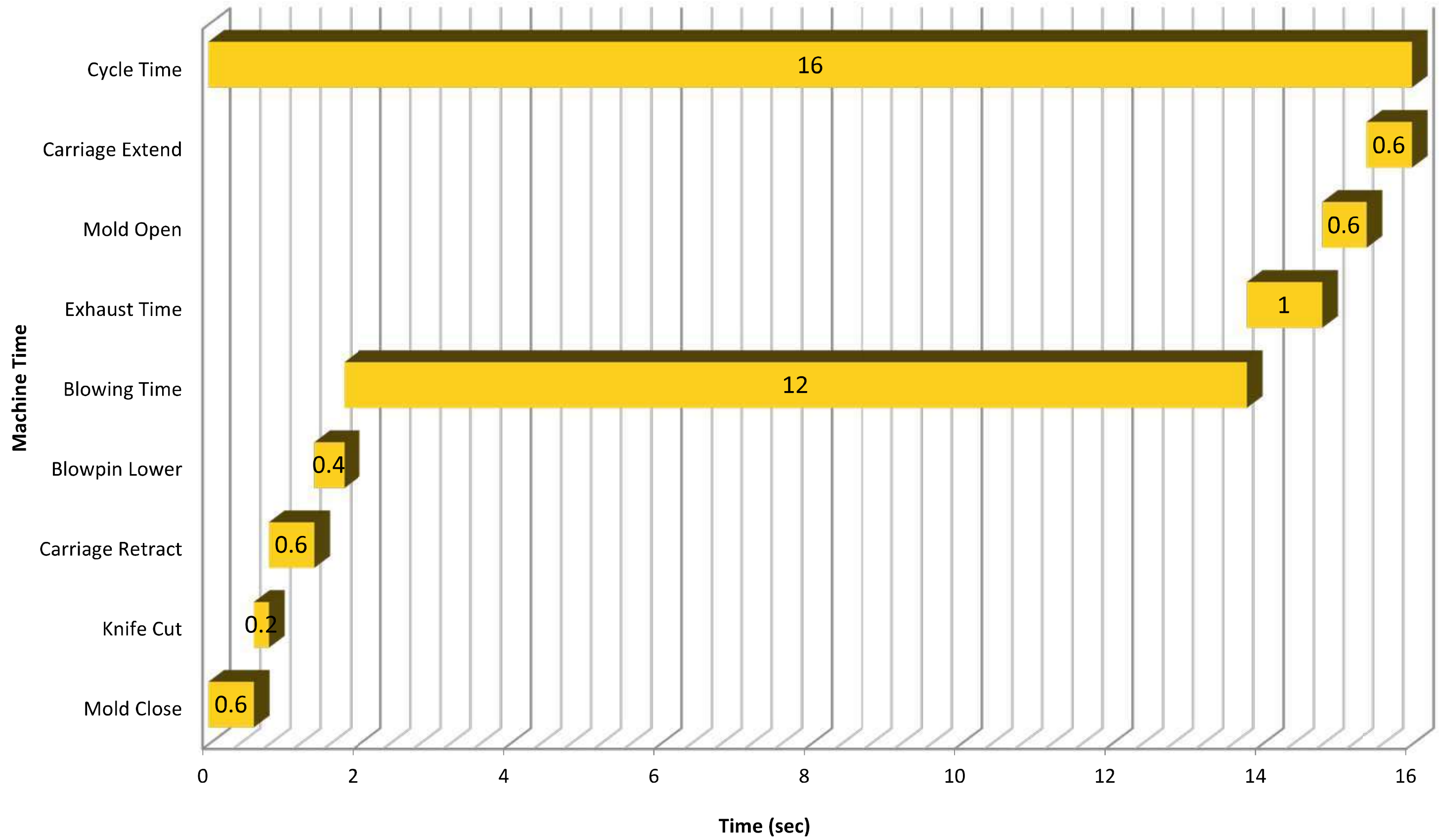
# MACHINE MOVEMENTS



- Shuttle Blow Molding Overview
- Parison Formation
- **Machine Movements**
- Automation Options



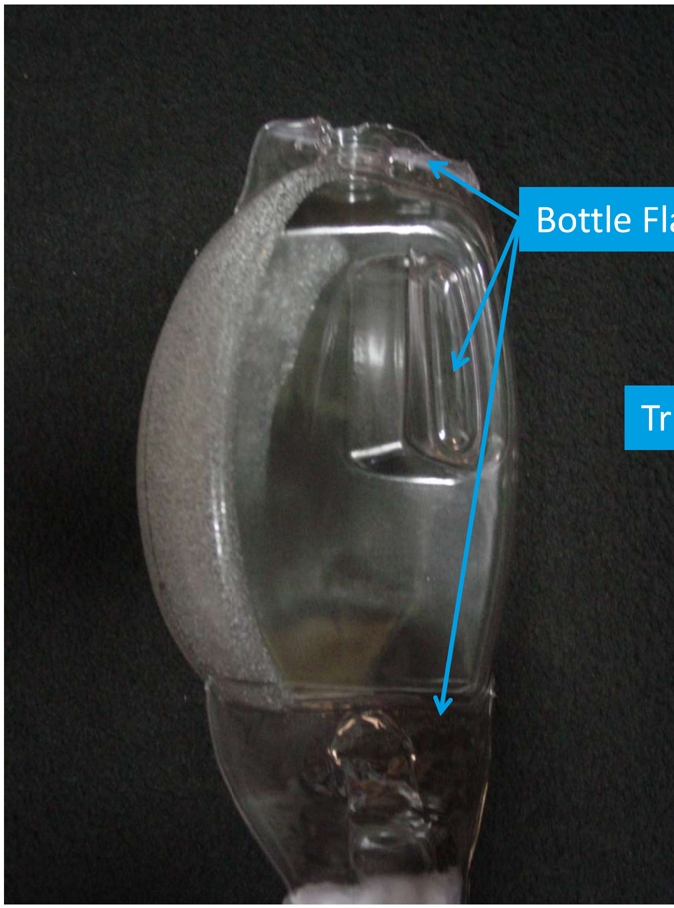
# MACHINE CYCLE

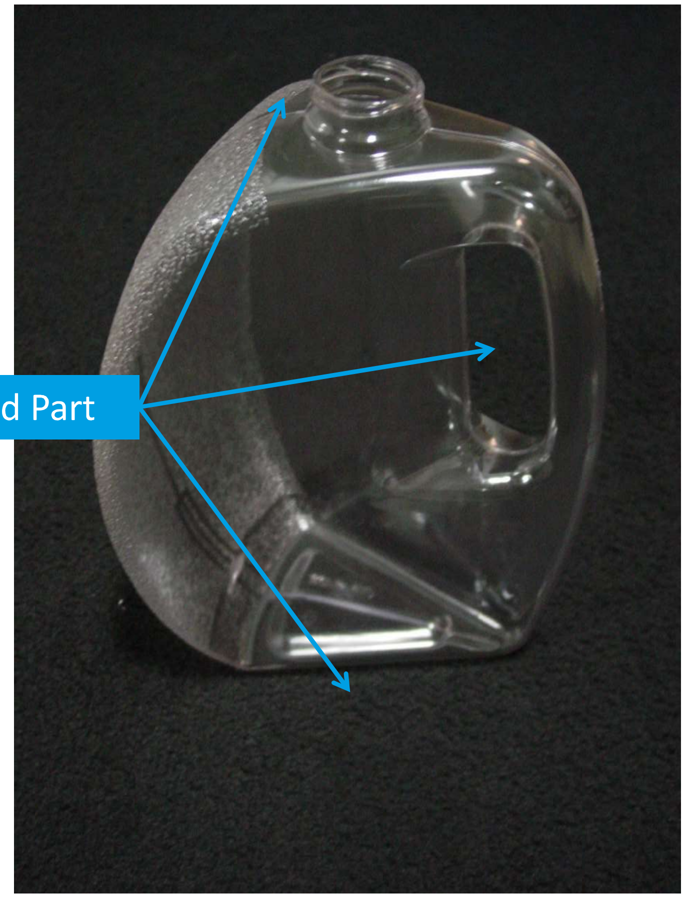


# MAIN MACHINE COMPONENTS

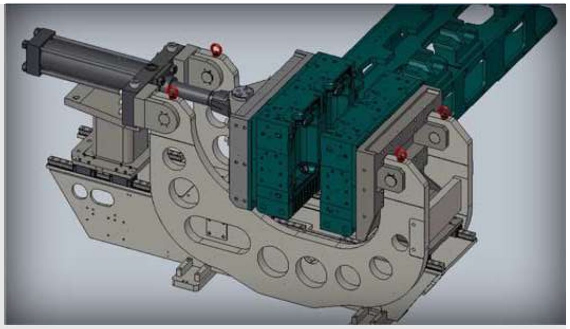


# FLASH



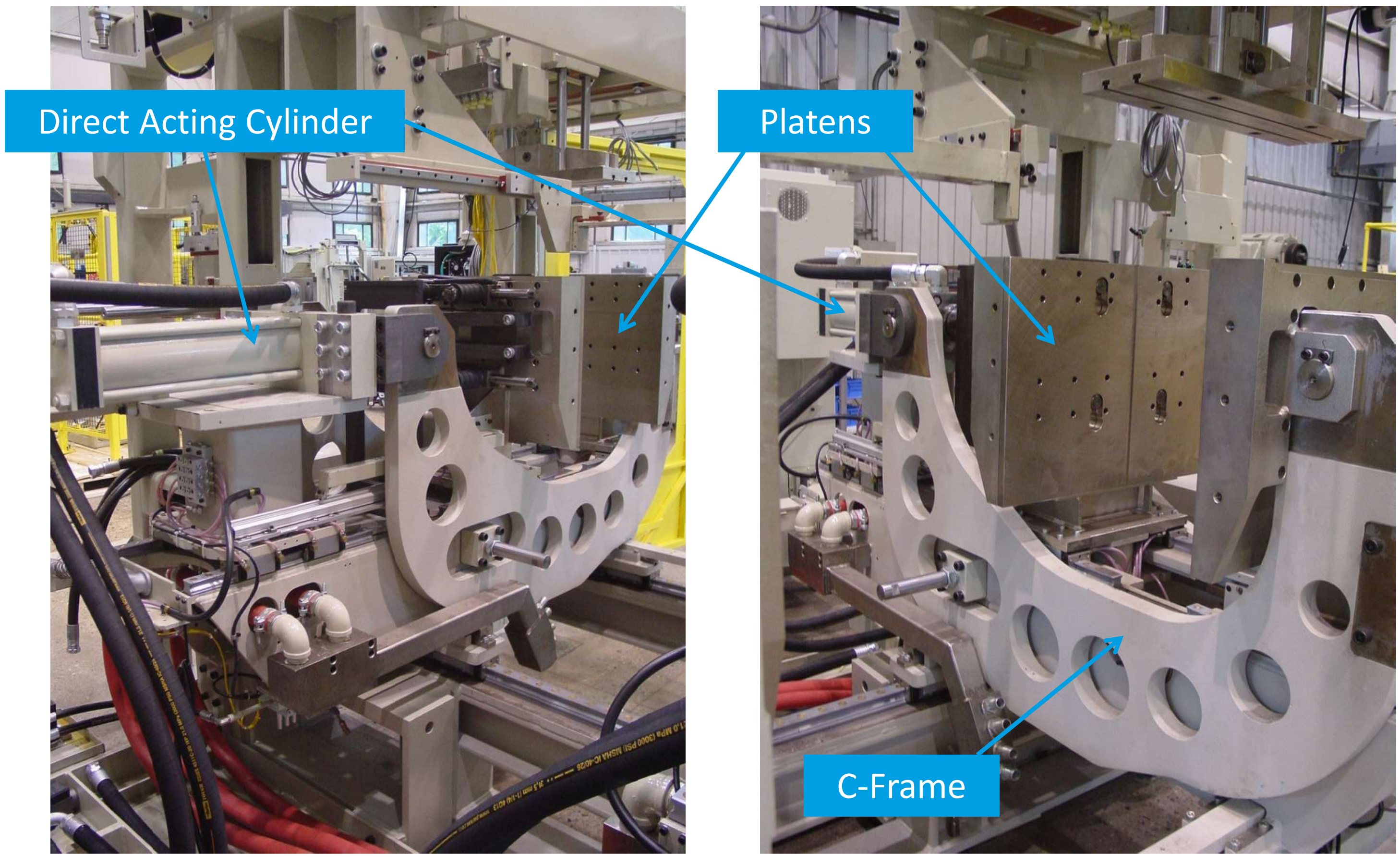



# CLAMPING SYSTEM



- Open/close mold around the parison
  - Must have enough stroke to allow for removal of the part
    - Referred to as daylight
- Provide enough force to trim flash
  - Based upon amount of linear pinch off
  - Material types have different force requirements to trim the same amount of flash
    - Normal wall (.030” - .050”) HDPE requires .224 US tons / in. of linear pinch off
    - Example: 1qt Oil Bottle
      - 4” top pinch + 3.7”. bottom pinch = 7.7” per cavity
      - .224 tons/in. x 7.7” x 6 cavities = 10.35 US tons
- Keep the mold closed during blowing
  - Based upon surface area of the cavities and blowing pressure
    - Length (in.) x Width (in.) x Blow pressure (psi) x 15% (safety) x Cavities / 2000 = U.S. tons
    - (4.1” x 9.8” x 100psi x 1.15 x 6) / 2000 = 13.9 US tons

## CLAMPING SYSTEM



## CLAMPING SYSTEM



**Clamping System – mold protection**

- Force deviation detection during movement
  - Integrated load cell
  - Motor torque
- If deviation exceeds limit the clamping system stops extremely fast
- Not possible with hydraulic systems
- Prevents from mold / cutting-edges damage by
  - Double blowing
  - Lost parts, tools

# CLAMPING SYSTEM



# MULTIPLE CAVITIES

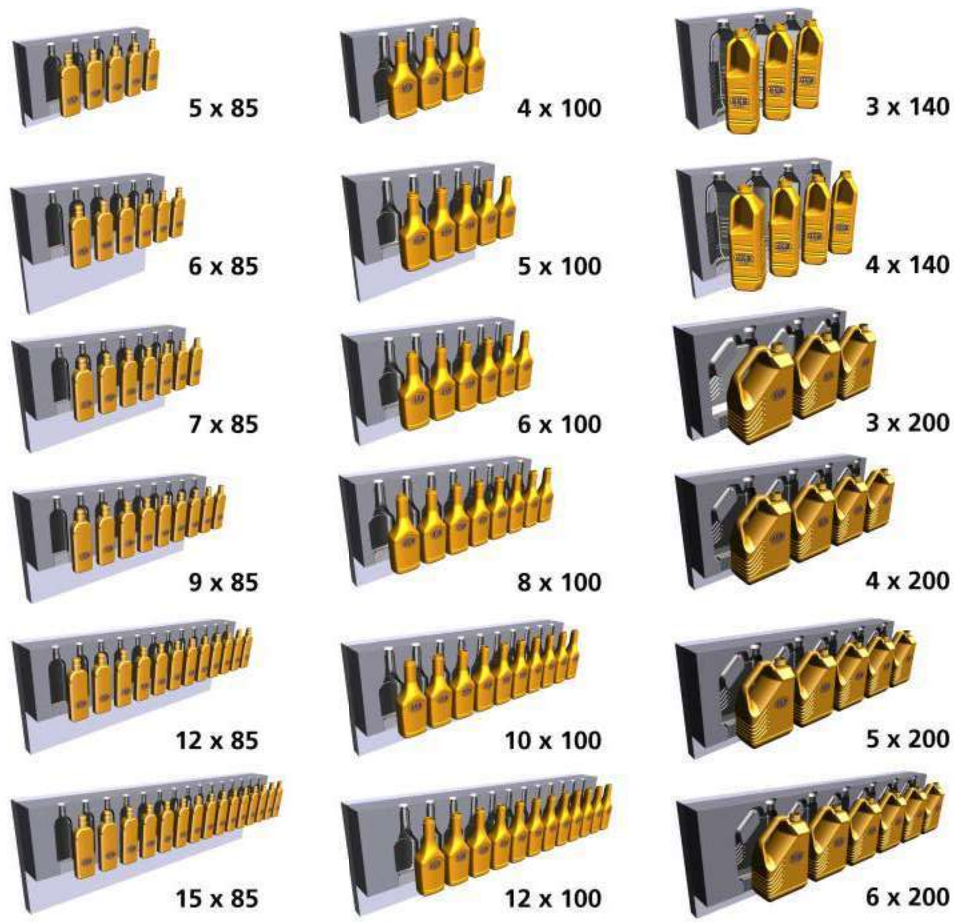


## Multiple Cavities

- A clamps sizing determines the number of cavities that can be processed of a particular sized bottle
- Typically referred to as center line distance (CLD)
  - Distance between center of mold cavities
    - Ex: A clamp that is 700mm wide can run the following CLD
      - 2 x 320mm
      - 4 x 150mm
      - 6 x 100mm
- The bottle size and type determines the minimum centerline required
  - Ex: A round bottle with an 85mm diameter can run on 100mm CLD
  - Ex: A handleware container with a width of 290mm would require a 320 mm CLD

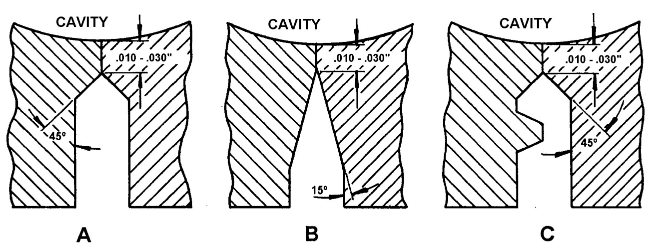
# MULTIPLE CAVITIES

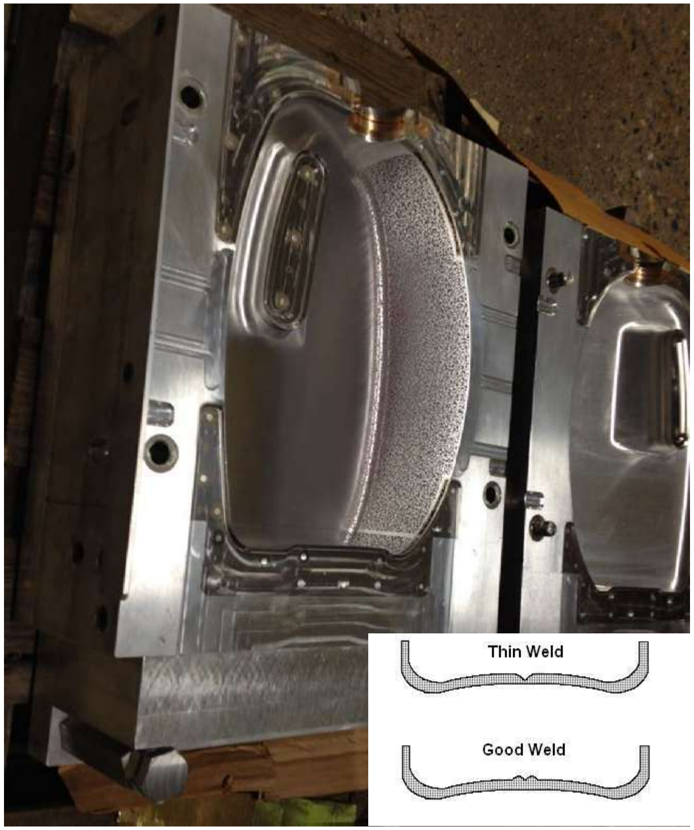




# BLOW MOLDS

- Form the final shape of the part
- Typically aluminum construction
  - Lightweight, inexpensive
- Must cut through material so that flash can later be trimmed
  - Flash pockets and pinch offs are used
  - Pinch offs are either flush with the mold face or higher (proud) to allow cutting
  - Pinch off areas inlayed with SS or BeCu to help with wear
- A good weld seam must be formed to prevent breaking



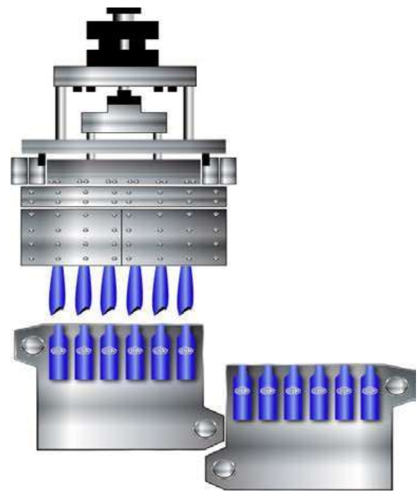



# CARRIAGE

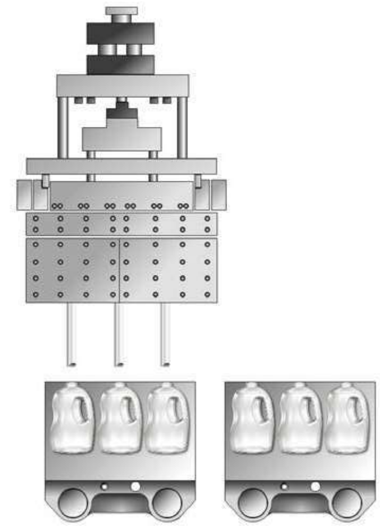


**Carriage Purpose: Move clamping system to/from extrusion head and blowing station**

- In continuous extrusion, the parison is always extruding and the mold must be moved from under the head
- Inclined carriage = Stationary extruder
  - Typically for smaller molds
- Horizontal carriage = Bobbing extruder
  - Typically for larger molds and long stroke machines
  - *exception of accumulator head machines



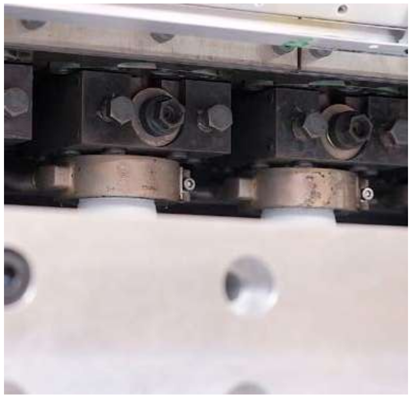
Inclined Carriage

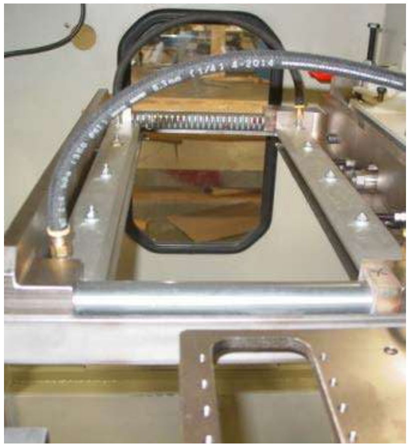


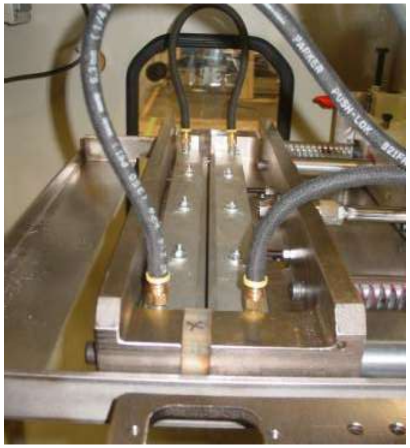
Horizontal Carriage

## PARISON CUTTING DEVICE

- Spear Knife
  - Used for smaller parisons / captive neck parts
  - Open parison
- Pre-Pinch Cold Cut
  - Seals parison allowing for inflation using support air
  - Cuts using overlapping knife blades
  - Typically used for handleware applications

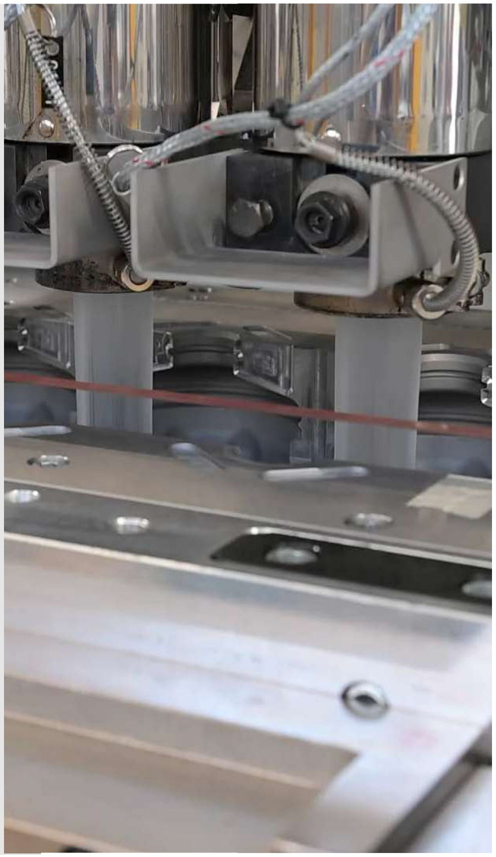






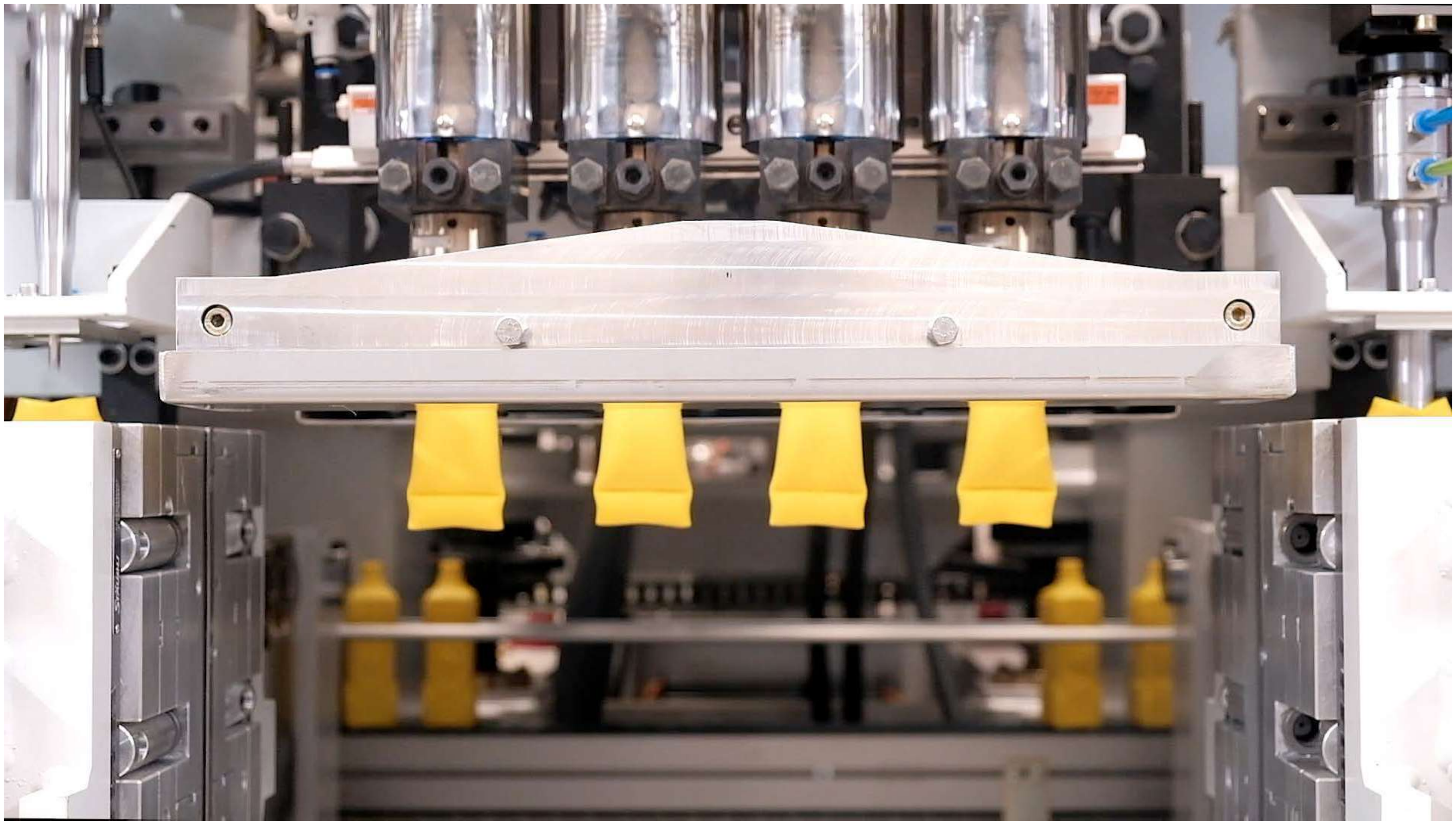
## PARISON CUTTING DEVICE

- Pre-Pinch Linear
  - Seals parison allowing for inflation using support air
  - Uses a linear knife to cut the parison
  - Typically used for handleware bottle with offset necks
- Hot Knife
  - Using electrical resistance, a metal strip or "blade" is heated and burns through the parison to cut
  - Used for materials that cannot be cut using cold blades
    - PP
    - PET
    - LDPE



# PARISON CUTTING DEVICE





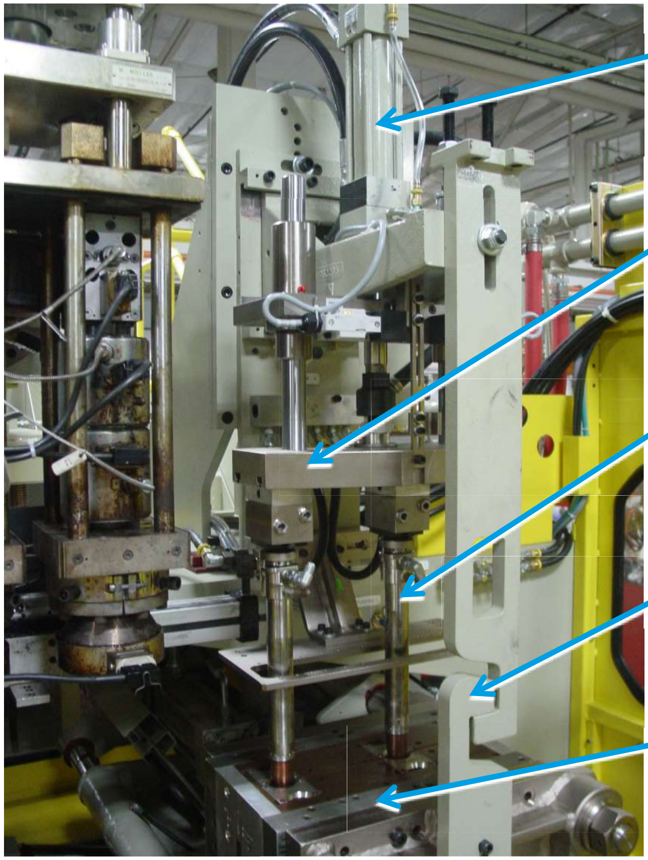
# CALIBRATION STATION



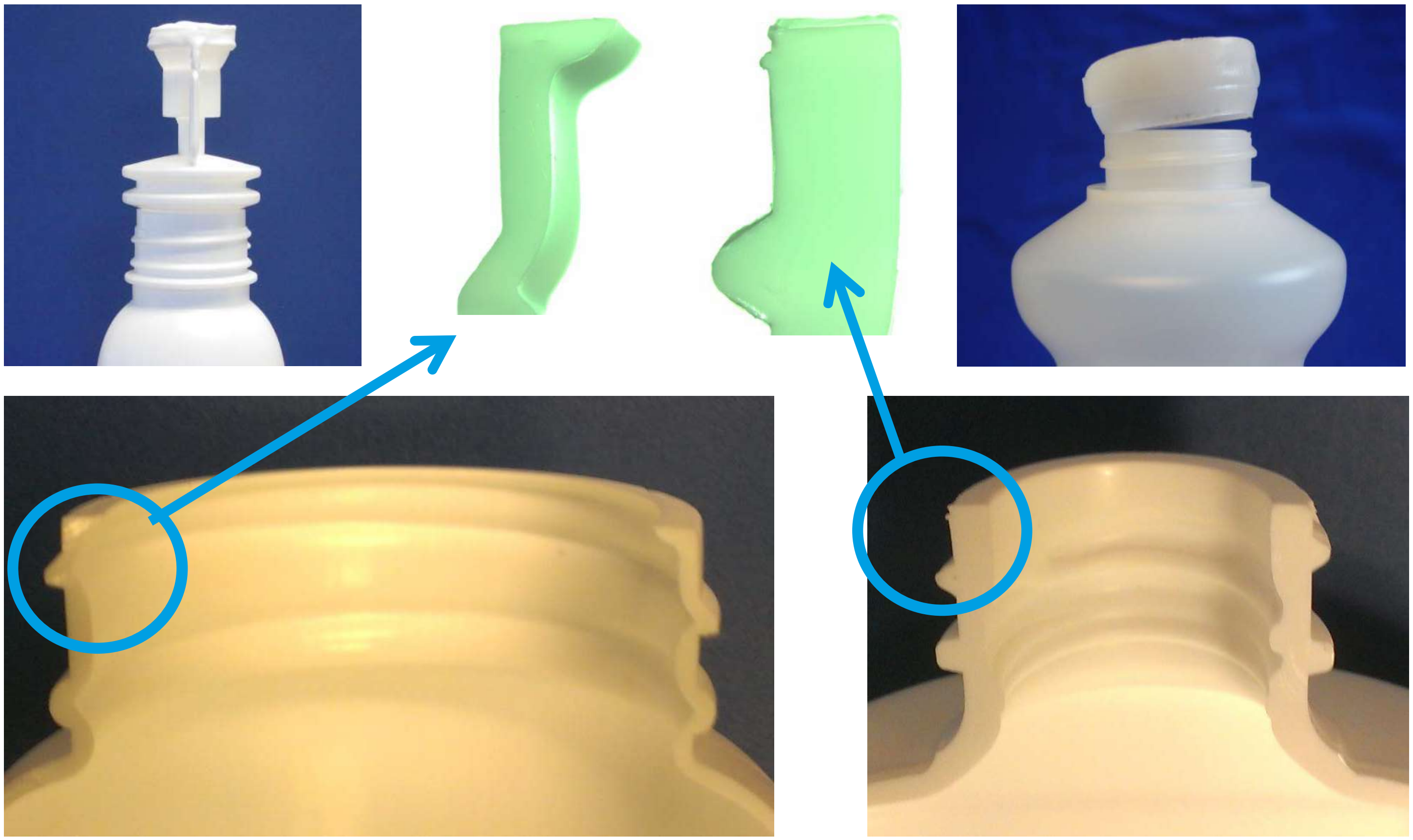
## Calibration Station

- Supply compressed air to inflate parison in the mold to form the finished part
  - Can be top or bottom blowpin (or both)
- Calibrate neck of part to form neck finish
- Exhaust compressed air from the blown part for demolding
- Supply chilled water to blow pin tip for neck cooling
- Hold parts on blow pins
  - Trim and transfer system
- Strip parts off blow pins
  - Blow and drop system

# CALIBRATION STATION

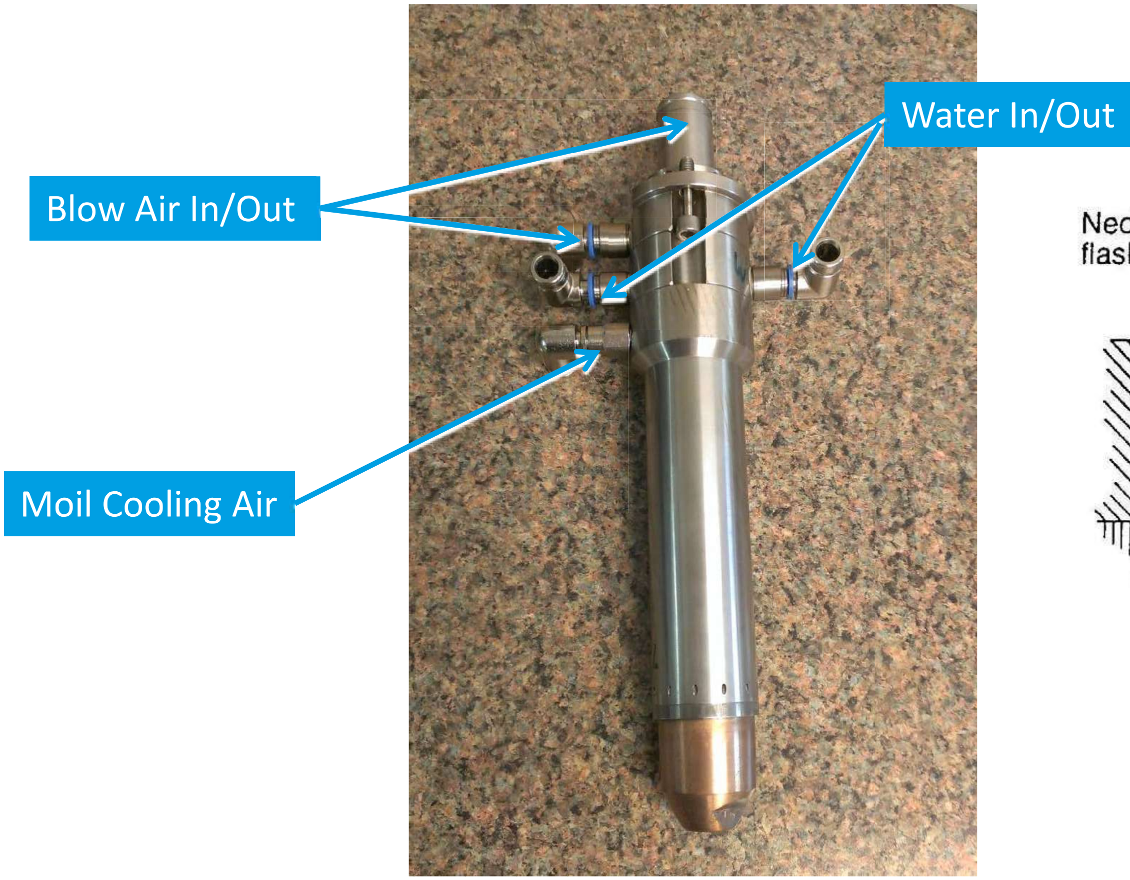


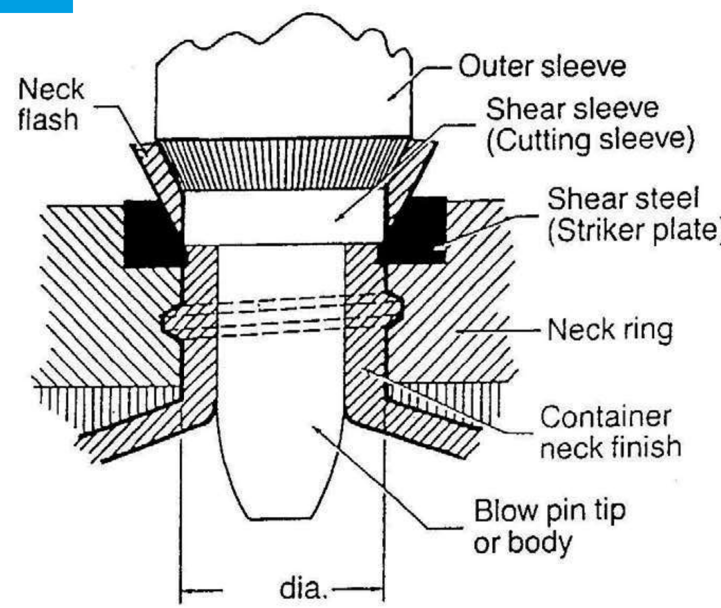
# NECK FINISH TYPES



# NECK CALIBRATION



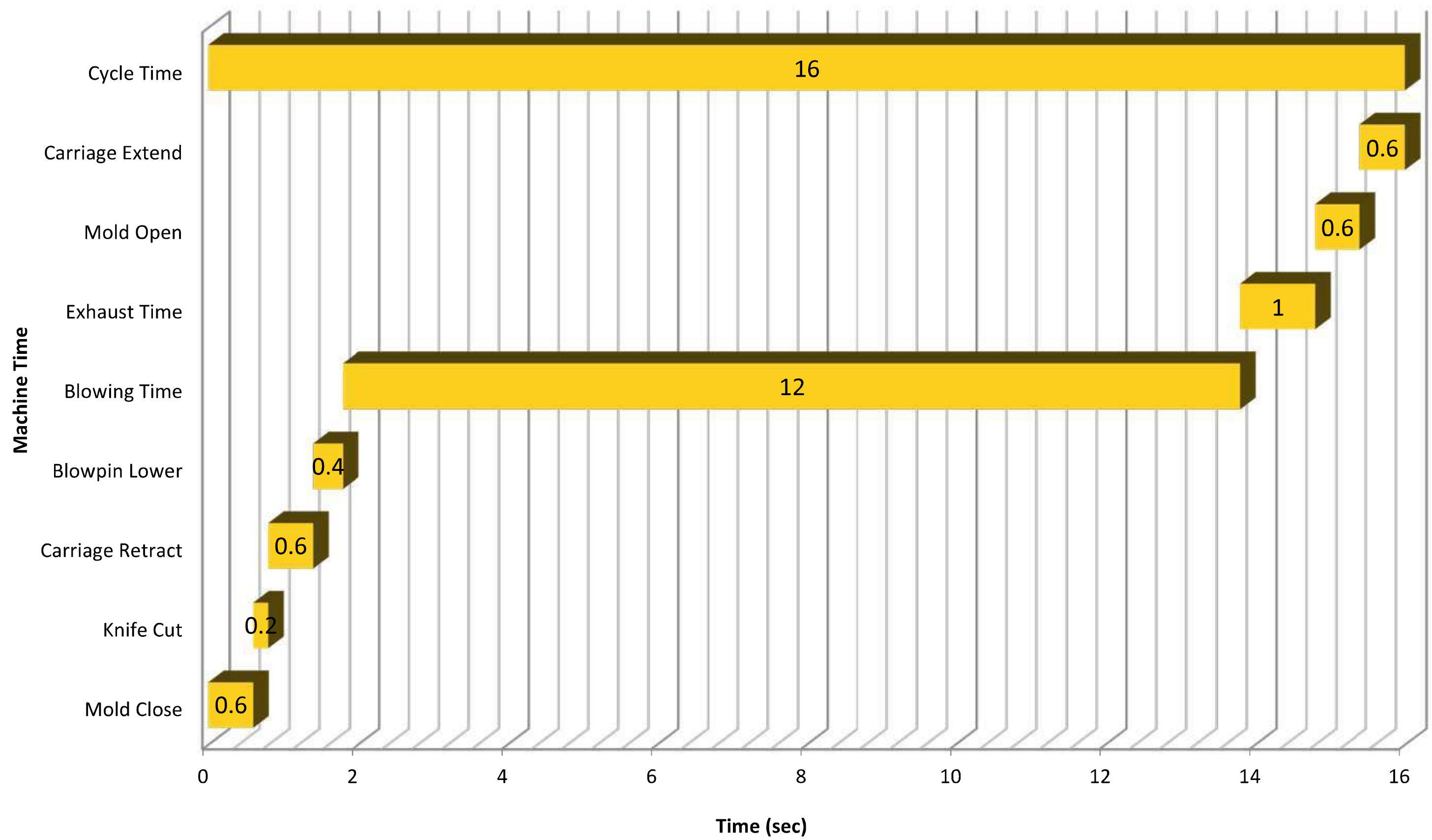


## Machine Movement Goals

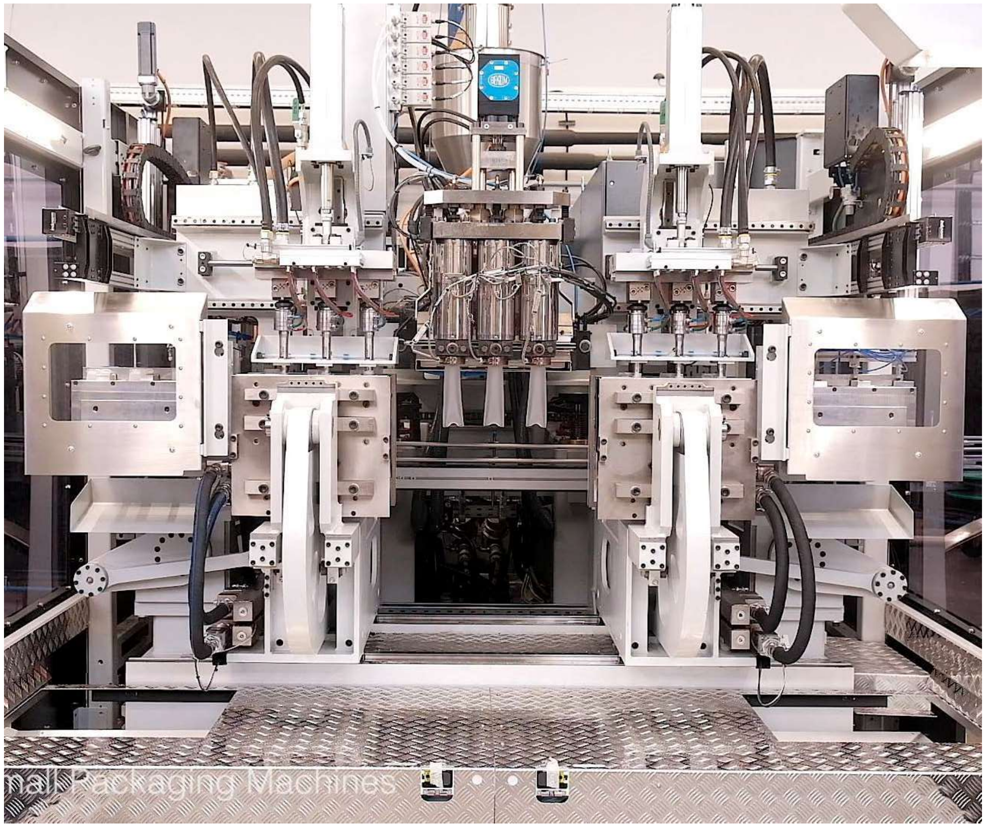
- All mechanical movements should be as fast as possible while maintaining a stable process
- Machine movements are considered unproductive for cycle time
  - Productive time = part cooling/blowing
- Dry Cycle Time = Time for a machine to cycle without adding cooling time
  - For example, a machine with a 4 second dry cycle time will have a 1 second longer cycle time than a machine with a 3 second dry cycle time

# MACHINE CYCLE



# AUTOMATION OPTIONS

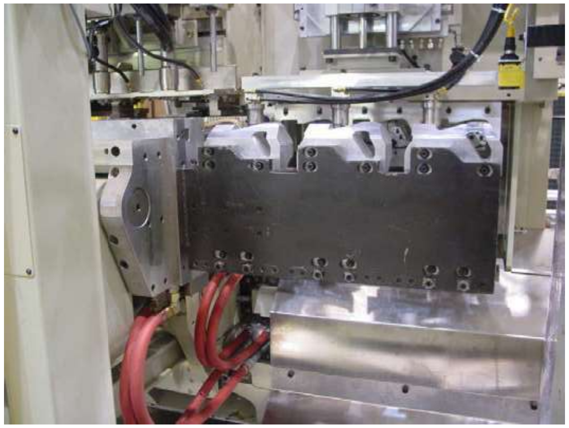
- Shuttle Blow Molding Overview
- Parison Formation
- Machine Movements
- **Automation Options**



## AUTOMATION OPTIONS

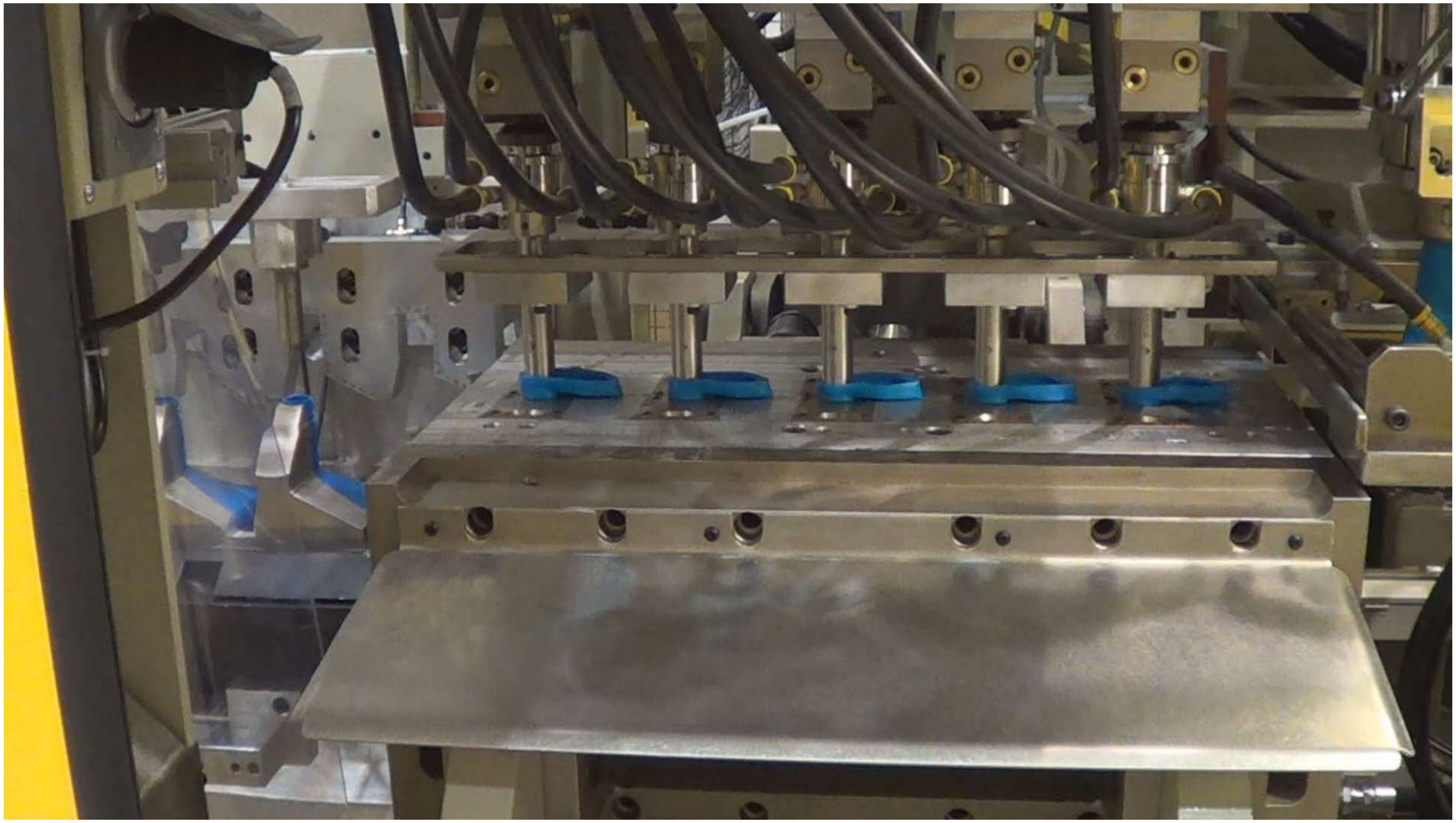
### Automation

- Article specific take out arms are mounted to the side of the mold
- As the carriage shuttles in to capture the parison, bottles are left on the blow pins
- When the mold closes on the parison, the holding arms connected to the mold close on the bottles hanging on the blow pins
- As the carriage shuttles back to the calibration station, the bottles in the holding arms are shuttled to the punching station
- An article-specific punch extends past the holding arms to trim the flash off the bottles
- The trimmed bottles are placed onto a conveyor
  - 1, 2, or 3 station handover



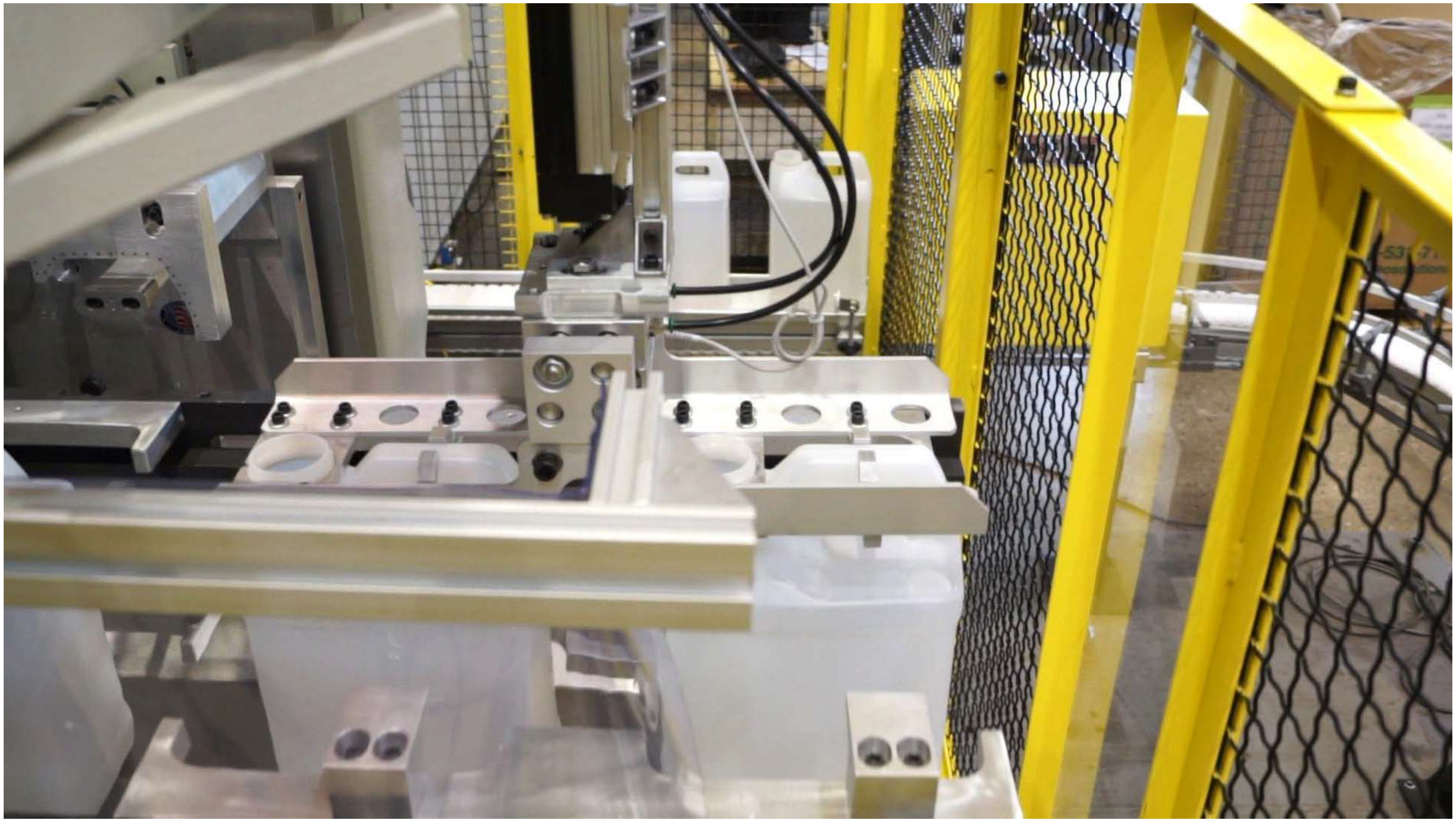
# AUTOMATION OPTIONS – 1 Station Handover w/ Takeout

## AUTOMATION OPTIONS – 2 Station Handover



# AUTOMATION OPTIONS





## AUTOMATION OPTIONS



### Other Options

- Tail Puller/Moil Separation
  - Captive neck only
  - Bottle unscrambling unit can be used to orient finished bottles
    - Mechanical systems using belts and hooks
    - Vision systems using robots
- Robotic Pick
  - Robot used to pick bottle from mold and take them outside of the machine frame
  - Typically combined with an external trim unit

# AUTOMATION OPTIONS



BEKUM

Benchmark for
Blow Moulding Machines