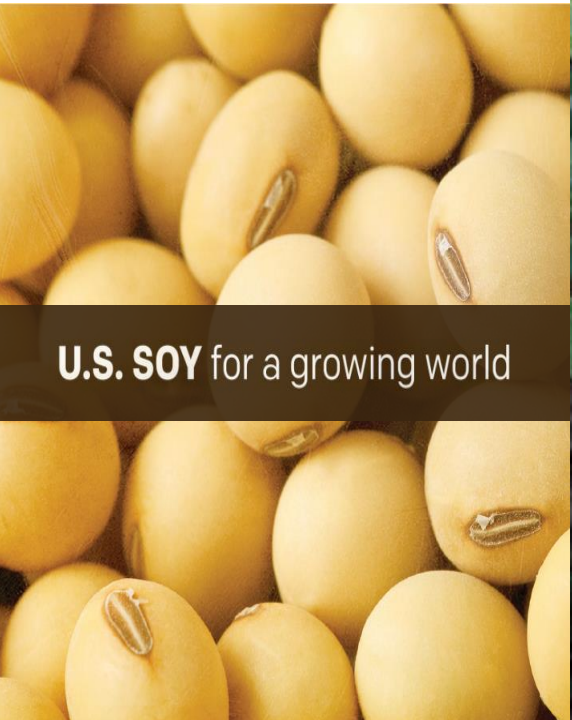


A background image of a vast soybean field under a clear blue sky. The rows of green soybean plants stretch to the horizon.

# **EXTRUSION APPLICATIONS Feed and Petfood**

A close-up background image of numerous yellow soybean seeds, showing their characteristic oval shape and the small hilum.

**Keith C. Behnke  
Professor Emeritus  
Kansas State University**

**U.S. SOY** for a growing world

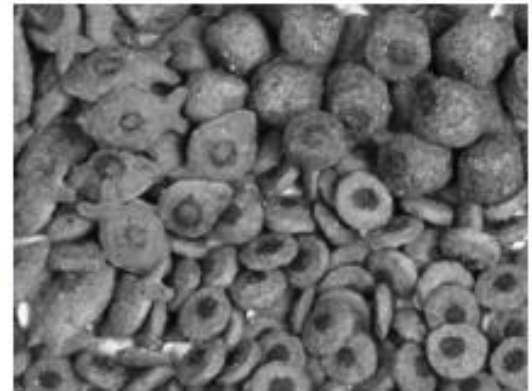
# Petfoods Overview

\$ 53 billion total  
U.S. expenditure  
on pets



World market: more  
than double in size  
(Europe, Latin  
America, Asia)

\$ 22 billion US  
market for pet foods



## Major Trends



- U.S. sales driven by higher prices rather than volume

- Premium products – health, natural/ organic, fortified/ functional, weight control, lifestage, gourmet, breed-/ size-specific

- Hundreds of new pet food products on the market shelf every year. Innovation is key!

# Various Extruded Pet food Products



Wenger Mfg., Inc.

## Petfood Categories

- Dry expanded
- Semi-moist
- Canned

## Product Properties

- Nutritional quality
- Palatability
- Bulk density
- Shelf life
- Owner appeal



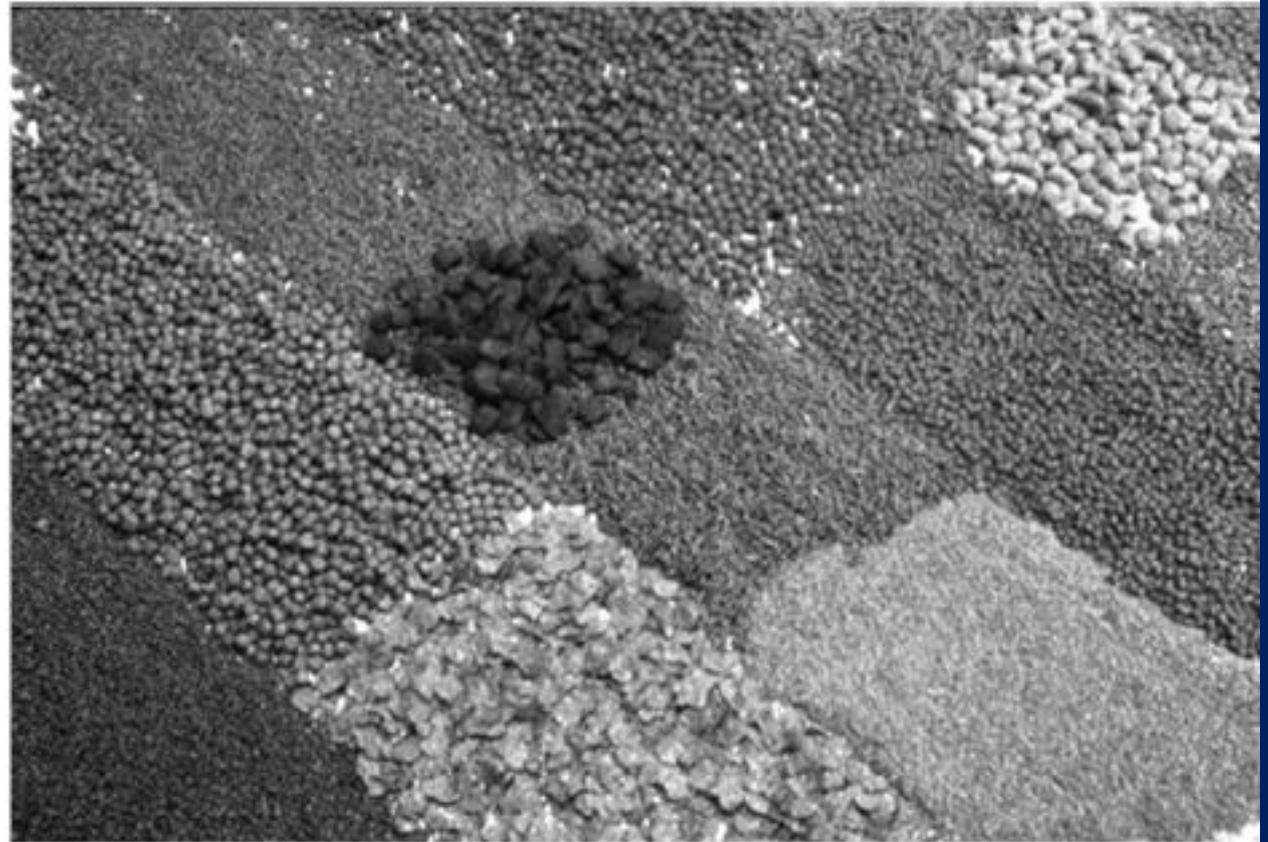
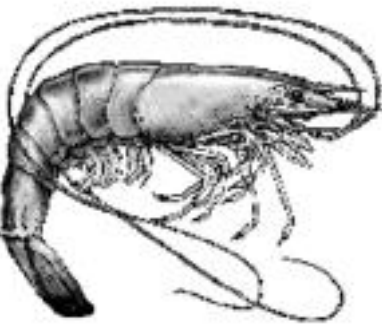
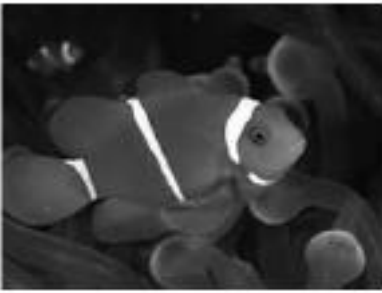
## Petfood Categories

- Dry: < 10% moisture (w.b.); various shapes, sizes and porosity
- Semi-moist: 22-35% moisture (w.b.); typical product ~30% moisture (w.b.); requires preservatives
- Wet: 65-80 % moisture (w.b.); retorted/ refrigerated; cans, pouches, cups, trays, etc.

## Why Extrusion for Making Petfood?

- Energy efficient
- Low cost of production
  - Manpower
  - Floor space
- Continuous
- Convenient
- Environmentally friendly
- Different shapes, sizes and colors
- Control of cooking, texture and palatability

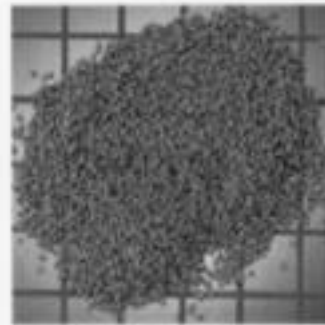
# Aquatic Feed



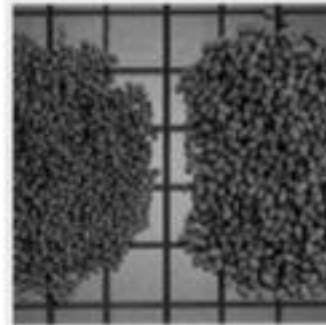
**Assortment of aquatic feed products**

# Aquatic Feeds

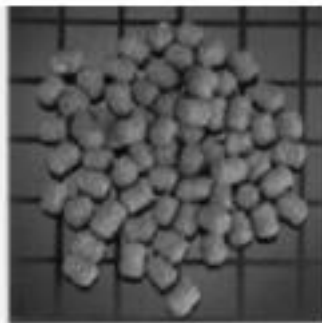
- Floating
  - Catfish
  - Carp
- Slow Sinking
  - Salmon
  - Trout
- Fast Sinking
  - Shrimp



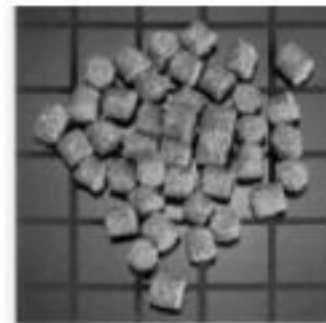
*Aquatic Feed  
.8 mm sinking*



*Aquatic Feed  
1 mm floating or sinking*



*Aquatic Feed  
3 mm diameter*



*Aquatic Feed  
4 mm diameter*

## Product Properties:

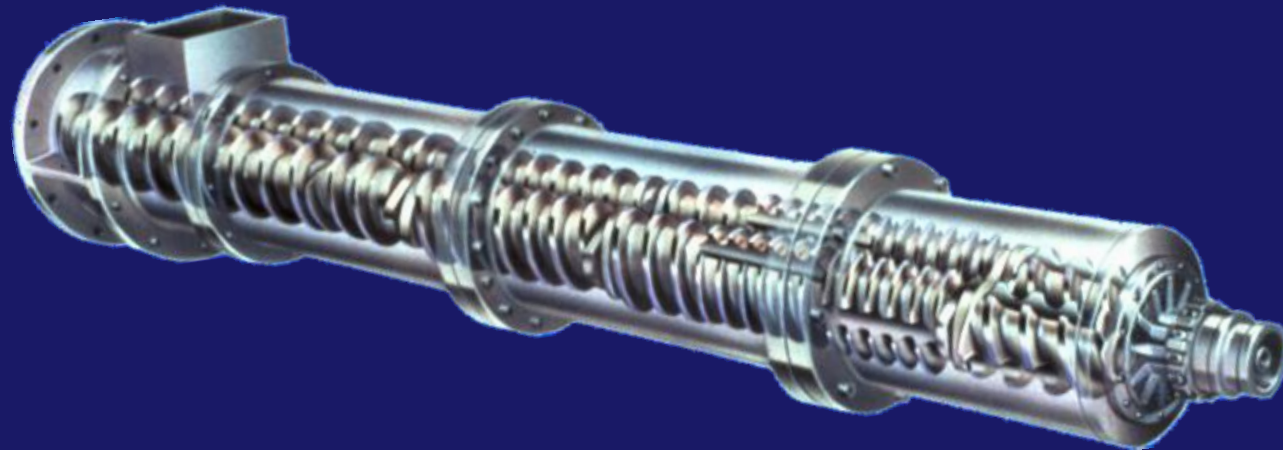
- Piece density
- Nutritional quality
- Water stability

# **PETFOOD AND AQUAFEED**

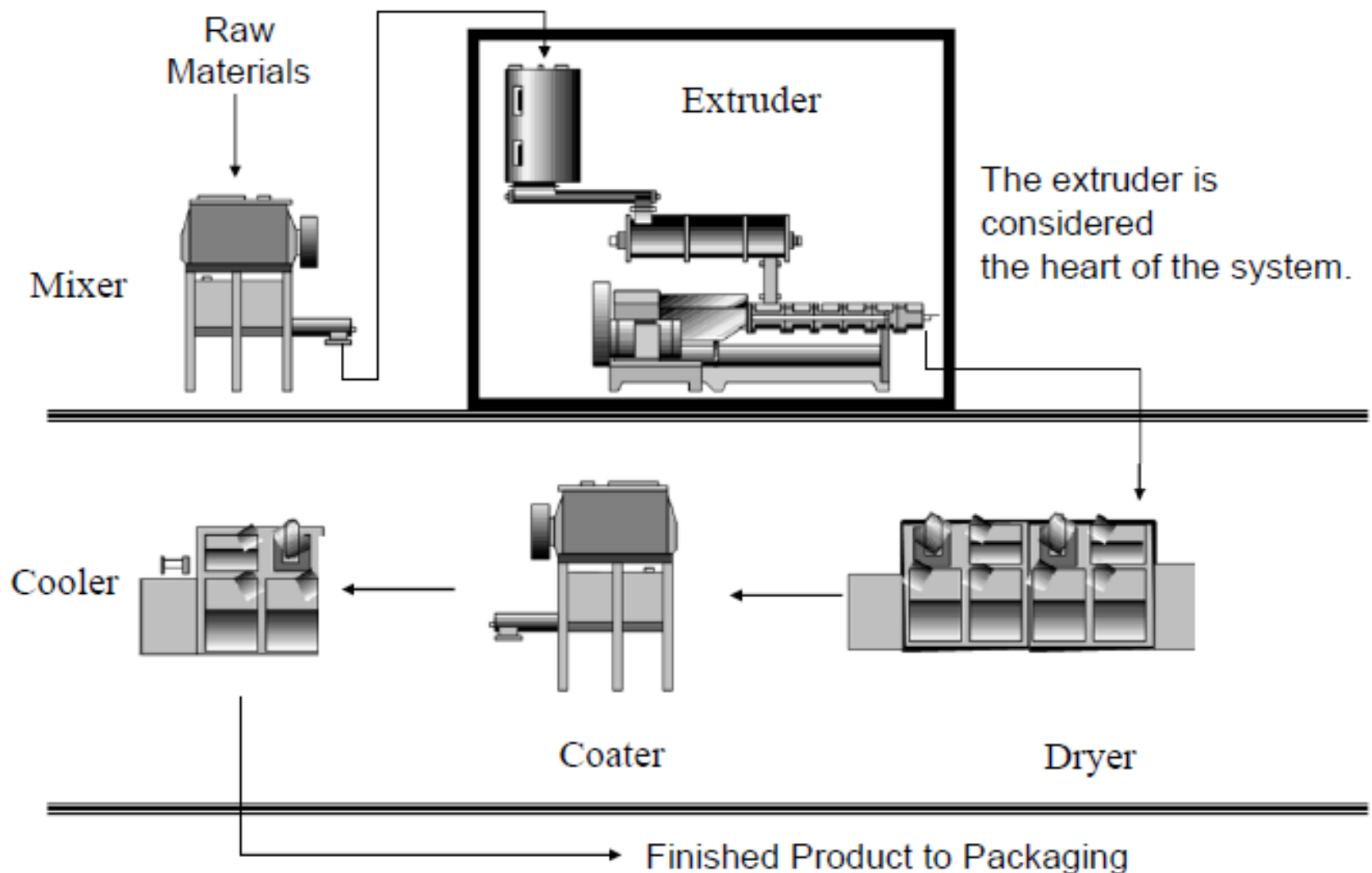
## **EXTRUSION BASICS**

# Extrusion Cooking

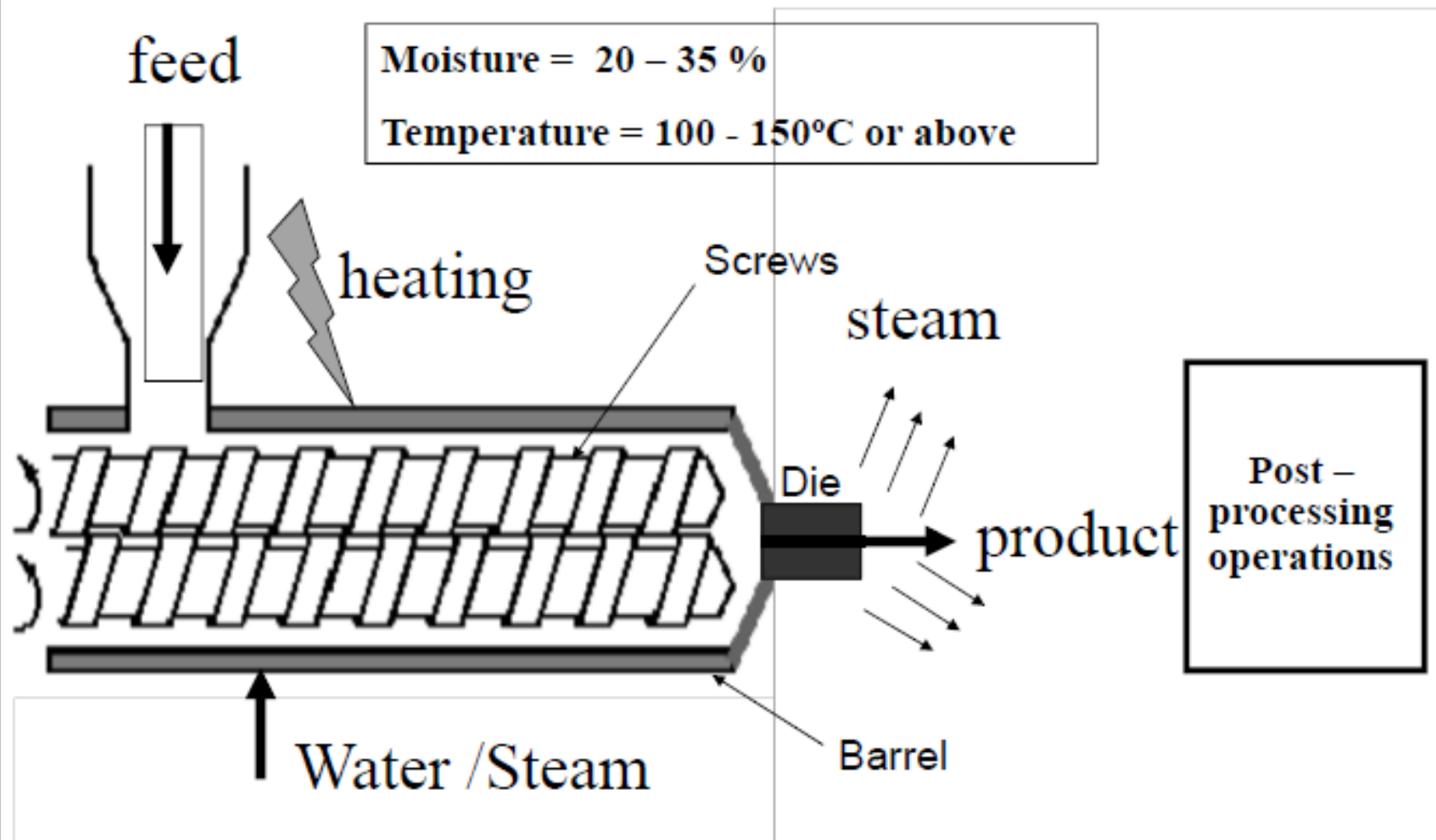
A CONTINUOUS PROCESS BY WHICH MOISTENED, STARCHY, AND / OR PROTEINACEOUS MATERIALS ARE PLASTICIZED AND COOKED BY A COMBINATION OF MOISTURE, PRESSURE, TEMPERATURE, AND MECHANICAL SHEAR



# Extrusion System for Pet Food and Aquatic Feed

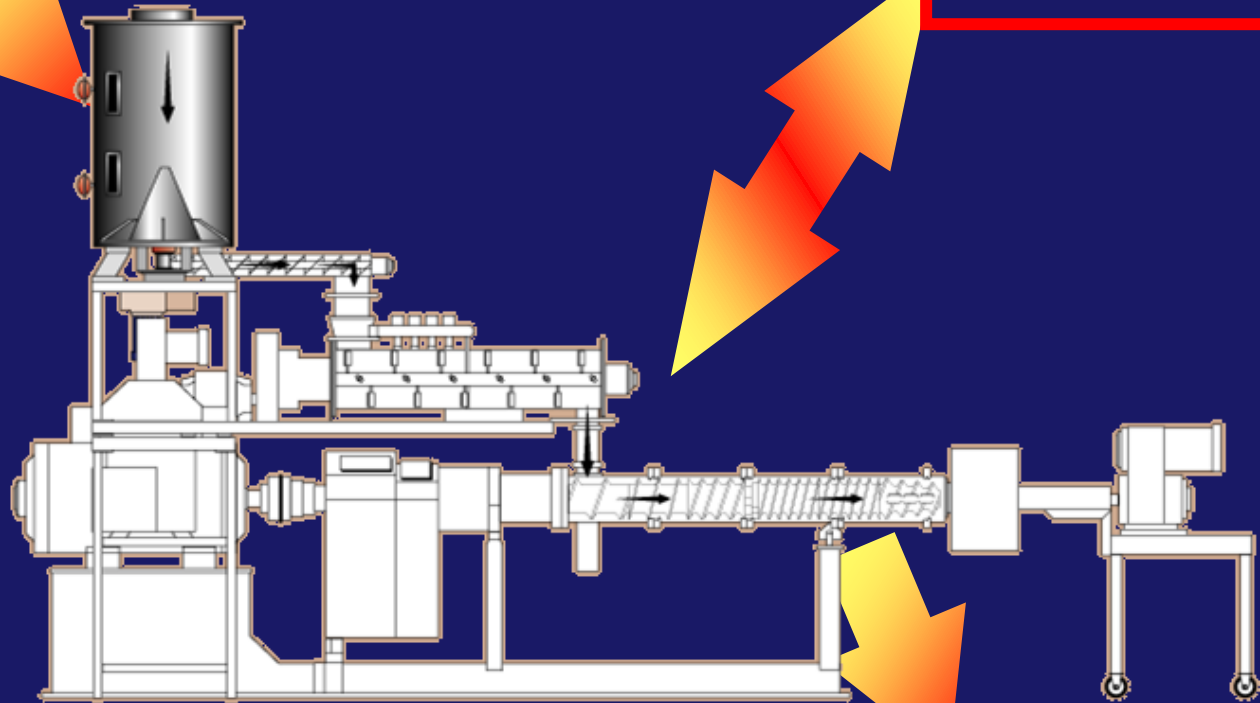


# Extrusion Process for Pet Food and Aquatic Feed



Raw  
Materials

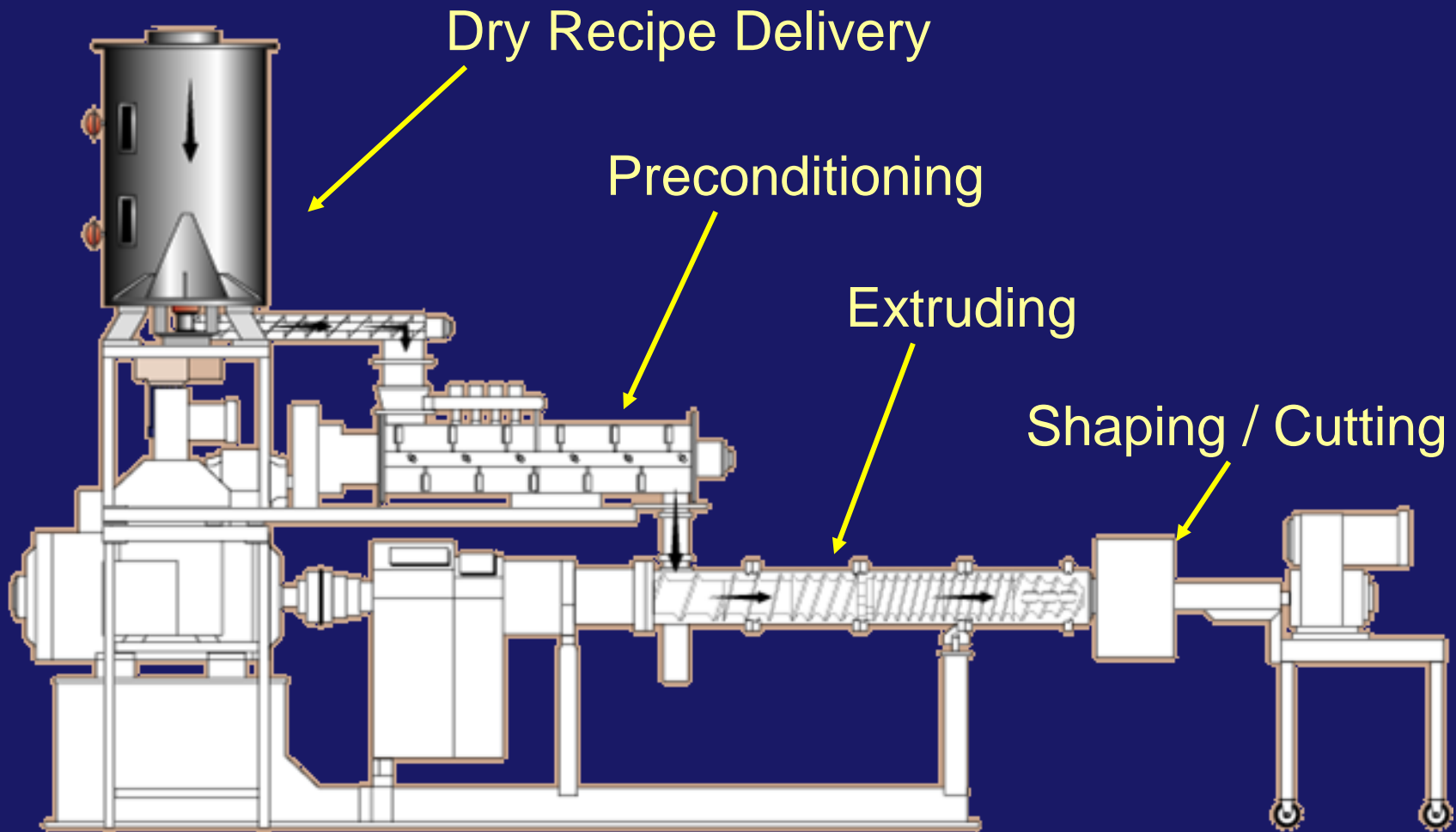
Processing  
Conditions And  
Control



Processing  
Hardware

Final Product

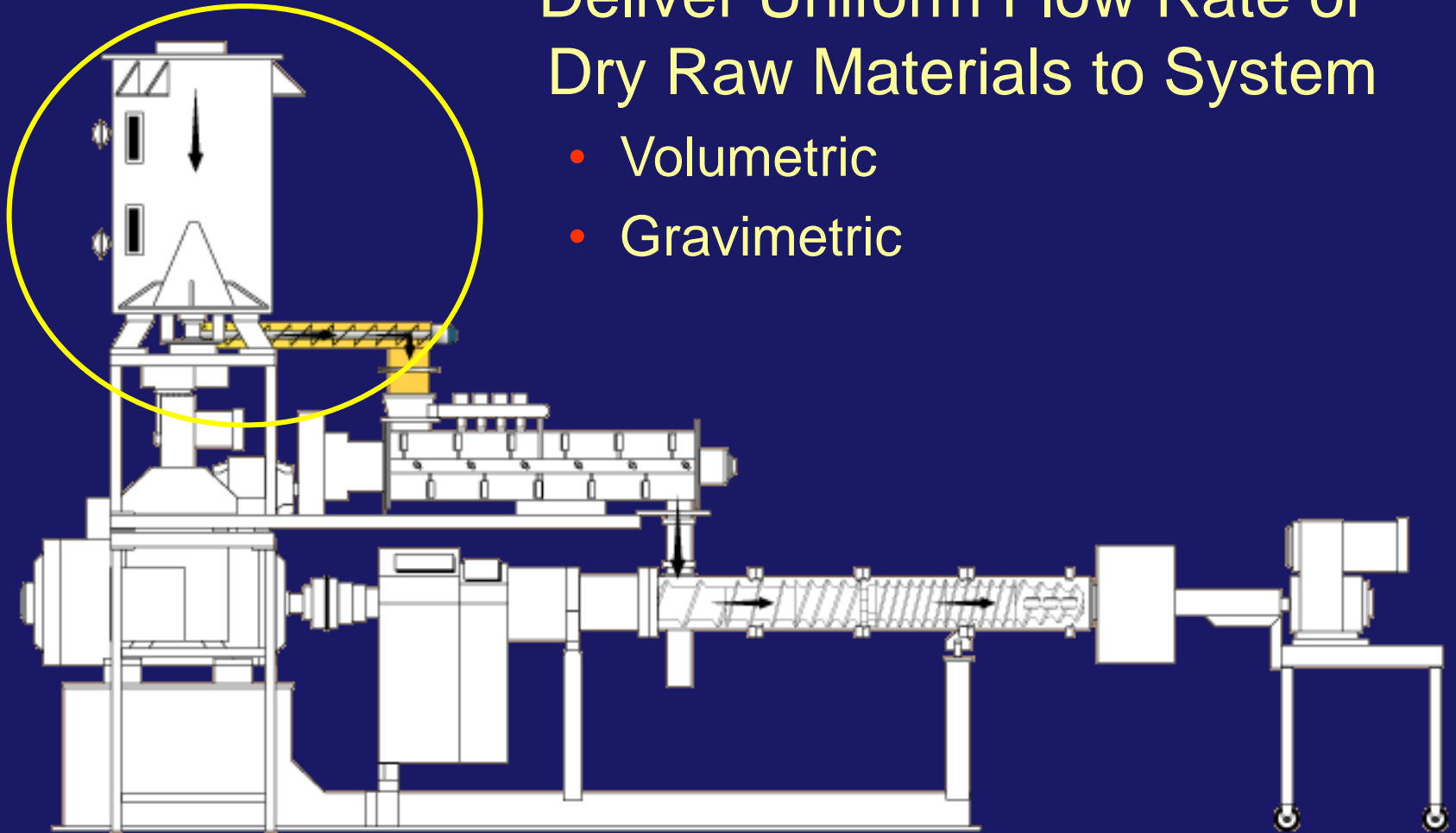
# Hardware



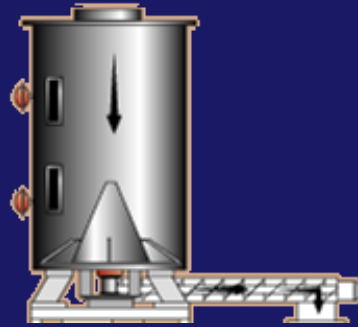
# Dry Recipe Delivery

Deliver Uniform Flow Rate of Dry Raw Materials to System

- Volumetric
- Gravimetric



## Volumetric



- Operator Sets Feeder Speed to Control Rate
- Actual Feed Rate Affected By Changes in Bulk Density of Raw Material
- Simple Mechanical Design
- Low Cost
- Requires Bin Fill Rate of 5X Extrusion Rate

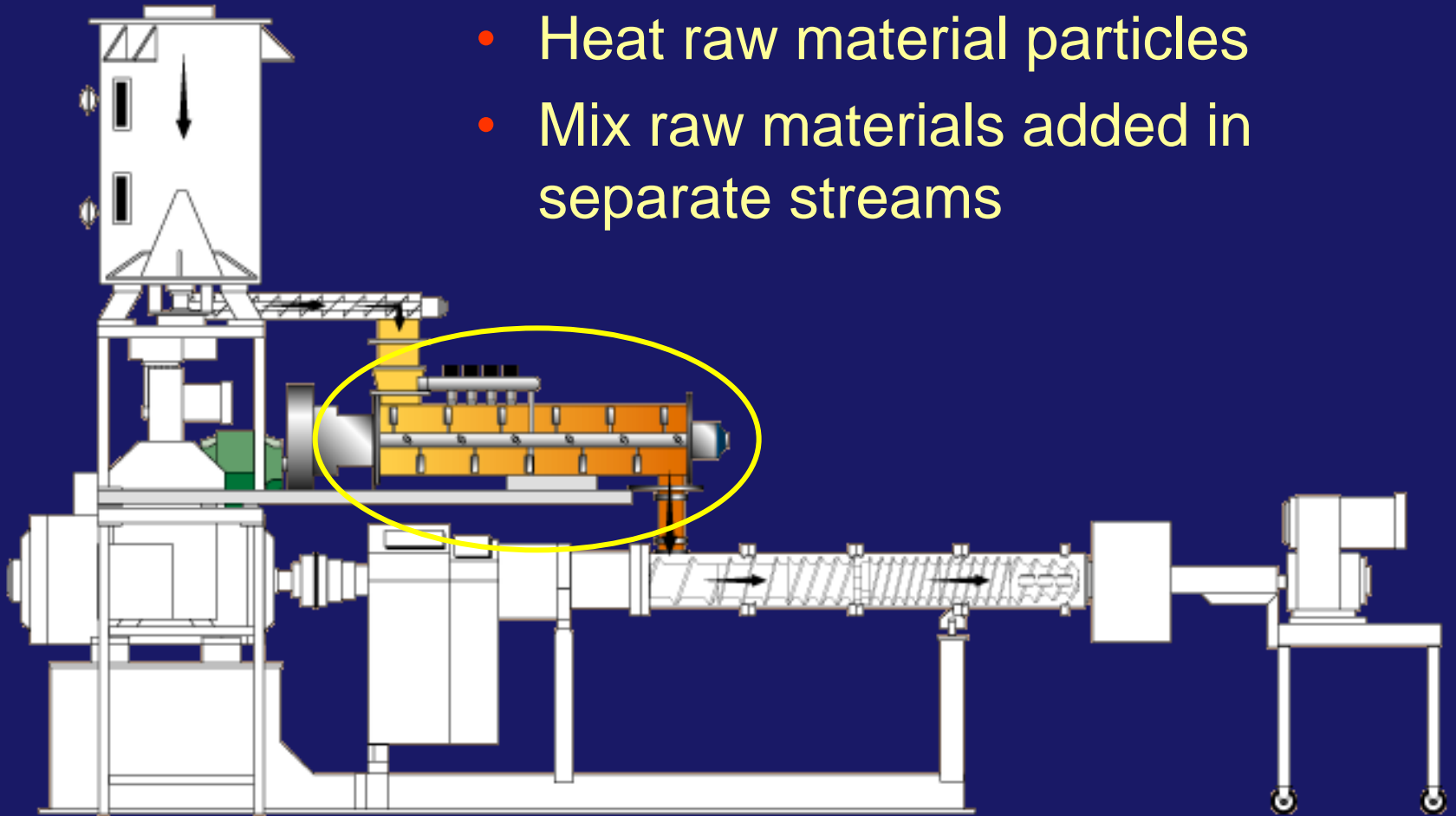
## Gravimetric (L-I-W)

- Operator Sets Feed Rate and System Controls Automatically
- Not Affected By Changes in Bulk Density of Raw Material
- More Complex Design and Control System
- Higher Cost
- Requires Bin Fill Rate of 10X Extrusion Rate

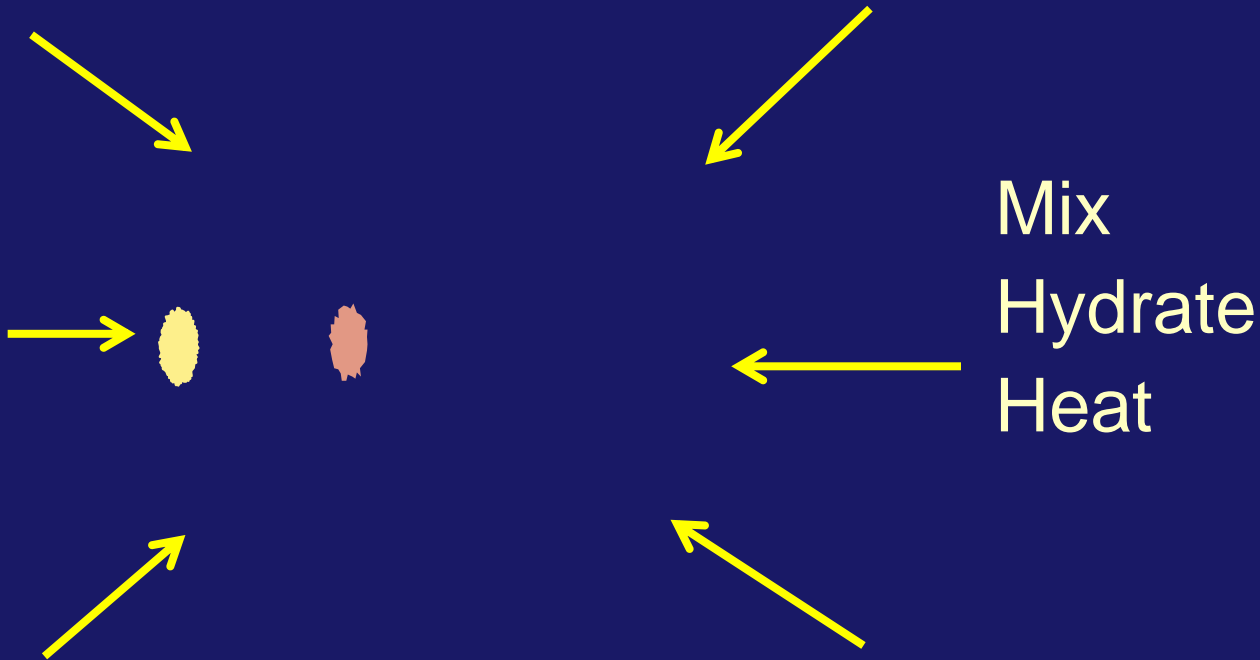
# Preconditioning

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- Hydrate raw material particles
- Heat raw material particles
- Mix raw materials added in separate streams



# Objectives of Preconditioning



Results in Partial Cooking of  
Raw Materials Prior to Extrusion

# Preconditioner Designs

- 1) Single Shaft Cylinder (SC)
- 2) Double Shaft Cylinder (DC)
- 3) Dual Diameter Cylinder (DDC)
- 4) High Intensity Preconditioner (HIP)

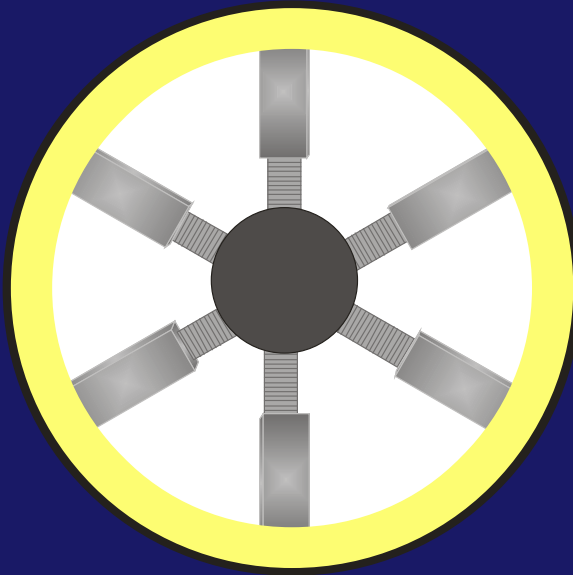
# Preconditioner Designs



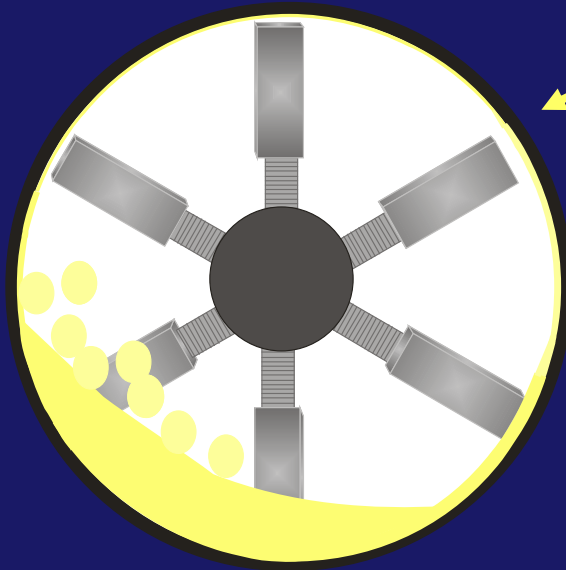
## Single Conditioner



High Shaft Speed

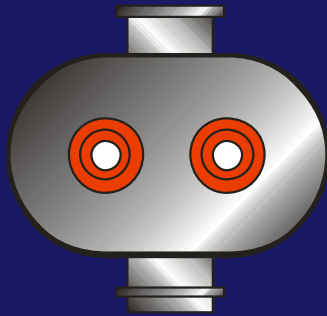


Low Shaft Speed



Single  
Cylinder

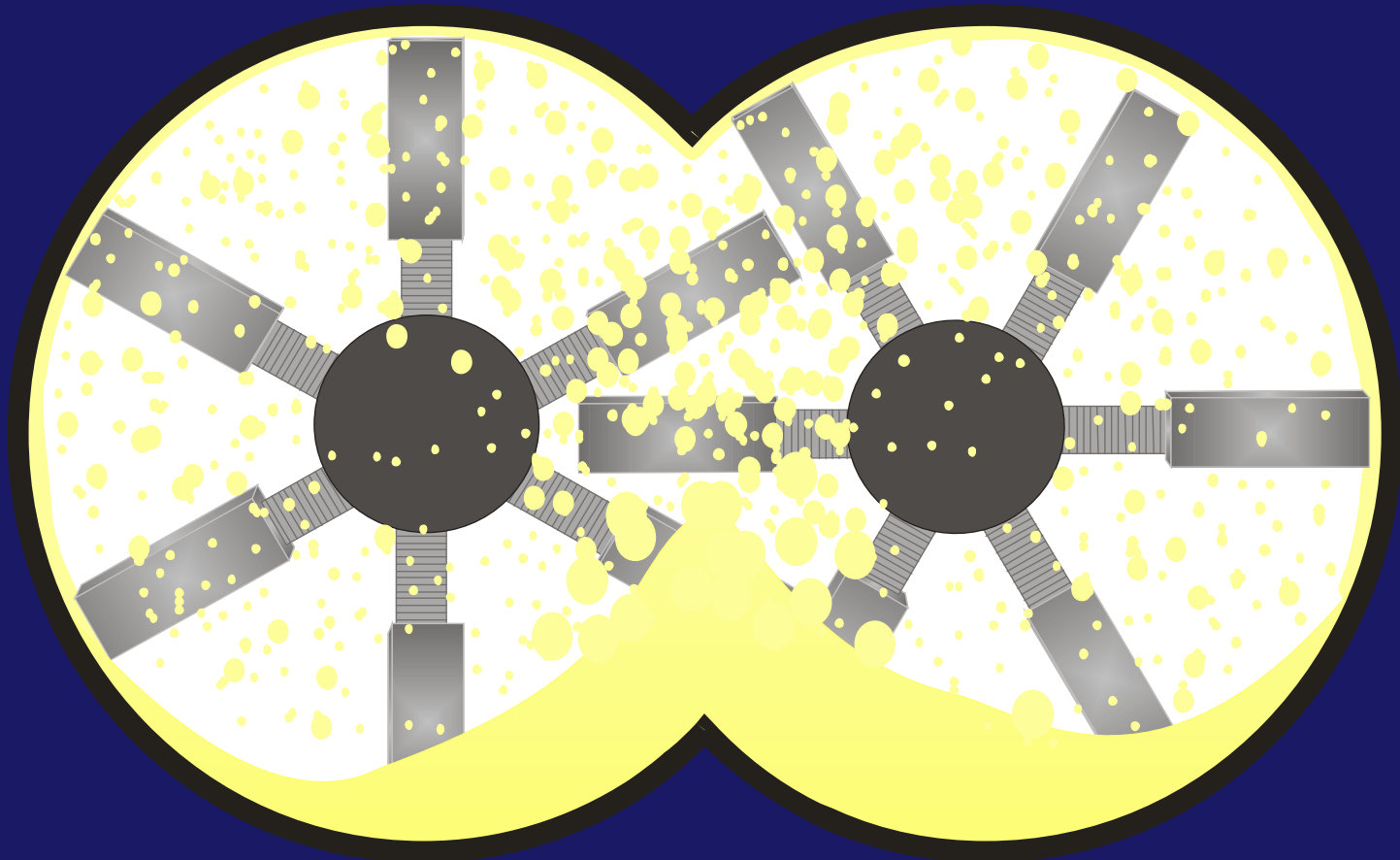
# Preconditioner Designs



**Double Conditioner**



# Intermeshing, Twin Shafted Conditioners



Double  
Cylinder

# Hydration & Heating

## Moisture Addition

- Steam
- Water

## Slurry Addition

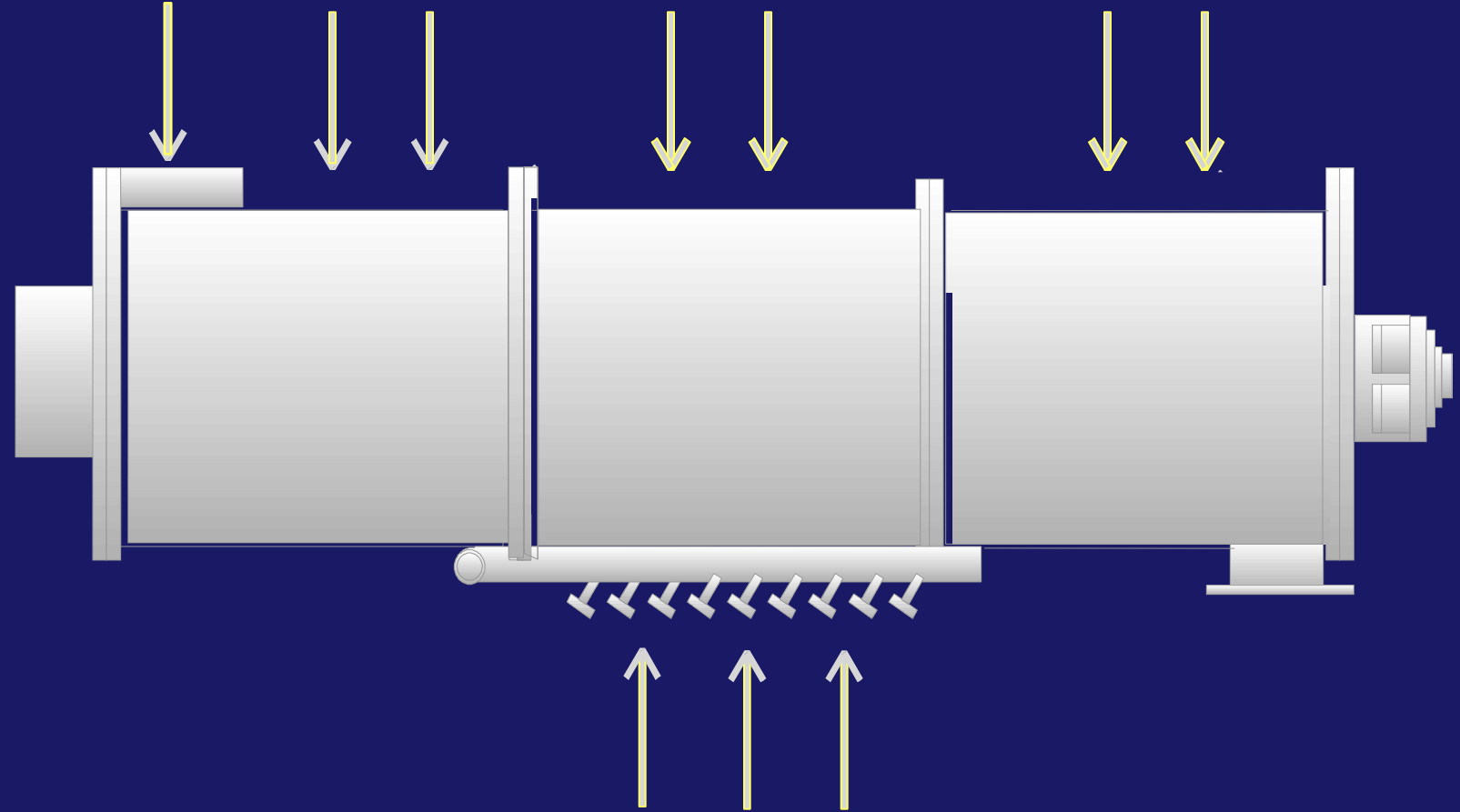
- Water-based
- Oil-based

Dry  
Recipe

Water

Other  
Ingredients

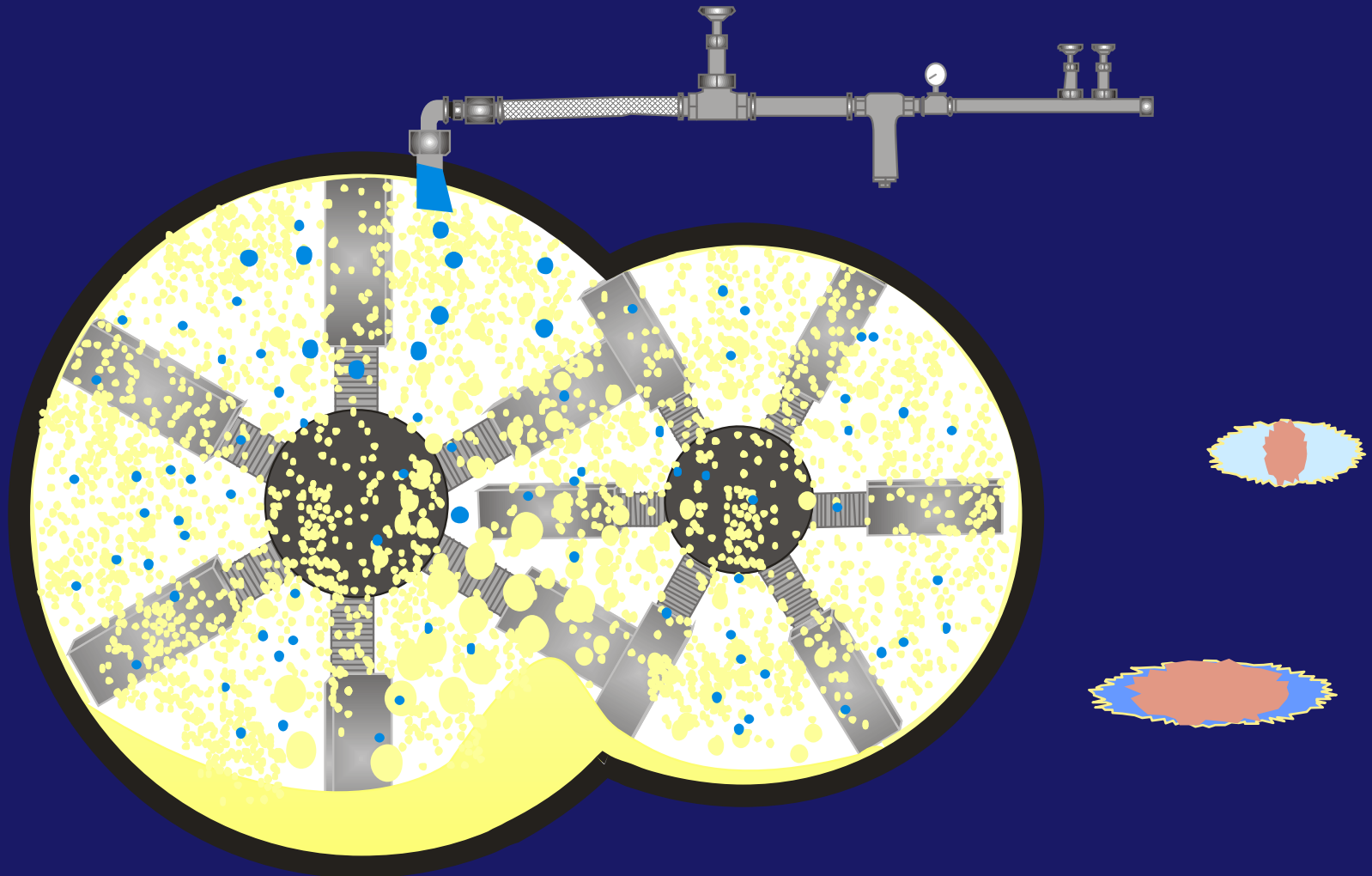
Fat



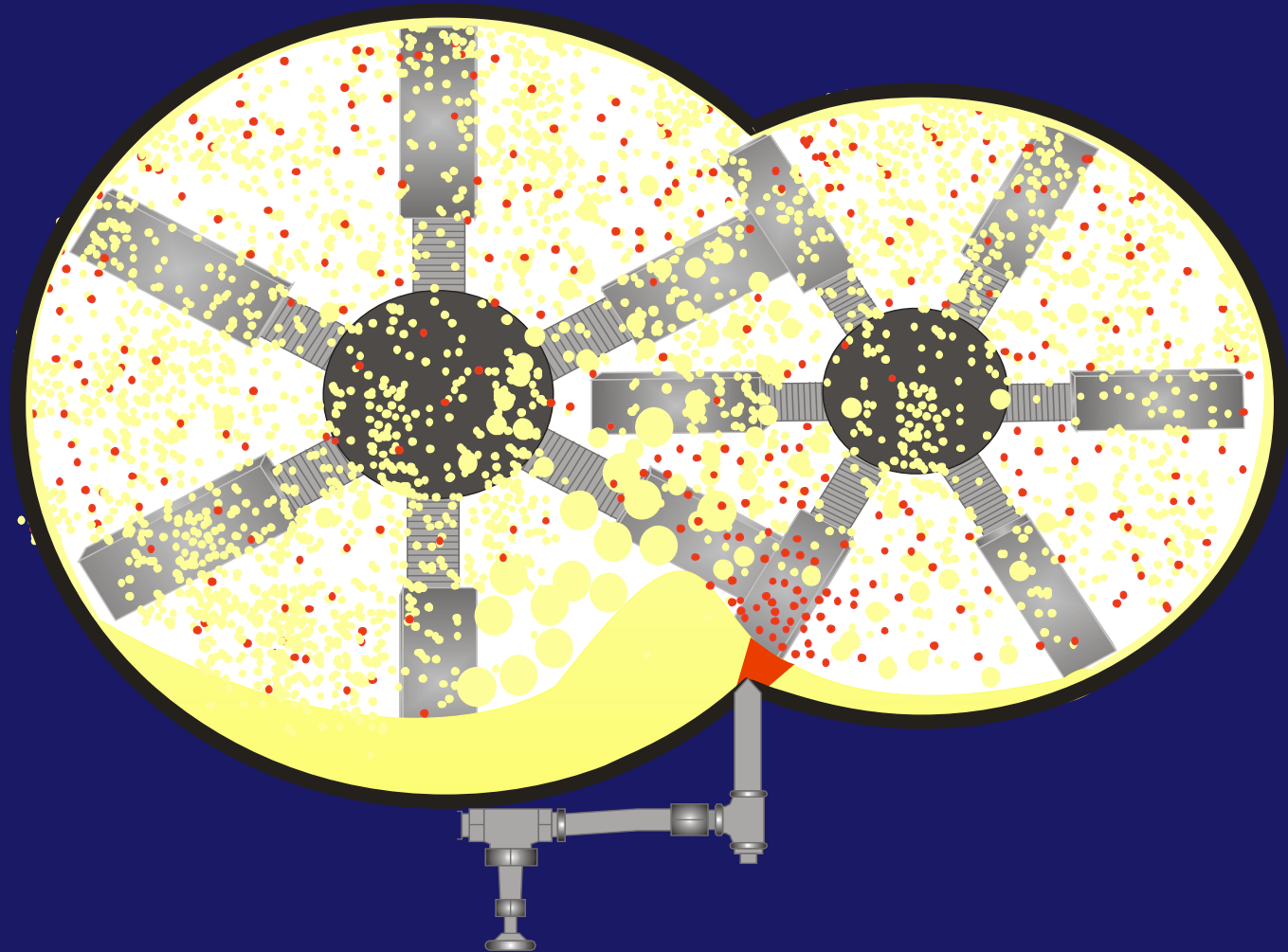
Steam

80/20 rule

# Importance of Proper Nozzle Selection and Installation



# Steam Injection on DDC



# Benefits of Preconditioning

Increased Capacity

Reduced Screw Wear

Reduced Mechanical Energy Input

Increased Thermal Energy Input

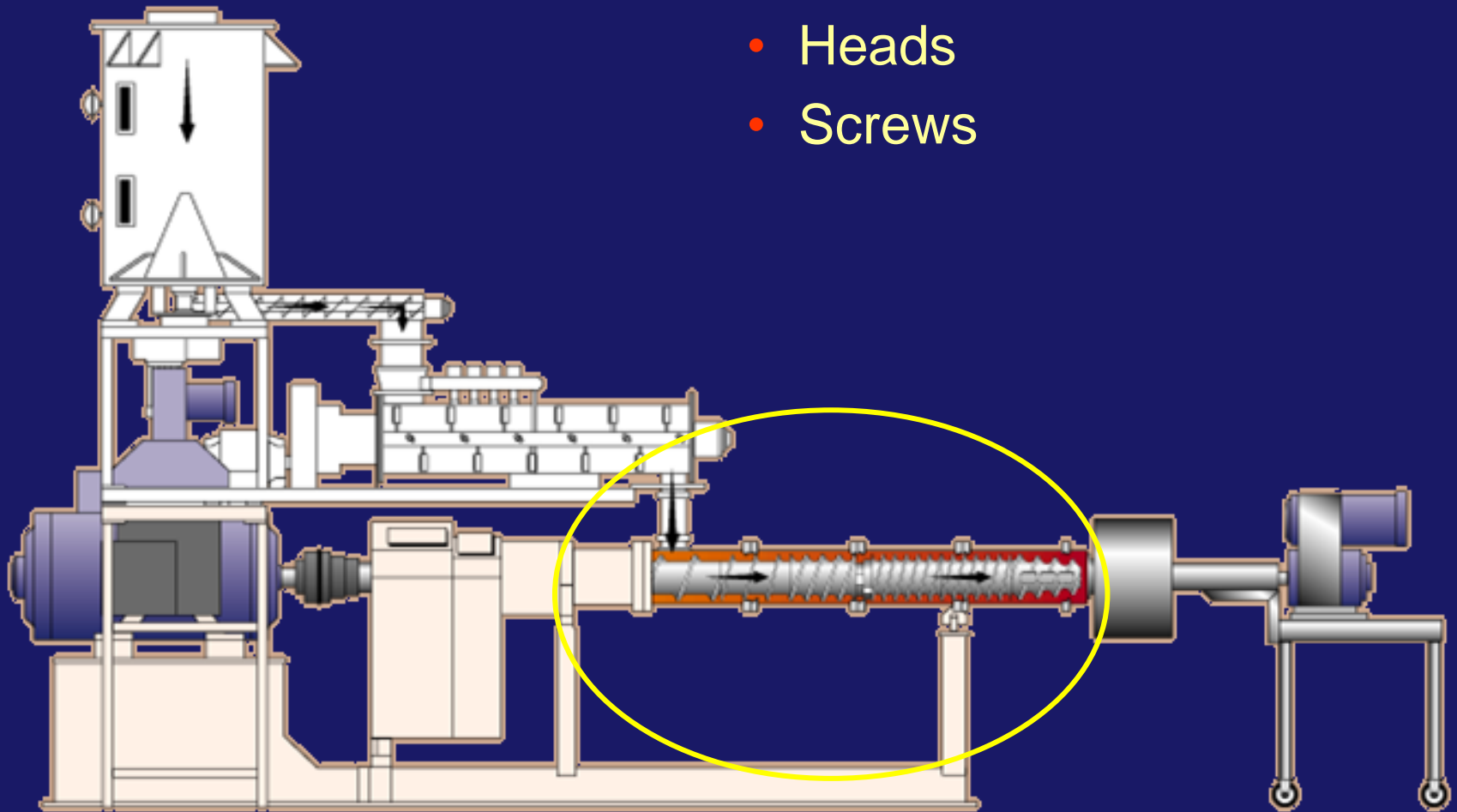
# When Should Preconditioning be Considered for Extrusion?

- Preconditioning **NOT** Necessary for All Extrusion Processes
- Any Process Benefitting From Higher Moistures and Longer Retention Times Benefits From Preconditioning
- As a Guideline, Consider Adding Preconditioning to Any Process Running at Greater Than 18% In-Barrel Moisture Content

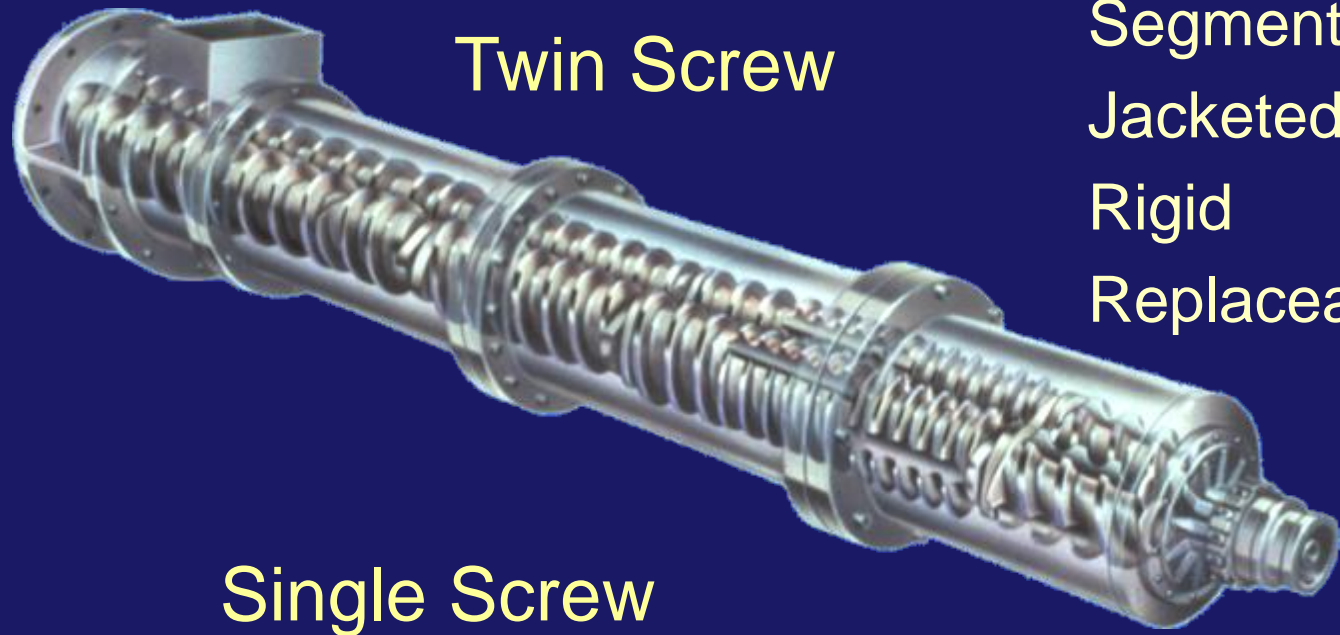
# Extruder Barrel

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- Heads
- Screws



# Extruder Barrel



Twin Screw

- Segmented (Heads)
- Jacketed
- Rigid
- Replaceable Liners

Single Screw

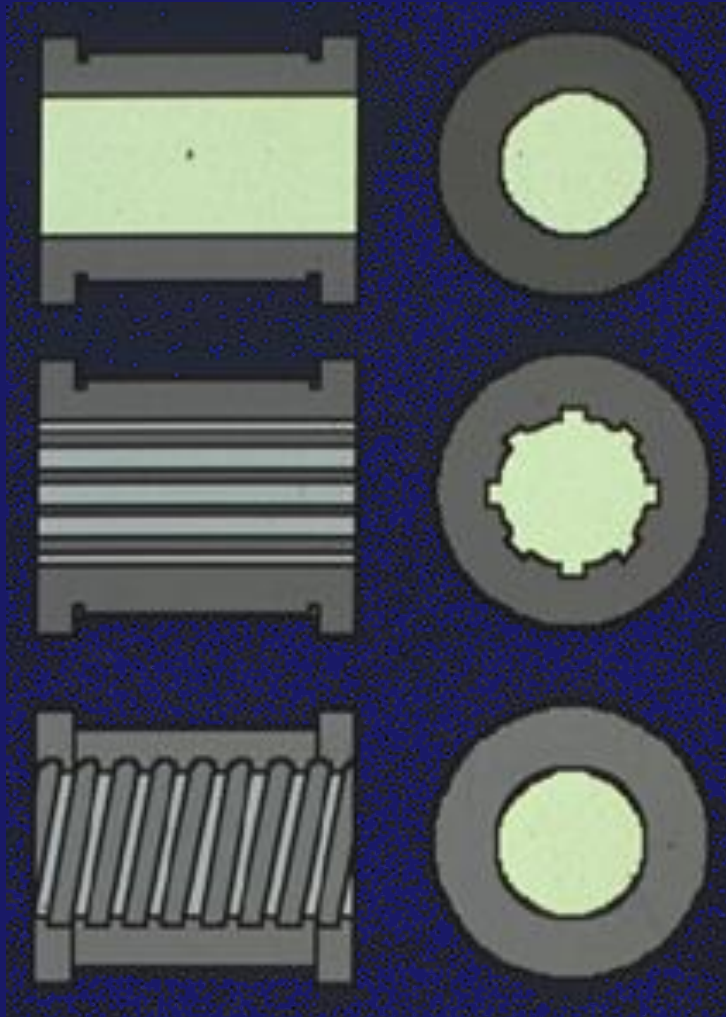


# Extruder Barrel Components

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- Barrel Sections
- Screws (Conveying & Restriction)
- Restriction Elements (Lobe & Round Locks)

# Barrel Wall Configurations

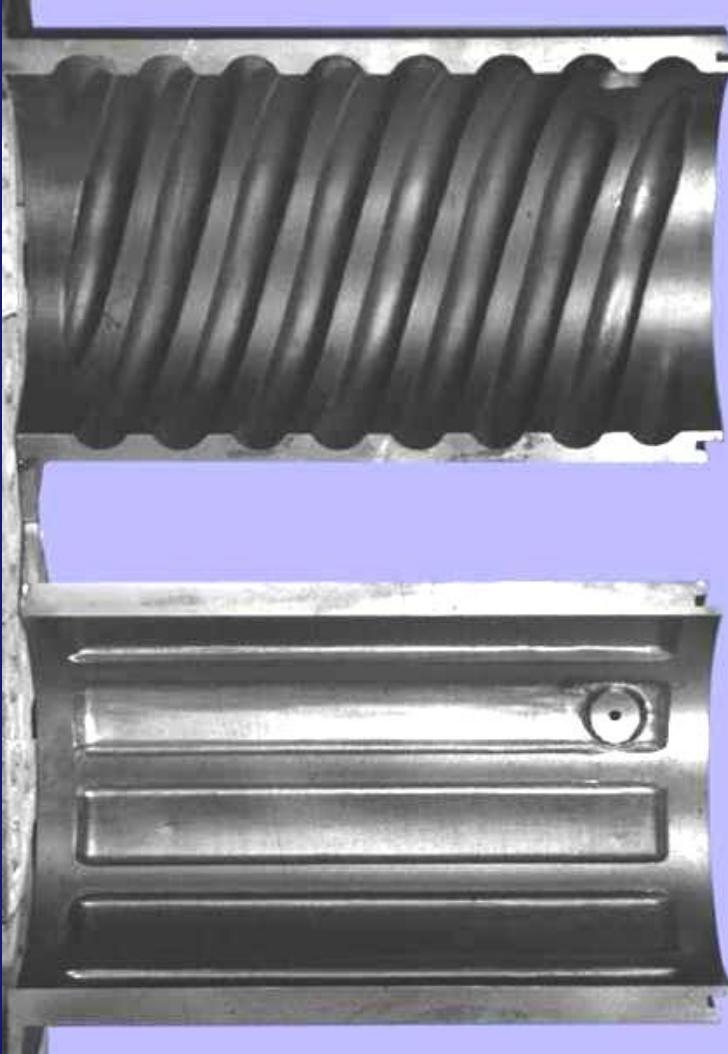


- Smooth Bore

- Longitudinal Grooves

- Spiral Grooves

# Single Screw Barrel Liners



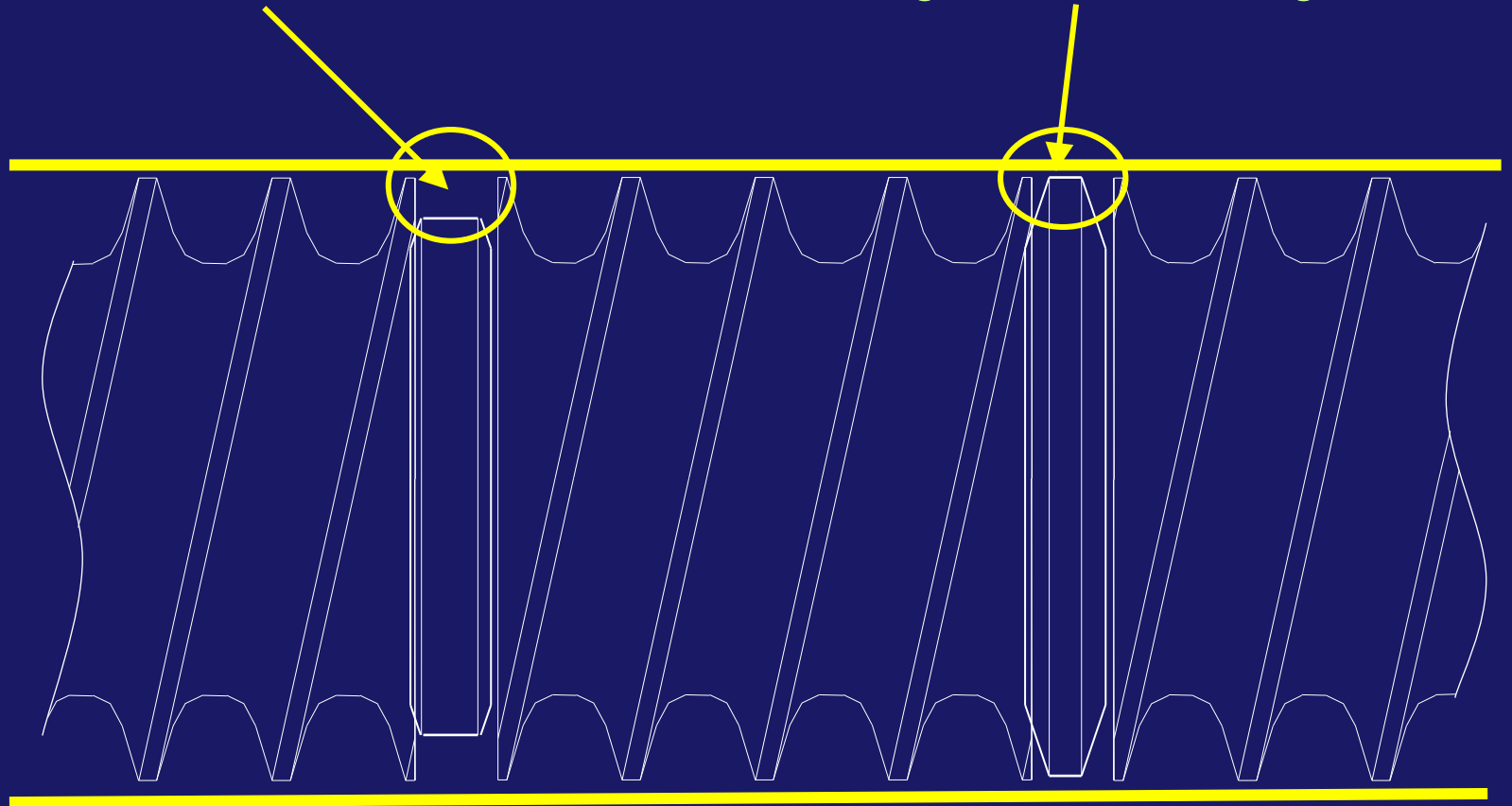
- Spiral Ribbed Liner

- Straight Ribbed Liner

# Round Shear Locks

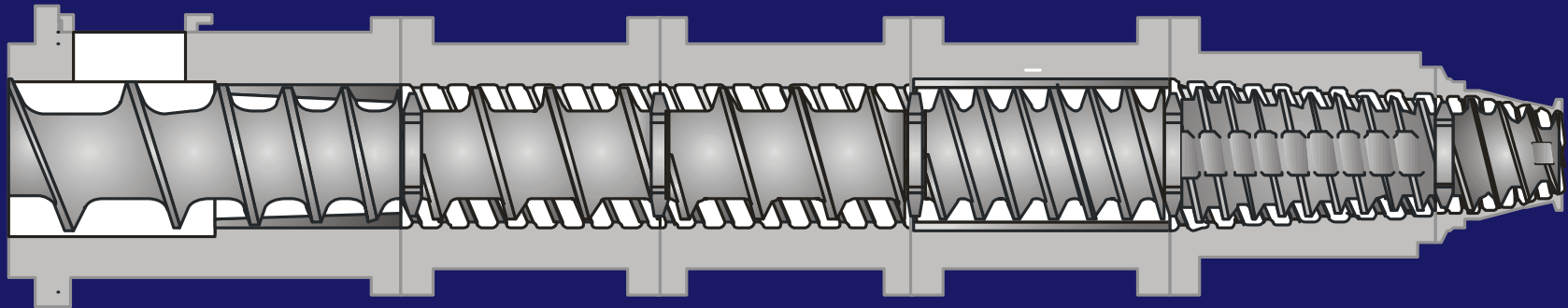
Small Diameter = Low Restriction

Large Diameter = High Restriction



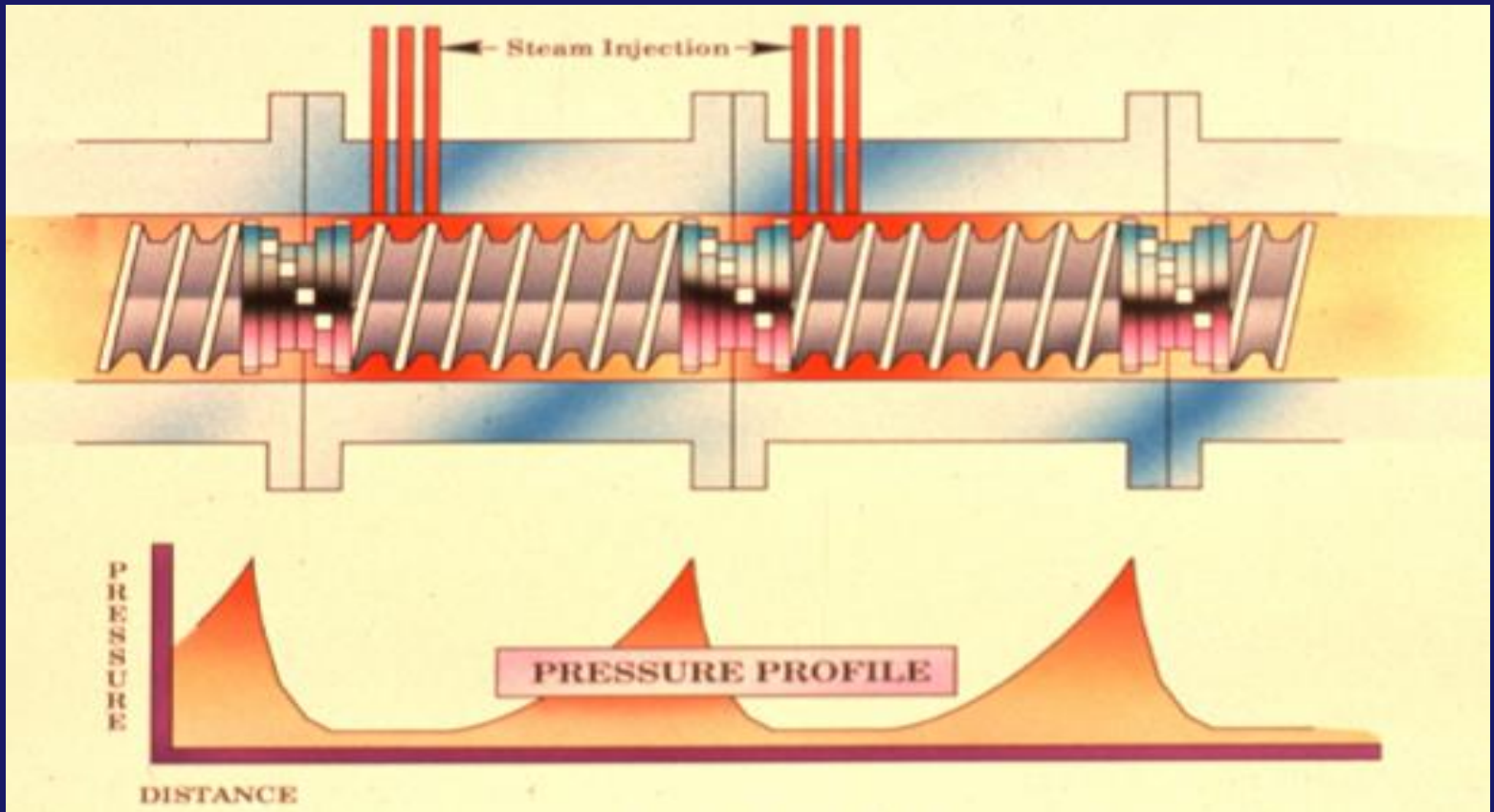
Commonly Used in Single Screw Extruder

# Configuring the Extruder



# Configuring the Extruder

- Conveying
- Restriction
- Venting
- Material Addition

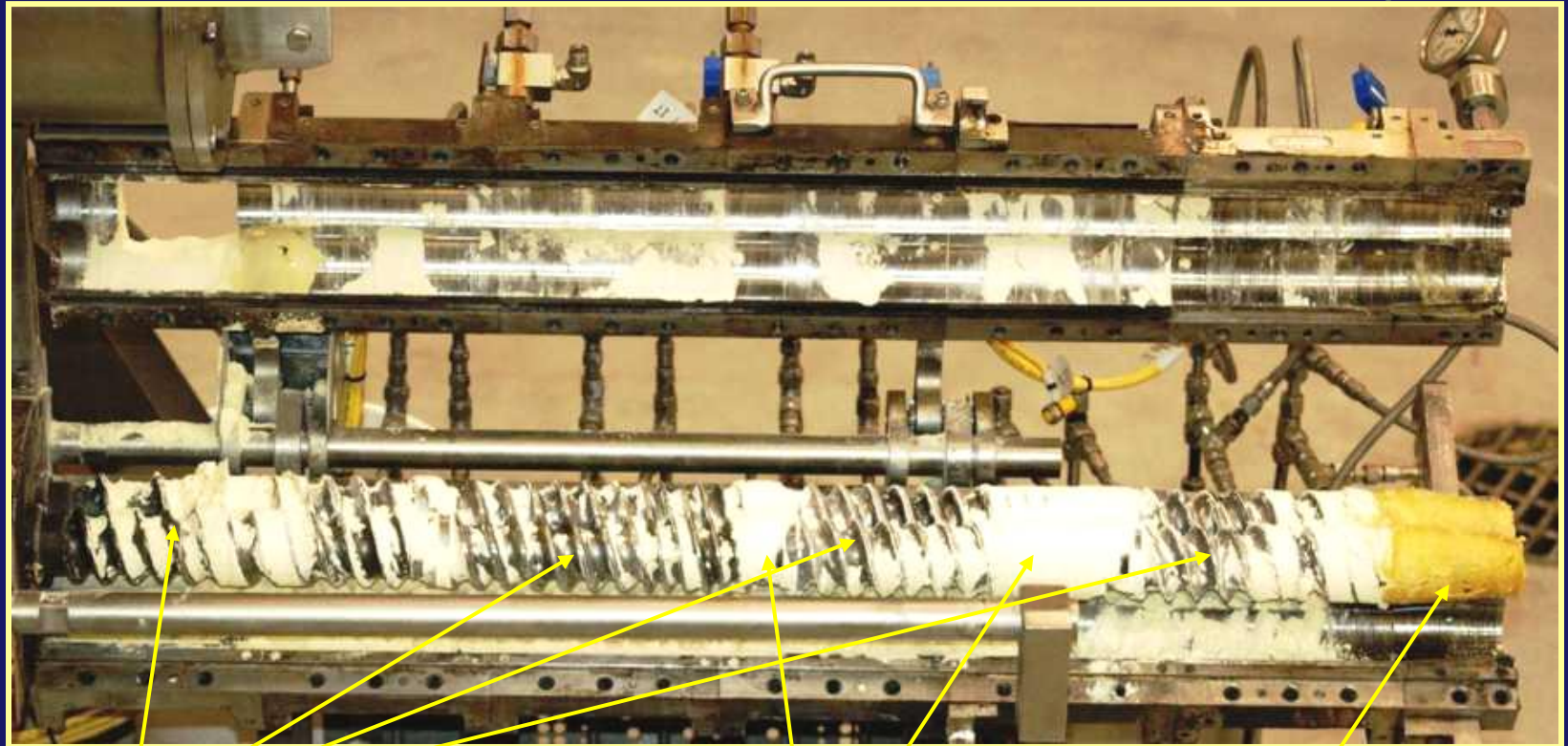


# Configuring the Extruder

Inlet



Discharge



Conveying Screws

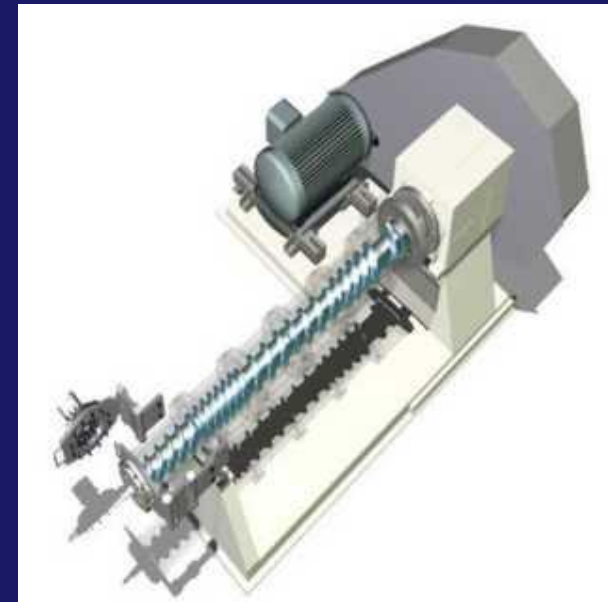
Shearlocks

Cone Screws

# Single Screw System

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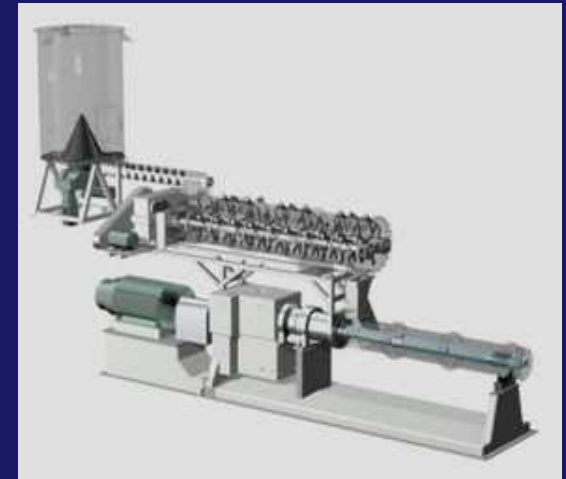
- Single shaft
- Replaceable components
- Variable speed
- Temperature controlled heads
- Robust bearing design (up to 1000 kW)
- High capacities (up to 22 ton/hr)
- Lower maintenance and operations cost



# Twin Screw System

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- Co-rotating
- Parallel shafts
- Wider ingredient flexibility
- Ultra high levels of internal fat (above 17%)
- Very uniform size and shape
- Ultra small product sizes (less than 1.5 mm)
- Pushing product long distances
- Difficult to convey products
- High SME products (>45 kW-hr/mton)



# Extruder Comparison

**Single Screw  
Extruder**

**Twin Screw  
Extruder**

Operating Ranges



Moisture  
Internal Fat  
Mechanical Energy Input  
Product Size

# Extrusion System Comparison

System	Single Screw	Twin Screw
Capital Investment	1	1.75
Operating Costs	1	1.75
Ingredient Flexibility	Good	Very good
Requires Extruder Configuration Changes	Yes	Yes
System Complexity	Medium	High
Turn-Down Ratio	2:1	2.5:1

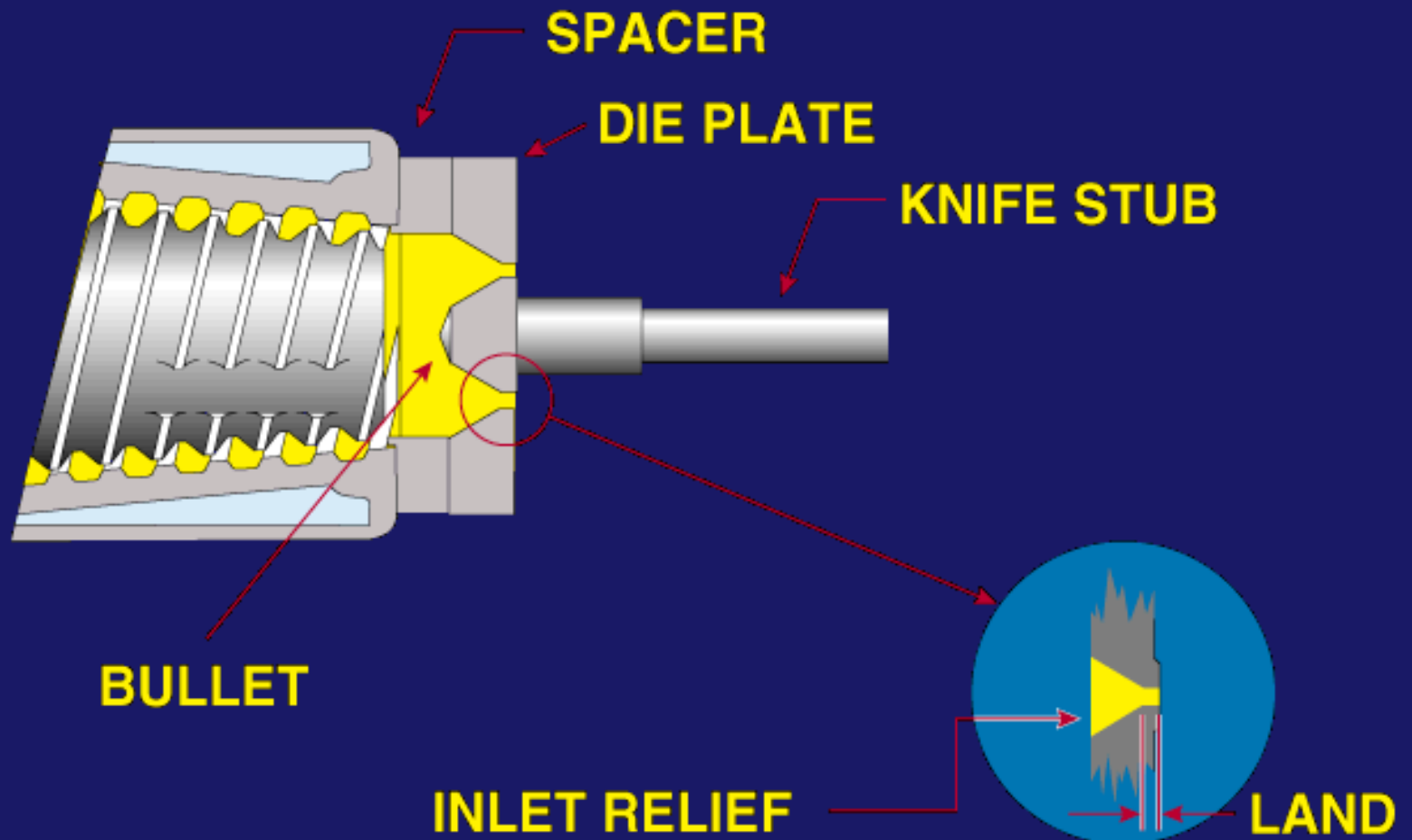
# **Principles of Die Design**

# Product Shaping



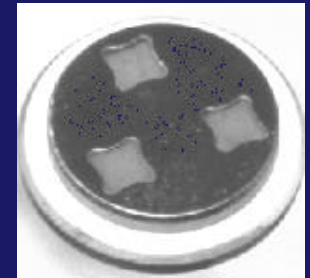
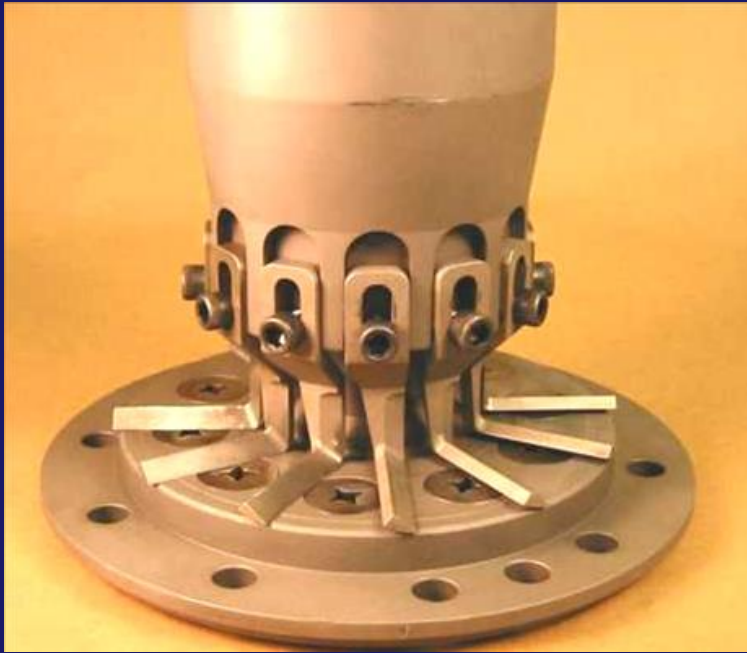
# Die Terminology

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# Insert Holder

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- Flexibility – Change Number of Inserts
- Good For  $> 4\text{mm}$  & Shapes

# Drilled Dies

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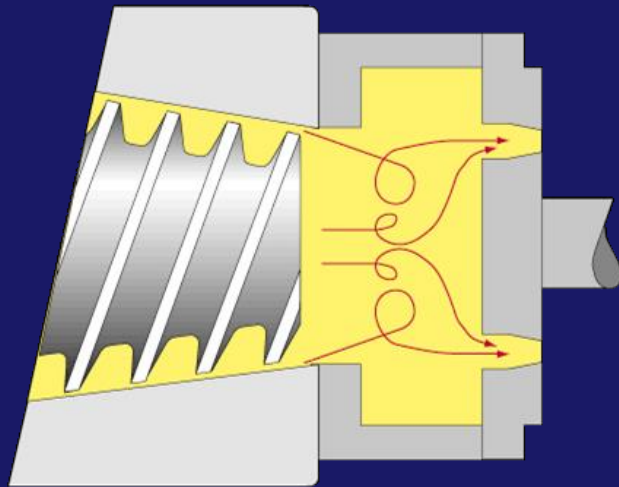


- Preferred for  $< 3\text{mm}$  Dia
- Maximized Space Between Holes
- Increases Permissible Open Area

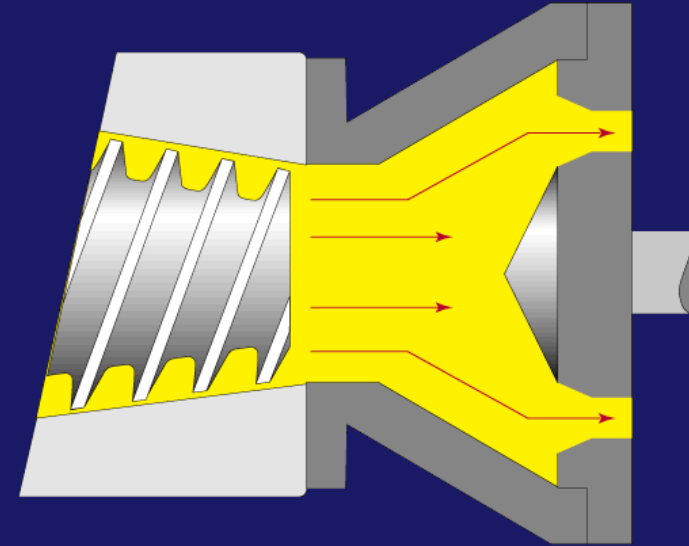


# Spacers / Adaptors

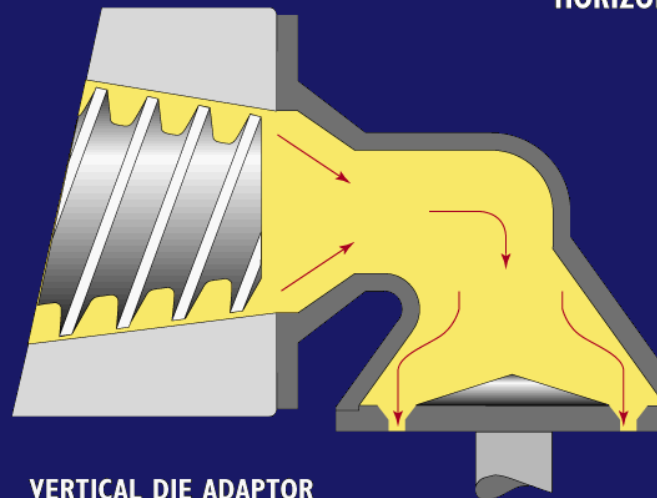
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SINGLE DIE WITH SPACER



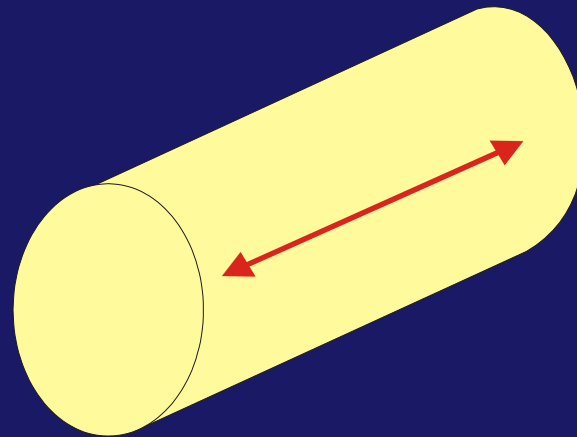
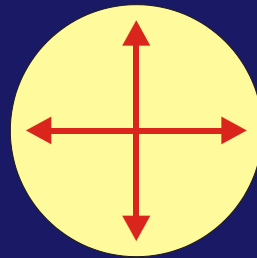
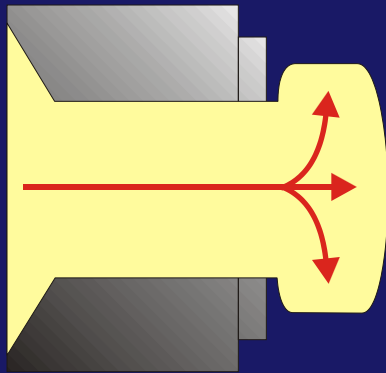
HORIZONTAL DIE ADAPTOR



VERTICAL DIE ADAPTOR

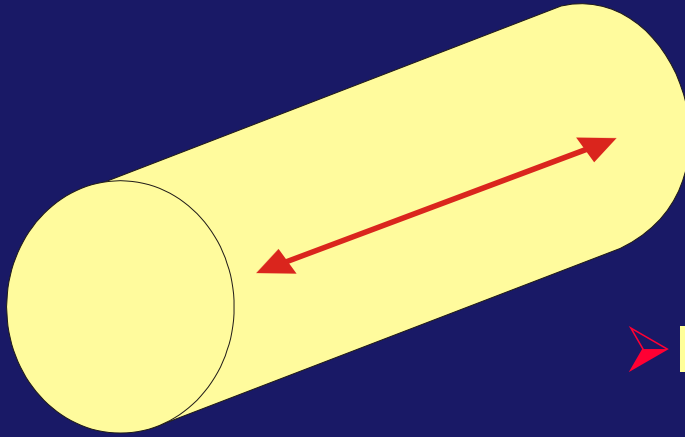
# Extrudate Expansion

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# Extrudate Expansion

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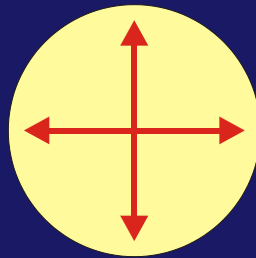
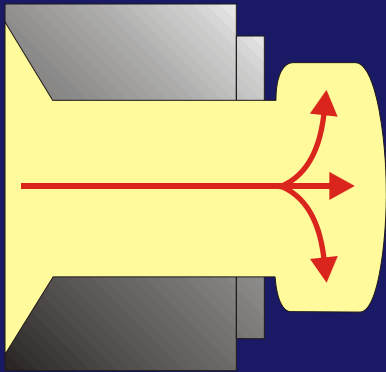


## Axial Expansion

- Influenced By:
  - Die Design
  - Processing Conditions (Temperature – Moisture)
  
- Controlled by:
  - Knife Speed

# Extrudate Expansion

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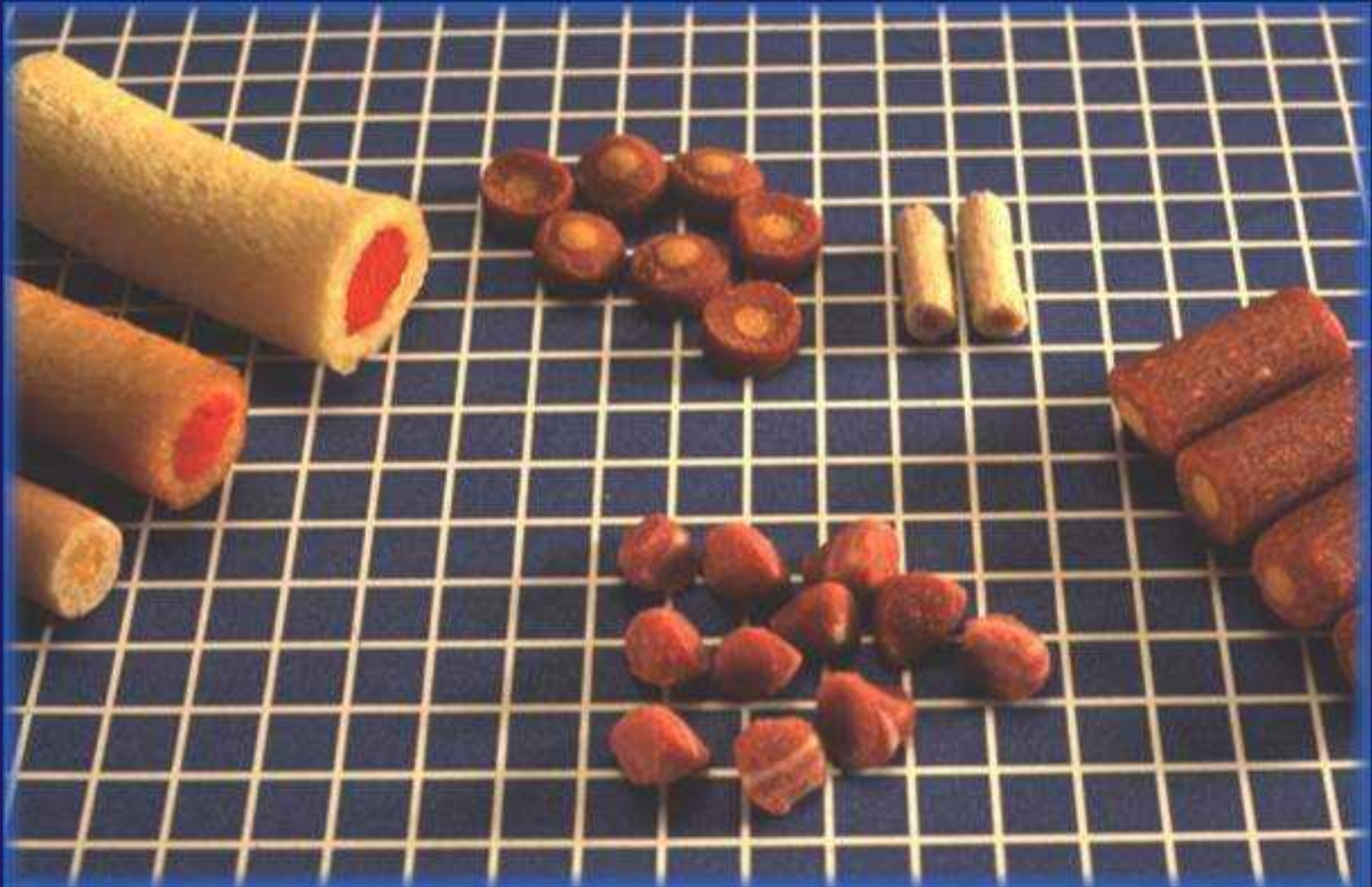


Radial Expansion

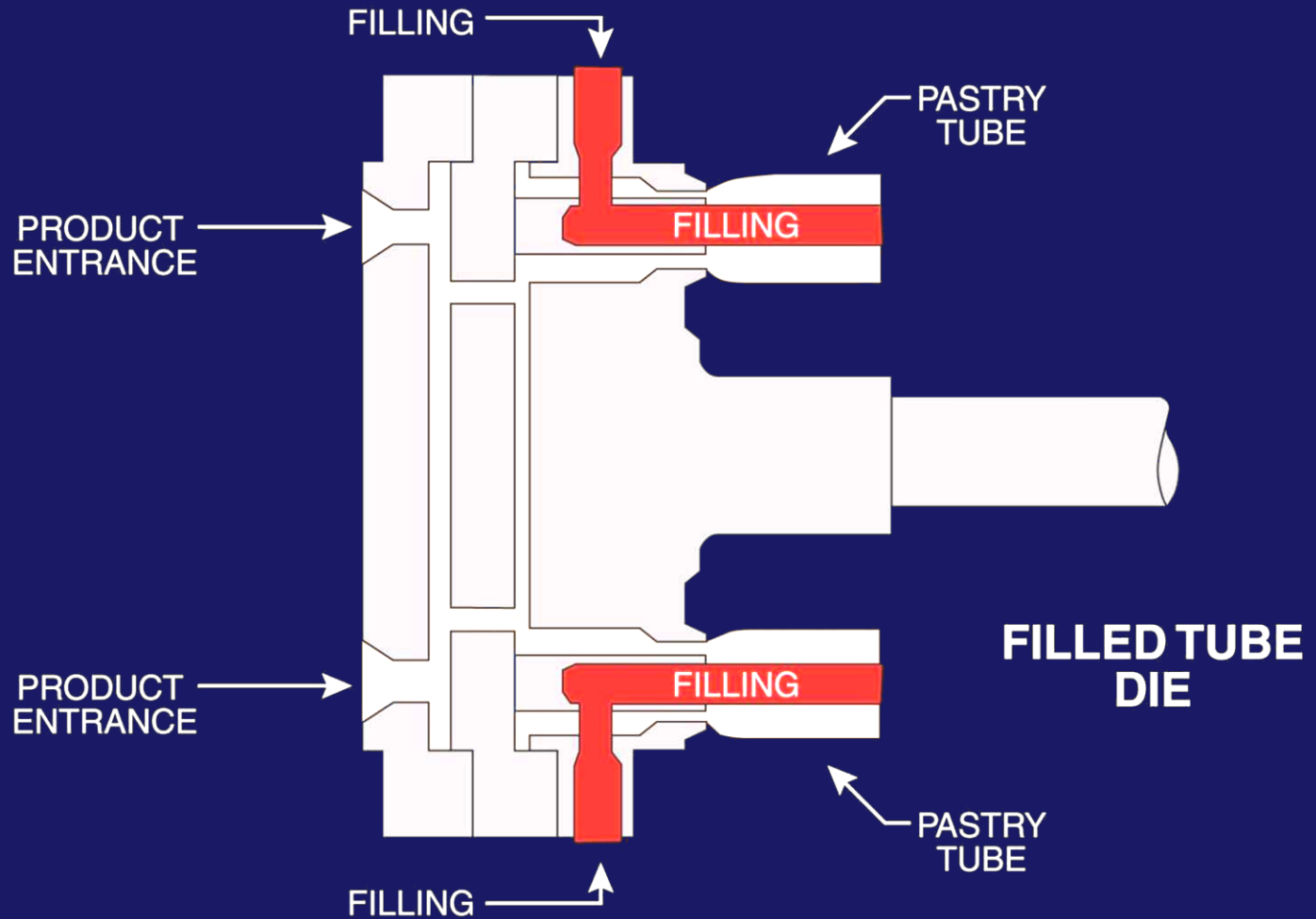
- Influenced By:
  - Die Design
  - Processing Conditions (Temperature – Moisture)
- Controlled By:
  - Die Opening Size

# Co-Extruded / Filled Products

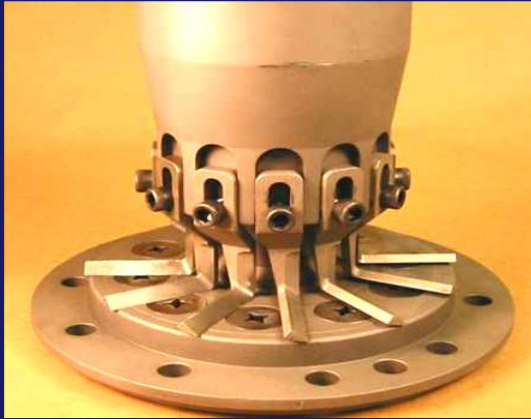
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# Co-Extrusion Die

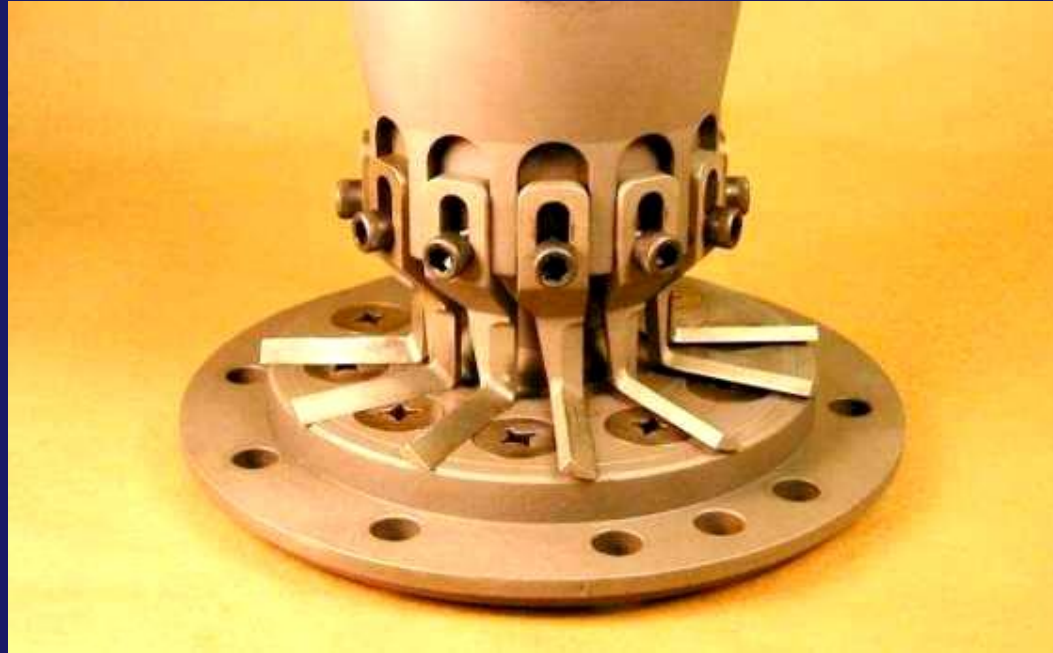


# Product Cutting



# Ridged – Thin Knife

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Good for :

- 2mm – 10mm sized products
- Shapes

# Flex Knife Blades

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- 0.8 – 3.0 mm sized pellets
- Sticky – Difficult to cut products

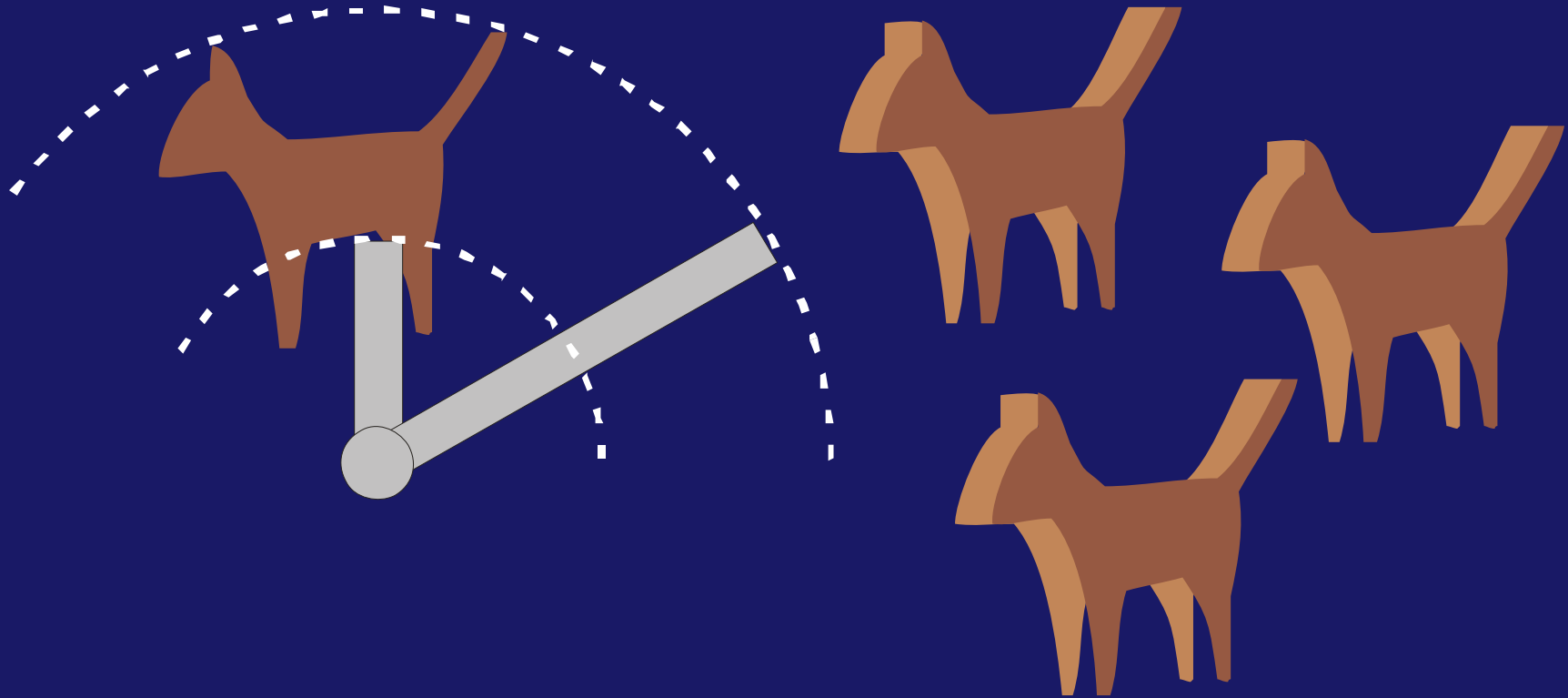


# Knife Sharpening / Adjustment



# Cutting of 3D Shapes

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# EXTRUSION OPERATION AND PROCESS VARIABLES



# System Variables

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Independent

Dependent

- ▣ Critical Parameters

Product Responses

# Independent Variables

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Dry Recipe

Dry Recipe Rate

Water Injected into Preconditioner

Steam Injected into Preconditioner

Preconditioner Speed

Preconditioner Configuration

Water Injected into Extruder

Steam Injected into Extruder

Extruder Configuration

Extruder Speed

Extruder Barrel Configuration

Die Configuration

# Dependent Variables

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Retention Time in Preconditioner

Temperature in Preconditioner

Moisture in Preconditioner

Retention Time in Extruder

Temperature in Extruder

Moisture in Extruder

Pressure in Extruder

Mechanical Energy input via Extruder

# Critical Parameters

---

- Moisture
- Thermal Energy Input
- Mechanical Energy Input
- Retention Time

# Product Responses

---

Water Absorption

Stickiness

Bulk Density

Piece Density

Solubility

Oil Absorption

Hardness

Digestibility

Texture

RAW  
MATERIALS

INDEPENDENT  
PROCESS  
VARIABLES

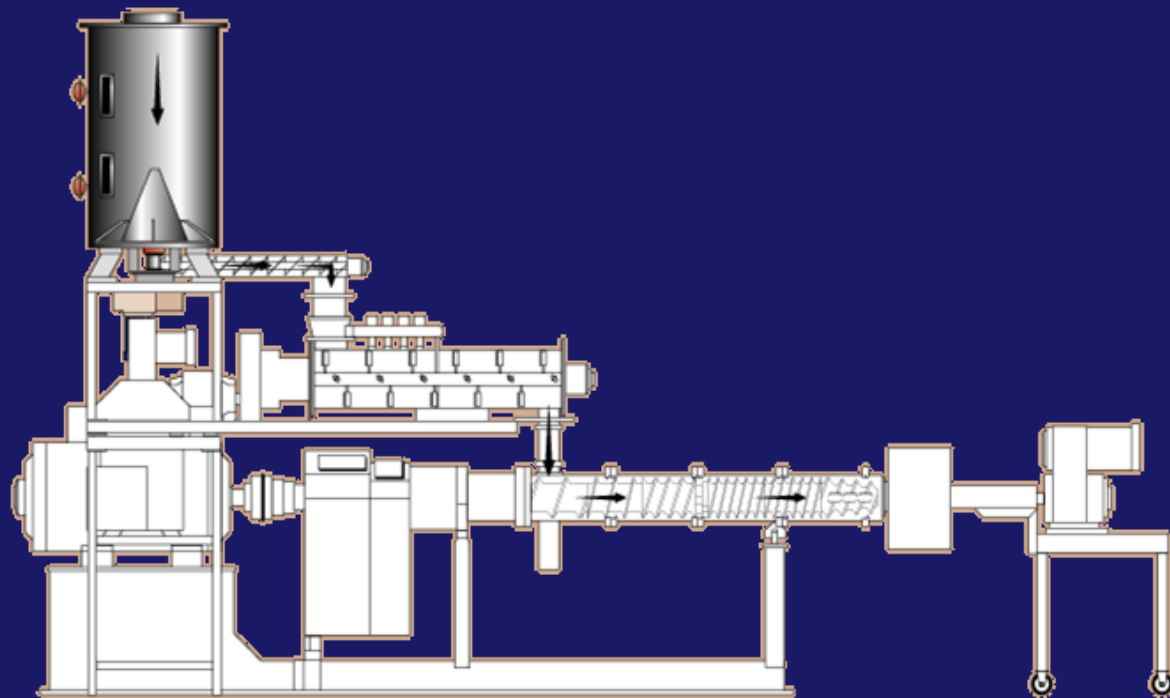
CRITICAL  
PARAMETERS

PRODUCT  
CHARACTERISTICS



# Extrusion Cooking...

A VERY FLEXIBLE PROCESS THAT USING THE PROPER RAW MATERIALS, HARDWARE, AND PROCESSING TECHNIQUES, CAN PRODUCE A WIDE RANGE OF FOOD, FEED, AND INDUSTRIAL PRODUCTS





# THANK YOU



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