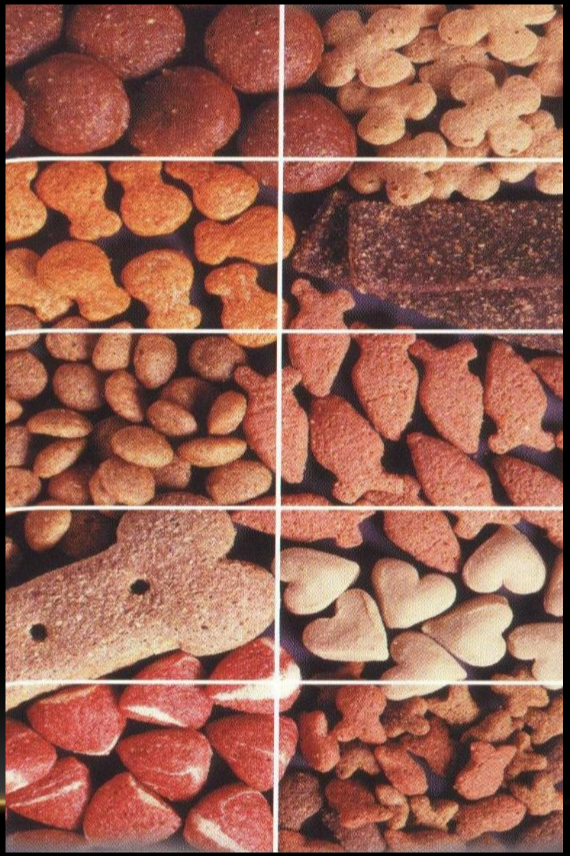
Advancements in Extrusion Process & Design

Pet Food Forum 2014, Bangkok, Thailand

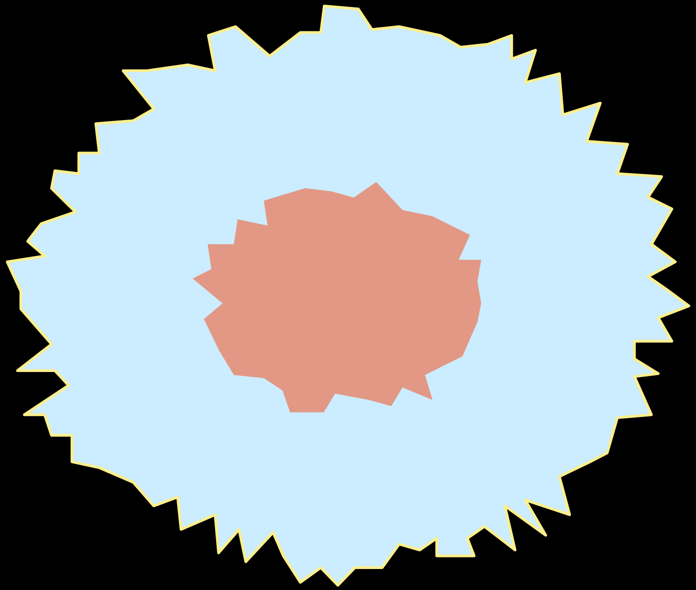


Will Henry
Director of Technology, R&D

EXTRU-TECH, INC.

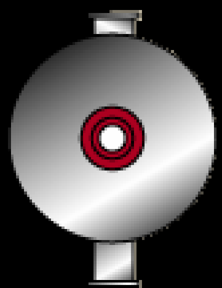
Objectives of Preconditioning

- Mix
- Hydrate
- Heat

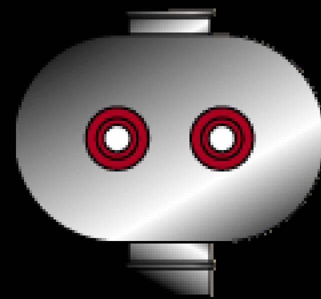


Your objective is to form a homogenous final product from a mixture of two or more dissimilar raw materials, hydrate to a particular moisture, pre-cook for ease of extrusion and product characteristics, and provide uniform/consistent flow to the extruder.

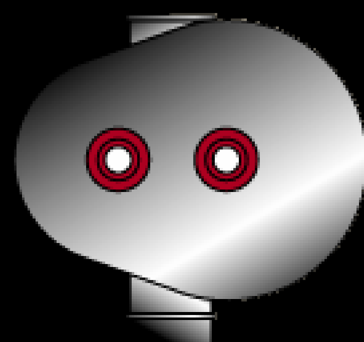
Types of Preconditioner



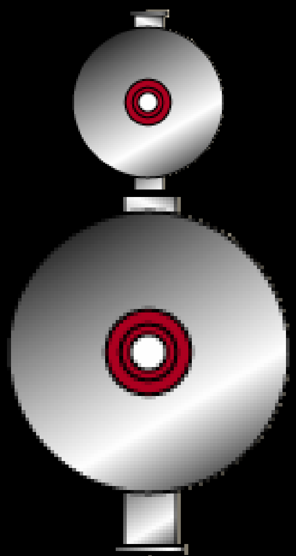
Single Shaft



Traditional Double Shaft

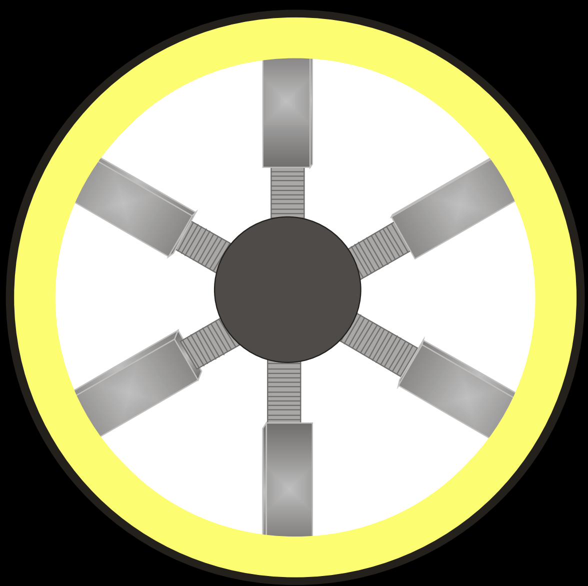


Differential Diameter/Speed
Double Shaft



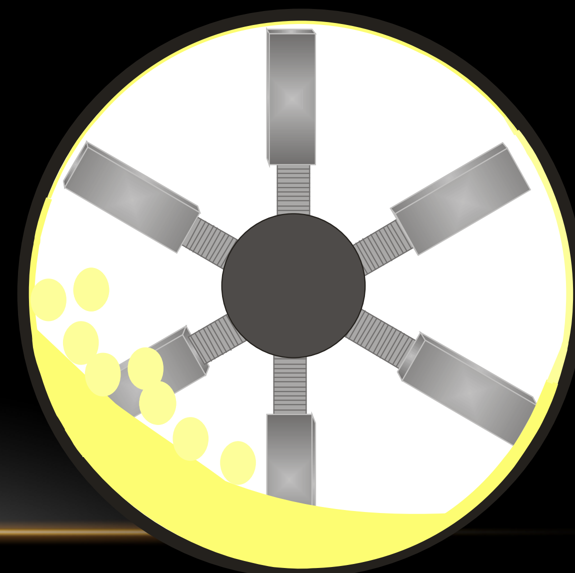
2-Stage Single Shaft

Single Shaft Preconditioner



High Speeds

Low Speeds



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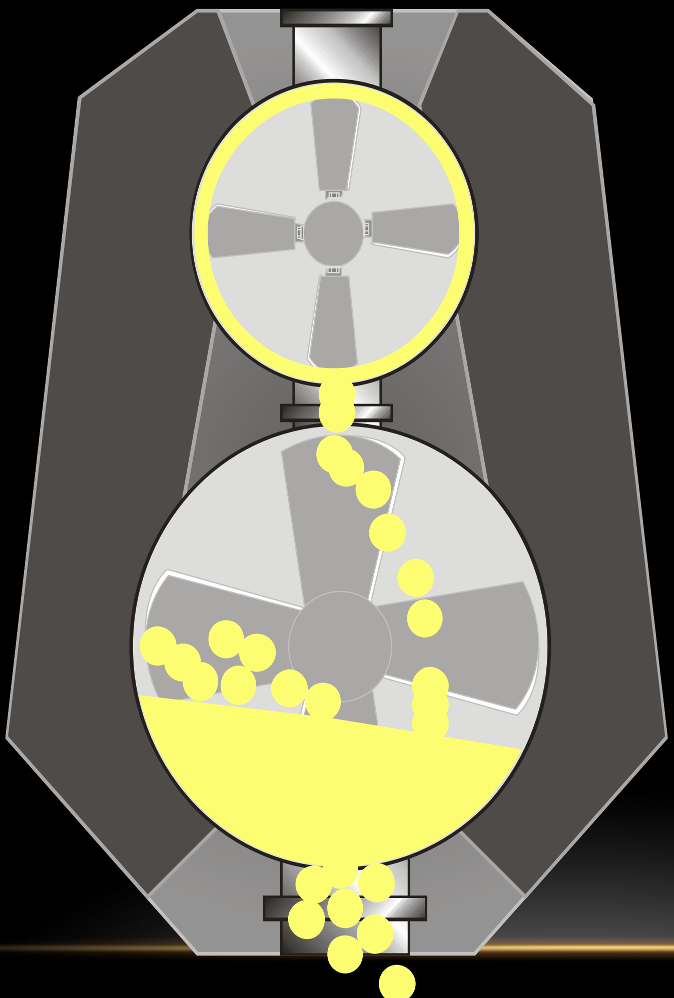
Single Shaft Preconditioner

When do I use a single shaft preconditioner?

1. Low cook required
2. Short Retention Times are sufficient
3. No liquid/slurry/meat addition involved
4. Minimal mixing required

Two Stage Single Shaft Preconditioner



High Speed Shaft

- Mixing
- Liquid Injection
- Meat Injection
- Water & Steam Injection

Low Speed Shaft

- Retention for Absorption
- Water & Steam Injection
- Cook

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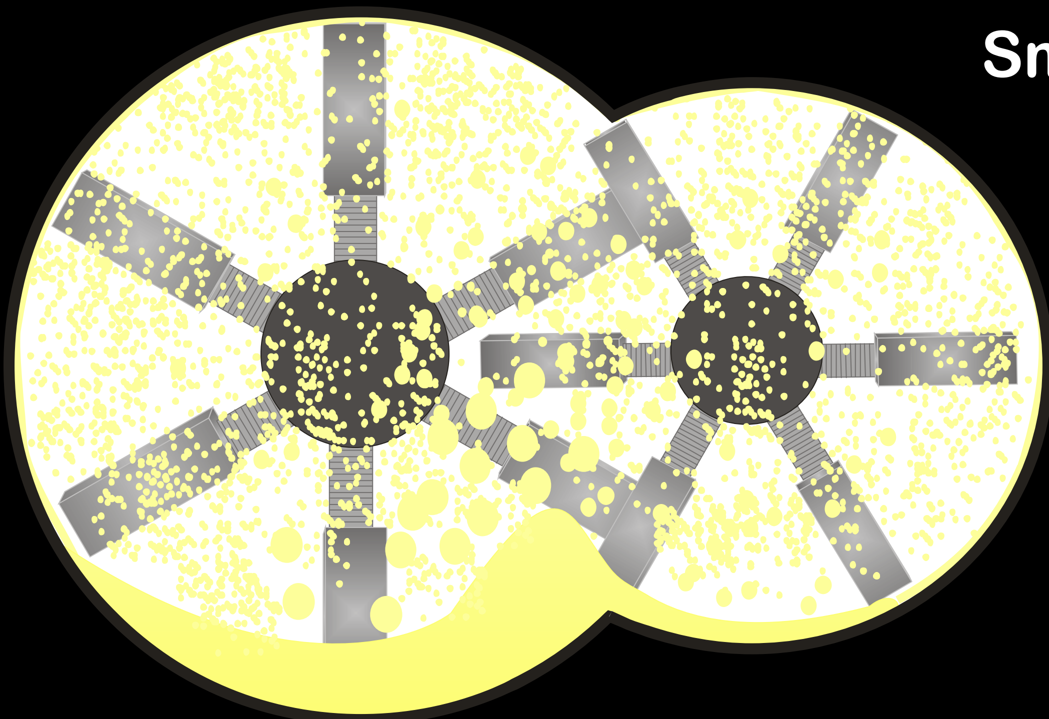
Double Shaft Preconditioner Differential Diameter Cylinder (DDC)



Smaller, high speed shaft (100-500 RPM)

Counter-rotating, intermeshing shafts.

Bi-Directional

- Clean-out

Larger, slow speed shaft (50 – 250 RPM)

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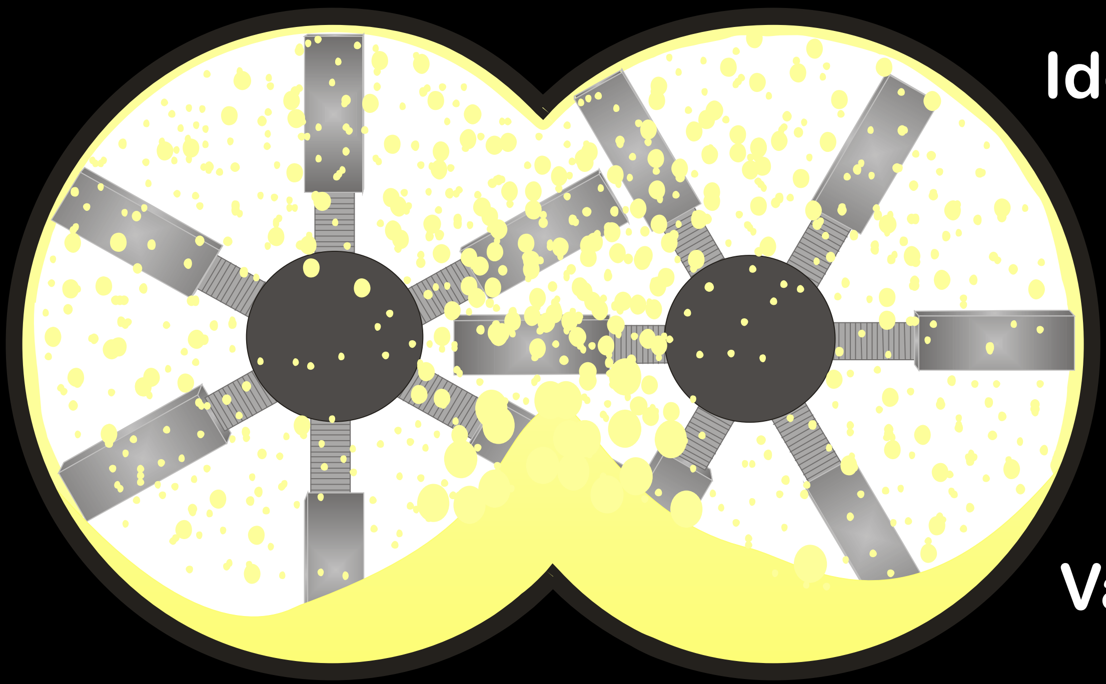
Double Shaft Preconditioner
ETI Asceptic Dual Preconditioner (ADP)



Identically sized, counter-rotating, intermeshing shafts.

Variable speed
- Retention Time

Bi-Directional
- Clean-out

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Double Shaft Preconditioner

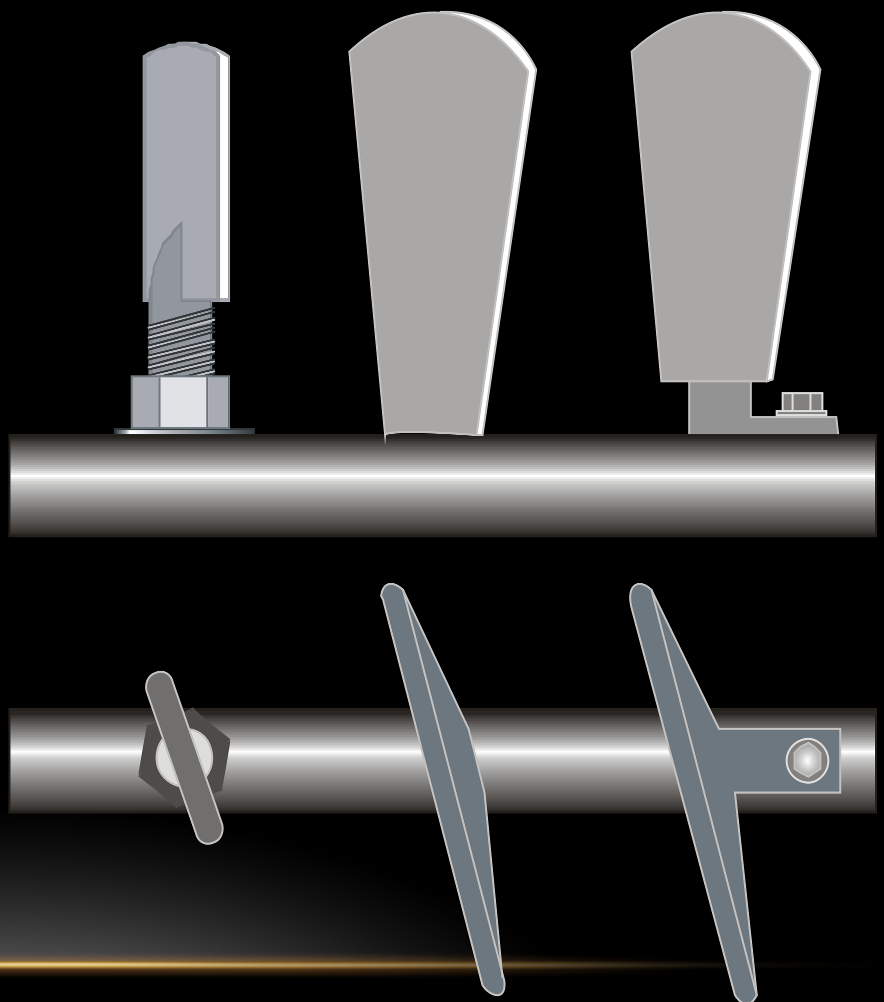
When do I use a double shaft preconditioner?

1. Higher levels of cook required
2. Longer retention times required
3. Liquid/slurry/meat addition involved
4. Intense, Distributive Mixing is required

Preconditioner Mixing Components

Attachment Mechanisms

- Welded
  - No Adjustment
- Bolted
  - Minor Adjustment
- Threaded
  - Excellent Adjustment



Preconditioner Mixing Components

Paddles

Thin narrow blade

Excellent mixing action

Beaters

Thin wide blade

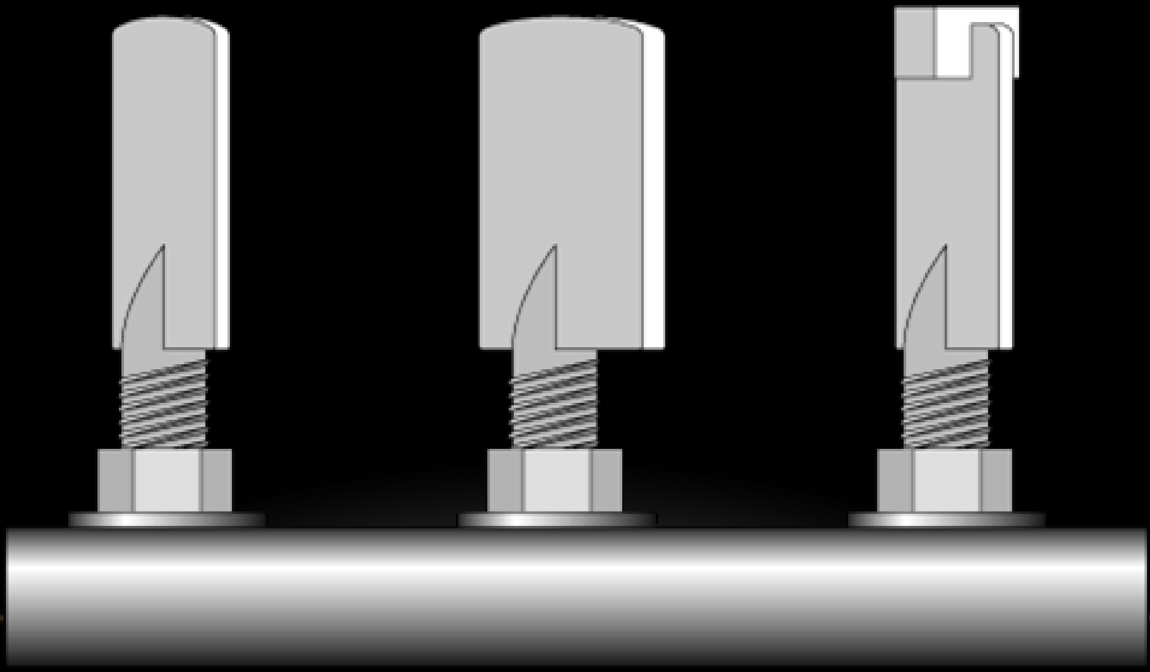
Good mixing

promotes build-up

T-Beaters

Thin narrow blade w/ perpendicular appendage.

Erratic mixing action



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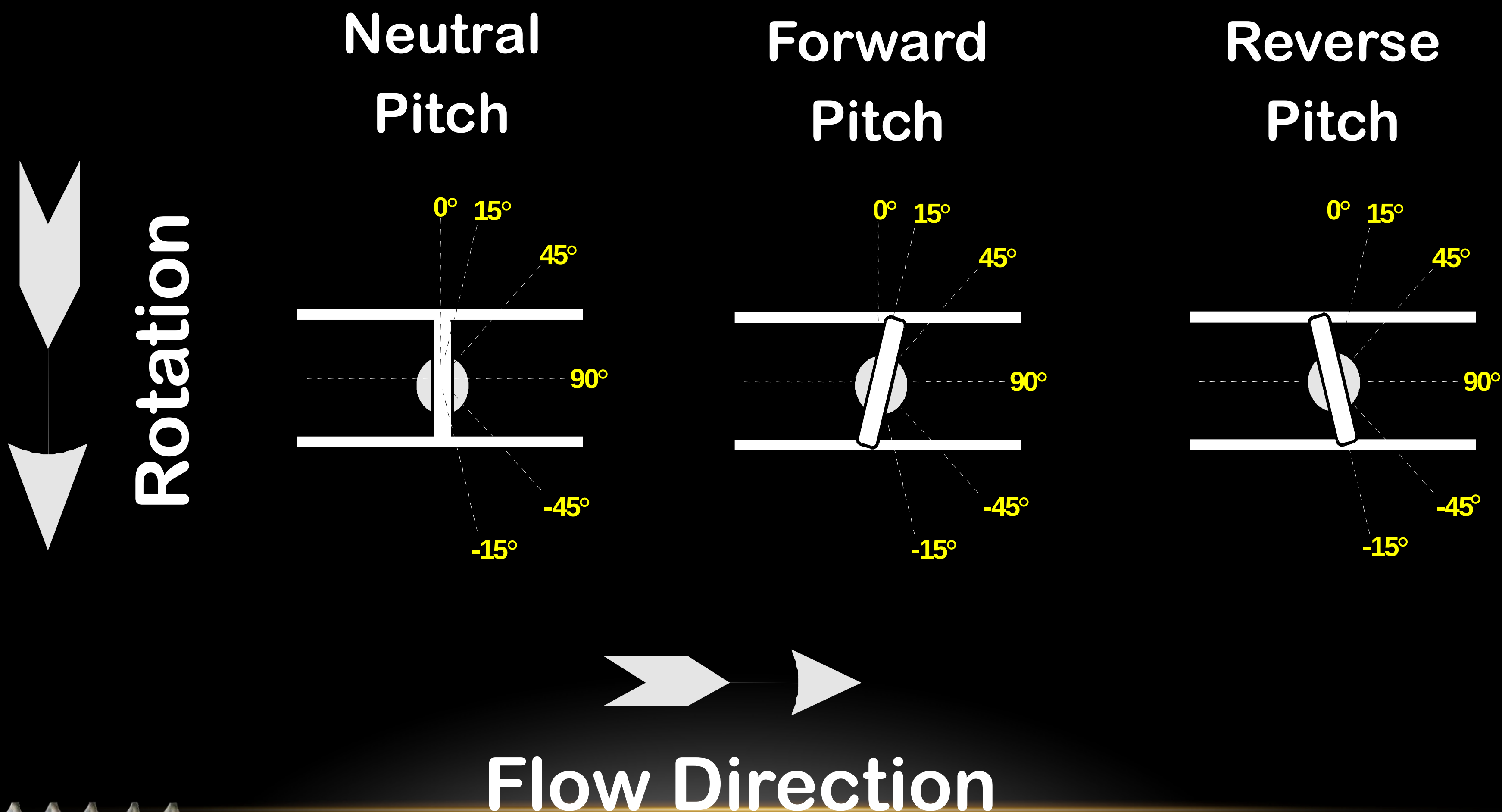
Preconditioner Mixing Setup



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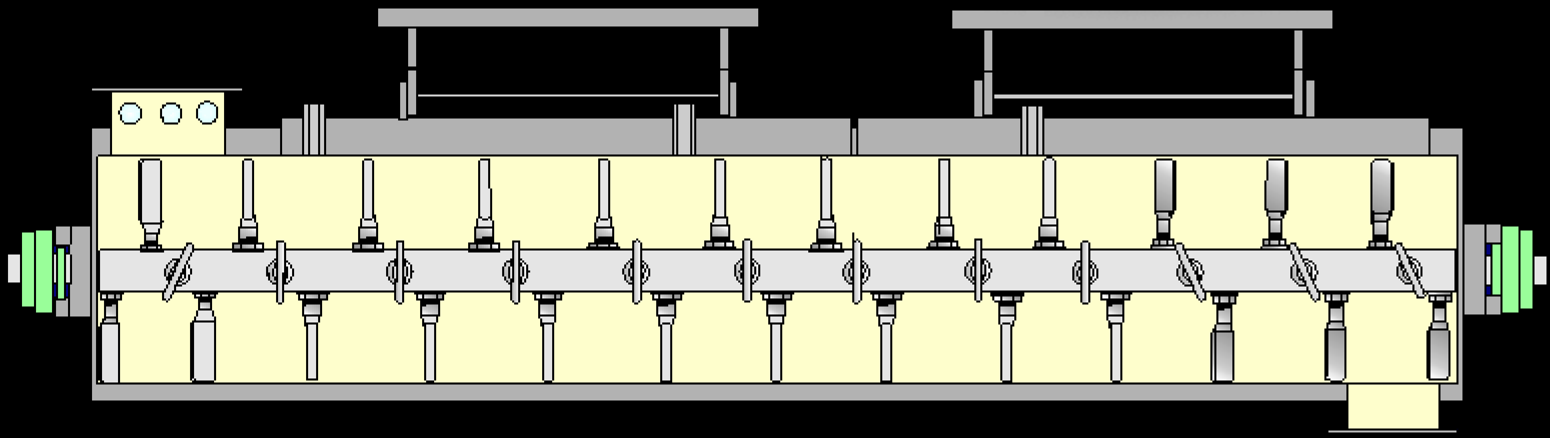
Preconditioner Level Management



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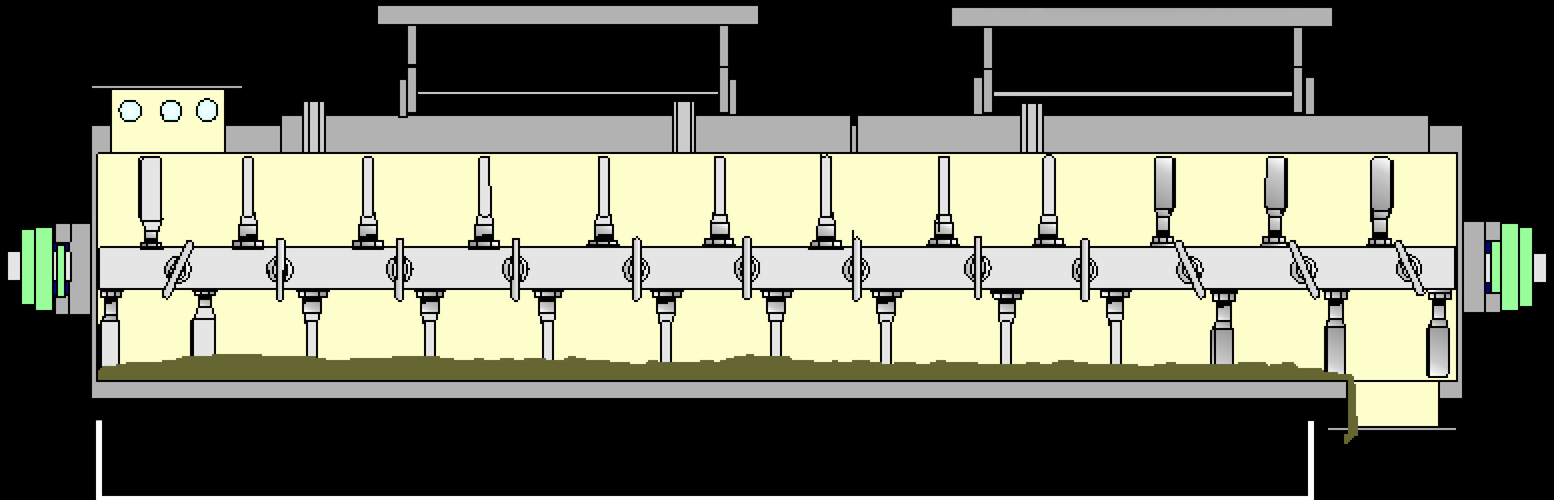
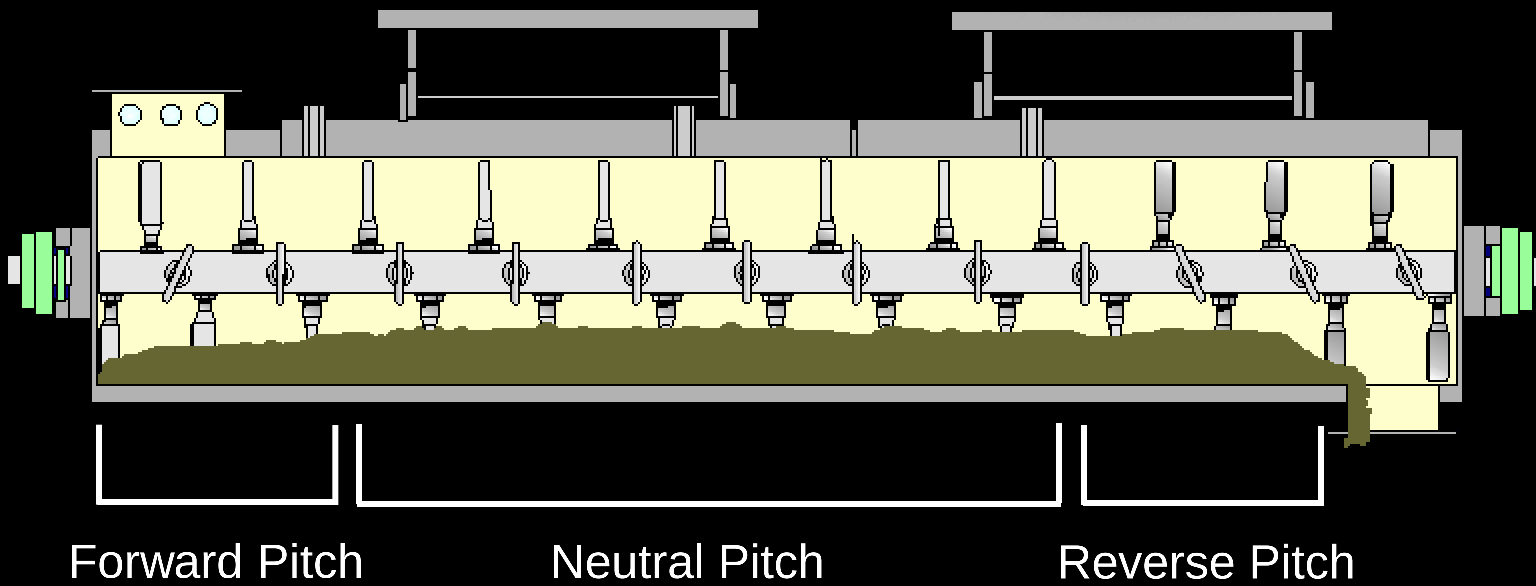
Preconditioner Level Management
In-Line Dynamic Mixing



All Forward Pitch

- Retention Time: 20 – 35 Seconds
- Dead Stop Weight – 50 – 60 lbs.
- Shaft Rotation has significant impact

Preconditioner Level Management Traditional Configuration



- **Retention Time: 35 – 55 Seconds**
- **Dead Stop Weight: 60 – 85 lbs.**
- **CAN NOT operate shafts in Reverse**

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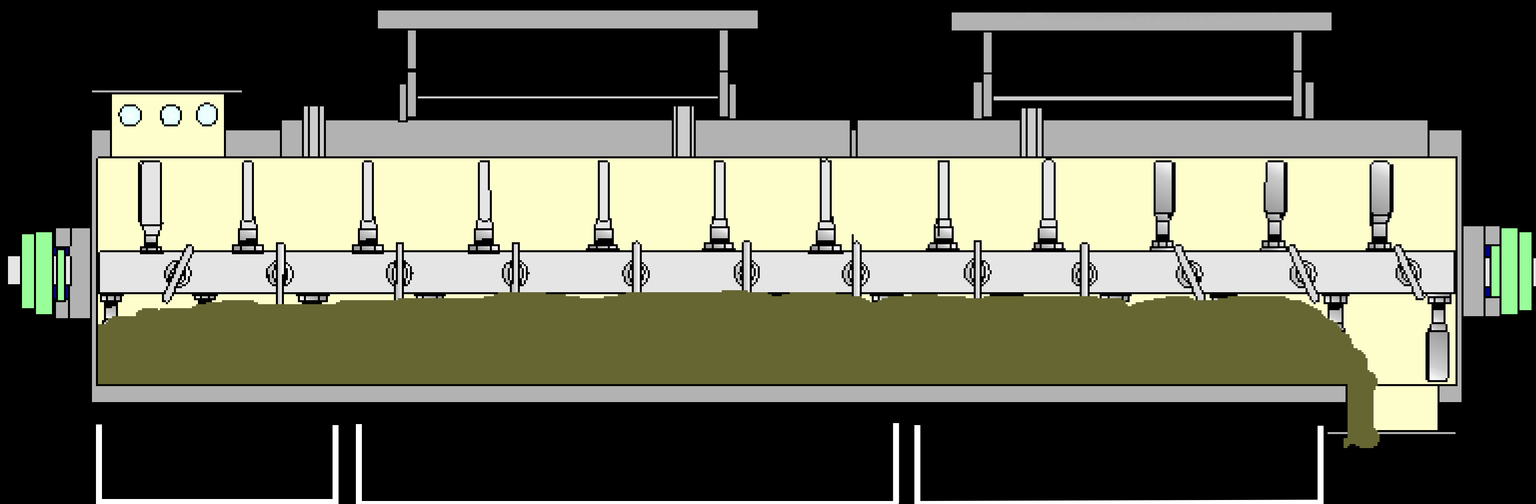
All reference data correlates to research on a ETI 16X72 DCC with an L/D of 4.5

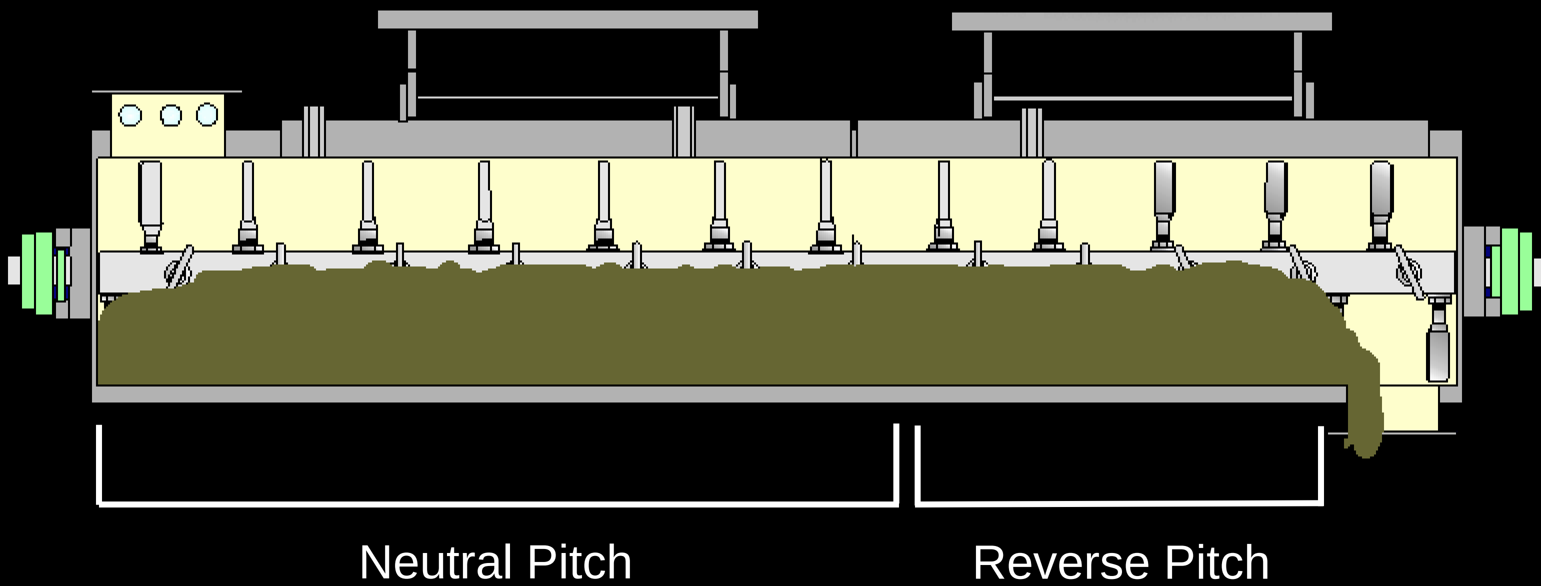
Preconditioner Level Management
Traditional Configuration



Forward Pitch   Neutral Pitch   Reverse Pitch

- **Retention Time: 45 – 65 Seconds**
- **Dead Stop Weight: 70 – 95 lbs.**
- **CAN NOT operate shafts in Reverse**

Preconditioner Level Management
Advanced Configuration

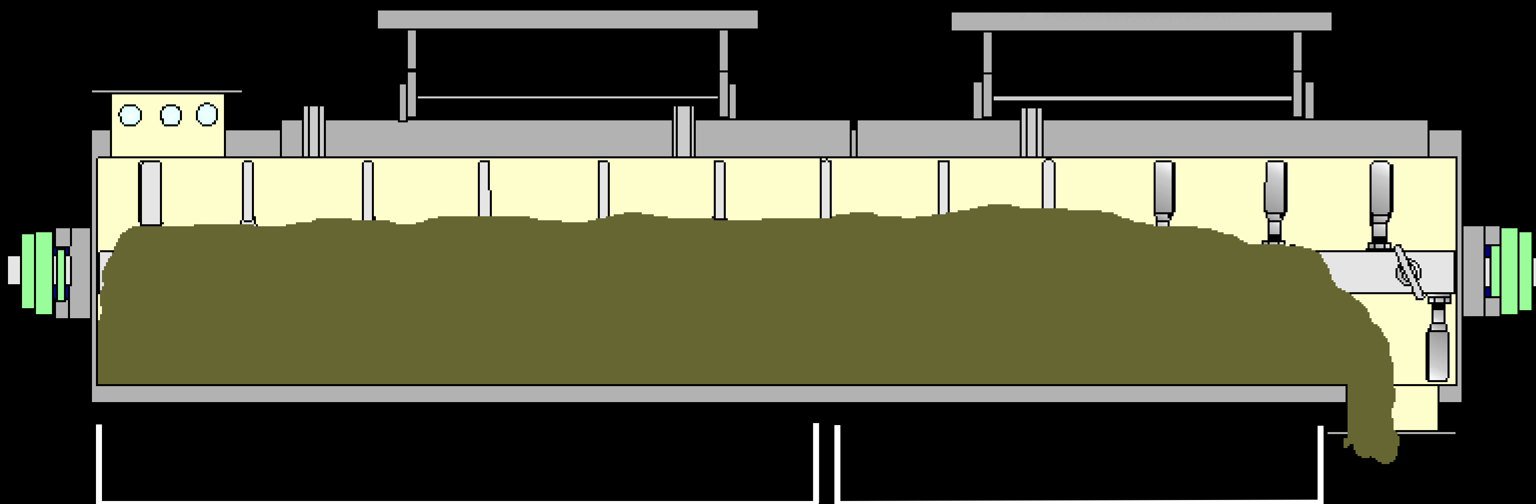


- Retention Time: 50 - 90 Seconds
- Dead Stop Weight: 120 – 170 lbs.

- Evacuation Time & Weight Greatly Improved
  - Traditional – 2 Minutes w/ 30 lbs.
  - Advanced – <40 seconds w/ <1lbs.
    - Increased Speed & Reverse Direction

All reference data correlates to research on a ETI 16X72 DCC with an L/D of 4.5

Preconditioner Level Management Advanced Configuration



Neutral Pitch

Reverse Pitch

- **Retention Time: 80 - 120 Seconds**
- **Dead Stop Weight: 160 – 232 lbs.**

- **Evacuation Time & Weight Greatly Improved**
  - **Traditional – 2 Minutes w/ 30 lbs.**
  - **Advanced – <25 seconds w/ <1lbs.**
    - **Increased Speed & Reverse Direction**

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All reference data correlates to research on a ETI 16X72 DCC with an L/D of 4.5

Preconditioner Level Management
Advanced Configuration

Any and all injections will affect fill quality

Without any injections, expect only 40–50% fill

Addition of 8% water, fill quality can increase to 80%

Addition of steam (3-5%), fill quality can increase to 90%

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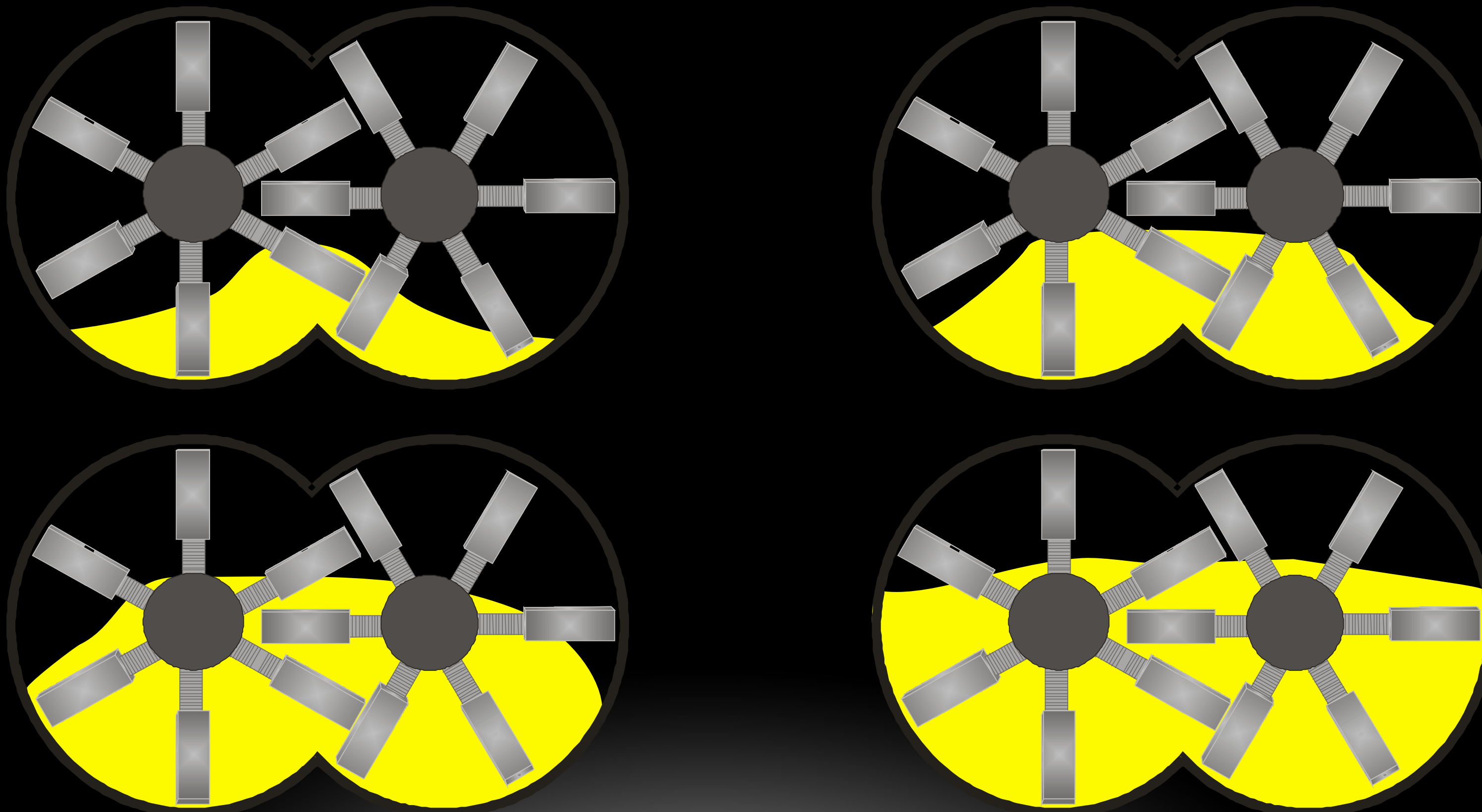
Preconditioner Level Management
Advanced Configuration

- Motor Load
  - Reduction as high as 50%
- Evacuation Time
  - Traditional configuration reaches maximum clean-out in 2 minutes
  - Advanced configuration reaches maximum clean-out in 25 seconds
- Evacuation Weight
  - Traditional configuration - > 30 lbs
  - Advanced configuration - < 2 lbs

Preconditioner Level Management
Cross-Section Profile



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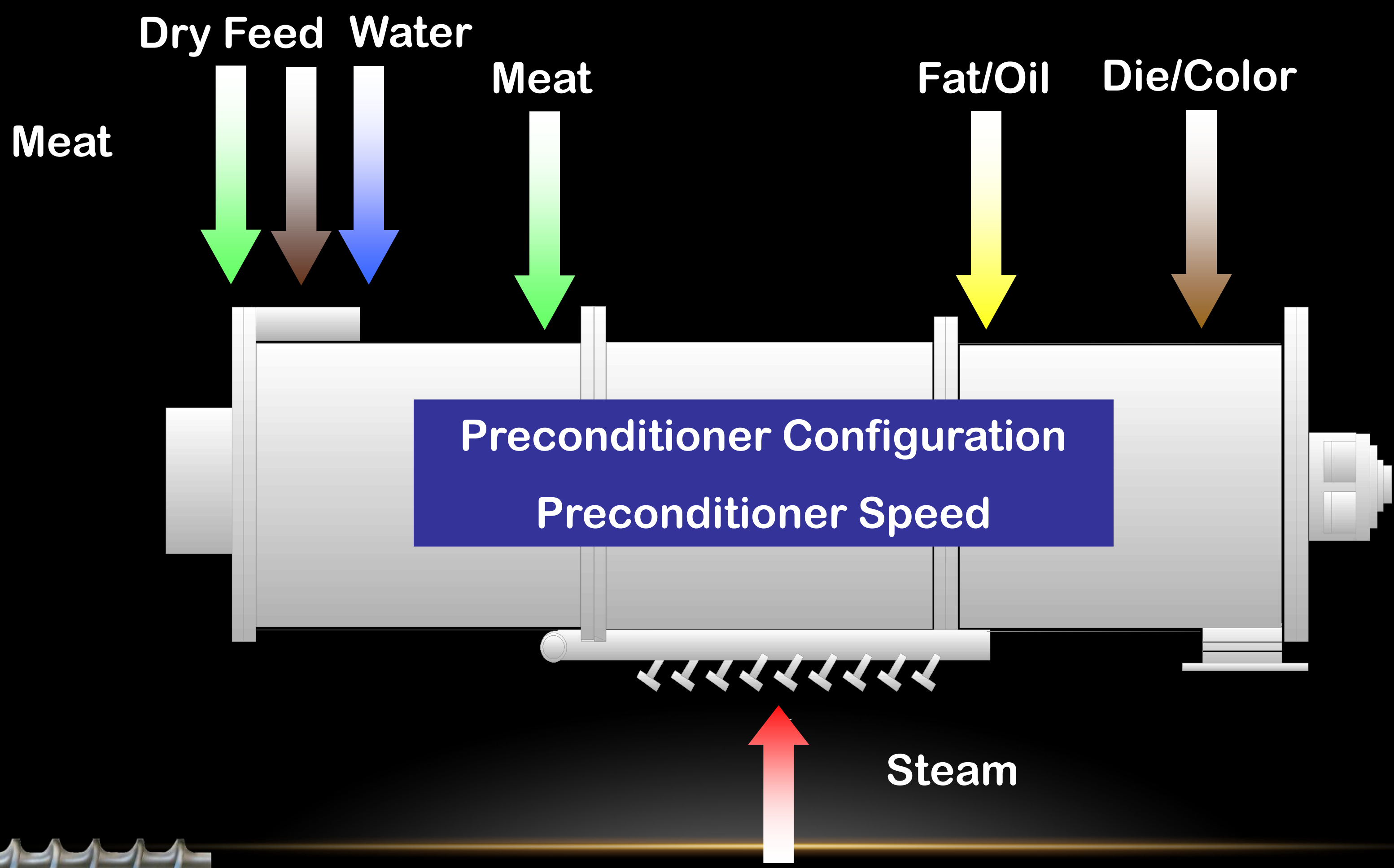
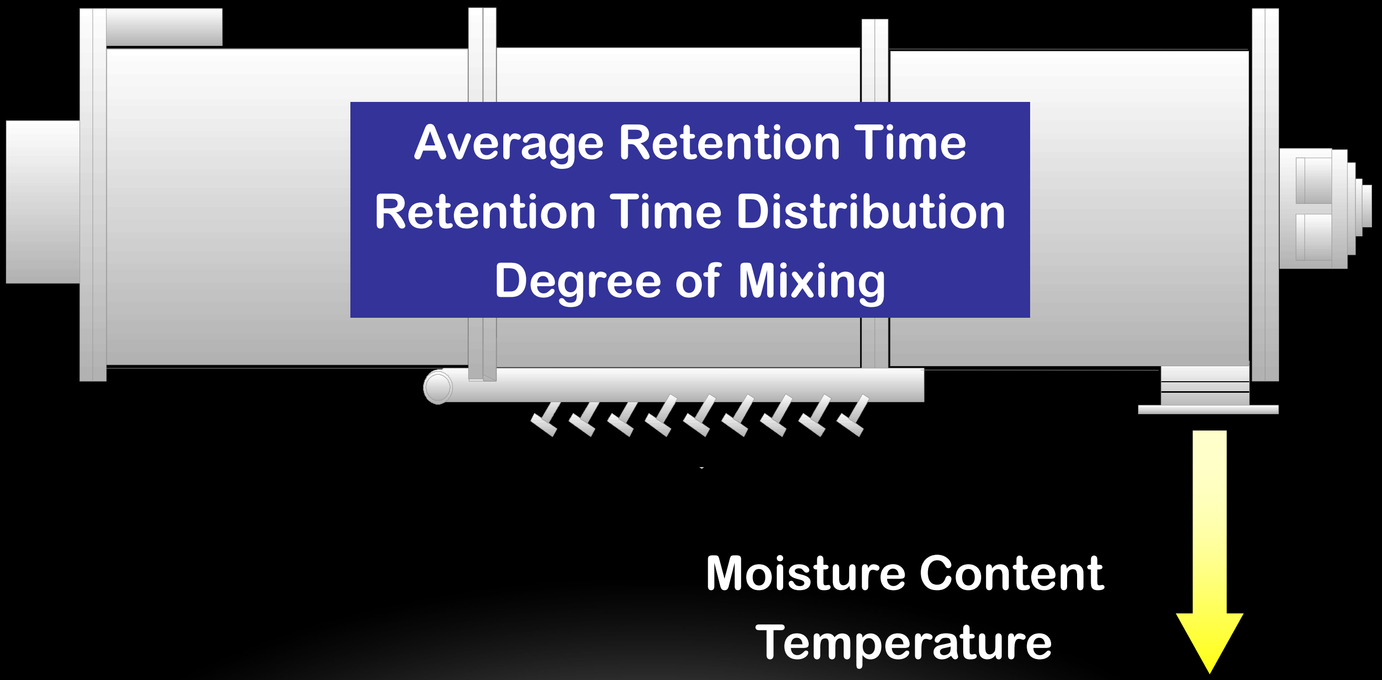
Preconditioner Operation Management
Independent Process Variables



Preconditioner Operation Management
Dependent Process Variables



Preconditioner Operation Management Dependent Process Variables

- Moisture Content
  - Water, Steam, Dry Feed, Additives
- Temperature
  - Water, Steam, Dry Feed, Additives
- Average Retention Time
  - Rate, Configuration, Speed
- Retention Time Distribution
  - Rate, Configuration, Speed
- Degree of Mixing
  - Rate, Configuration, Speed

Preconditioner Operation Management Critical Control Point Parameters

- Moisture Content
- Thermal Energy Input
- Retention Time

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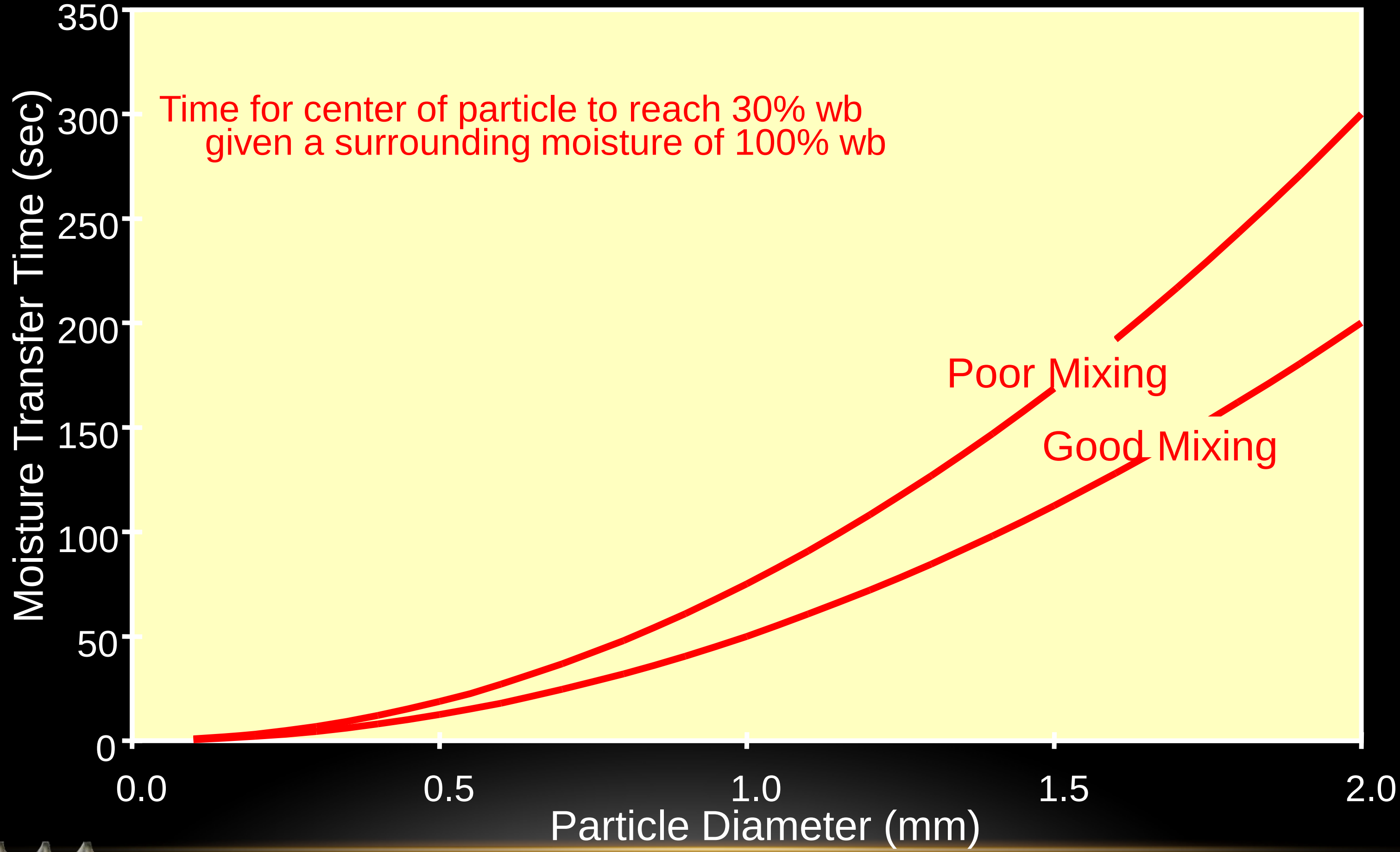
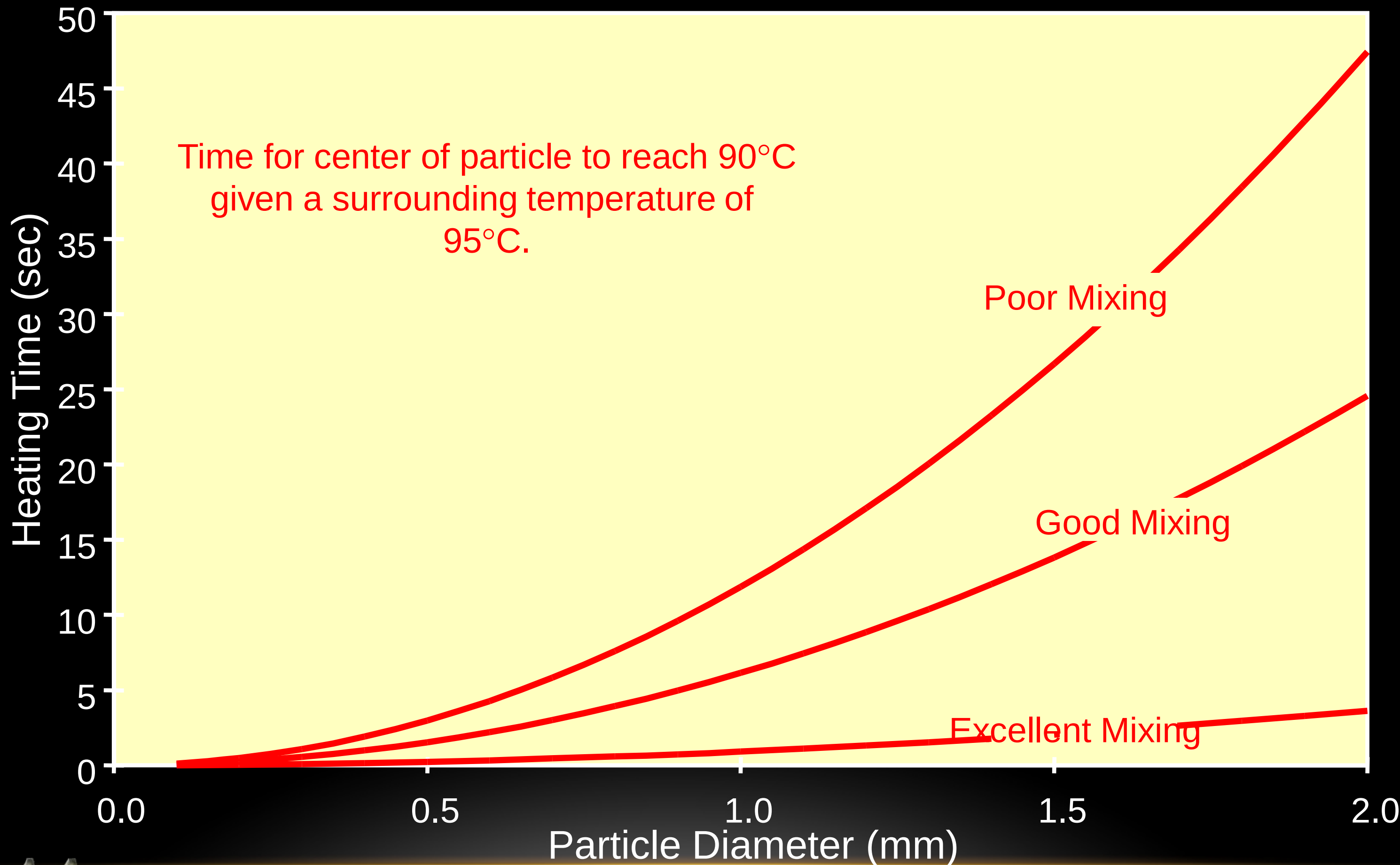
Preconditioner Operation Management
Water Absorption



Preconditioner Operation Management
Thermal Energy Transfer



Preconditioner Operation Management
Average Retention Time

$$\bar{t} = \frac{m}{\dot{m}} = \frac{\text{Amount retained at any given time}}{\text{Total flow rate through preconditioner}}$$

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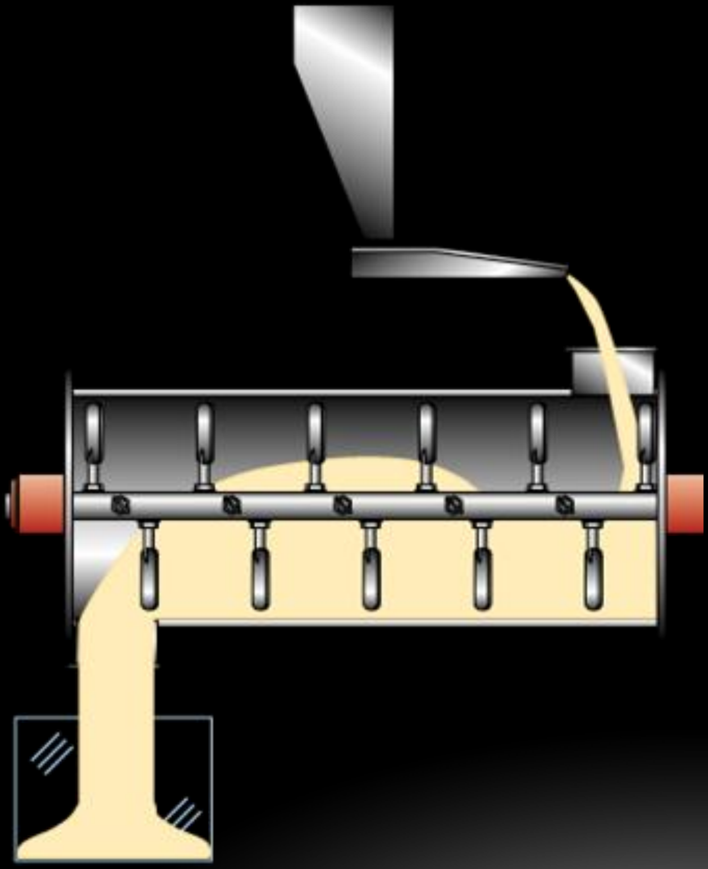
Preconditioner Operation Management
Average Retention Time



Operate preconditioner at steady state for some time, then measure or calculate the total flow rate.

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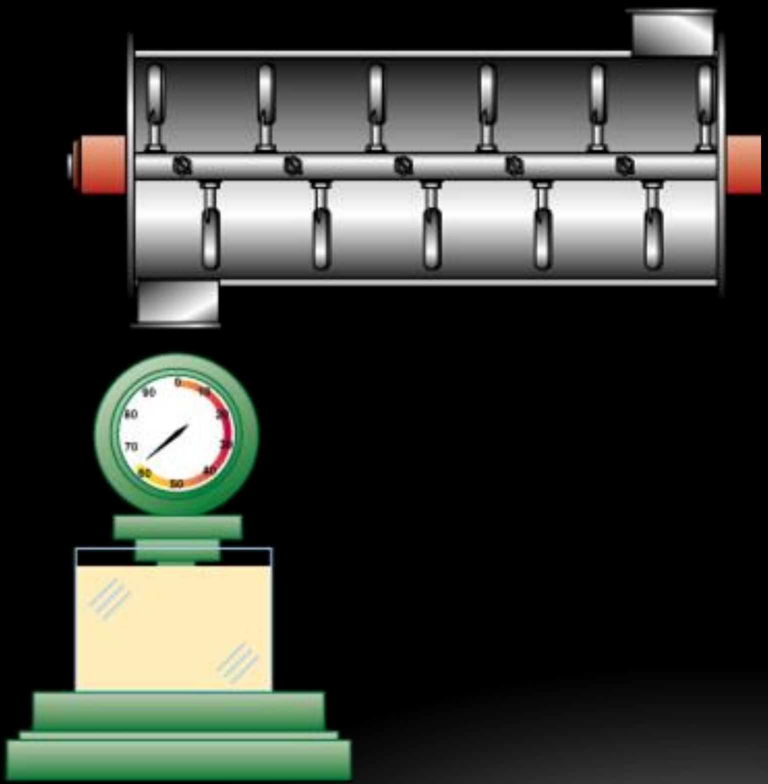
Preconditioner Operation Management
Average Retention Time

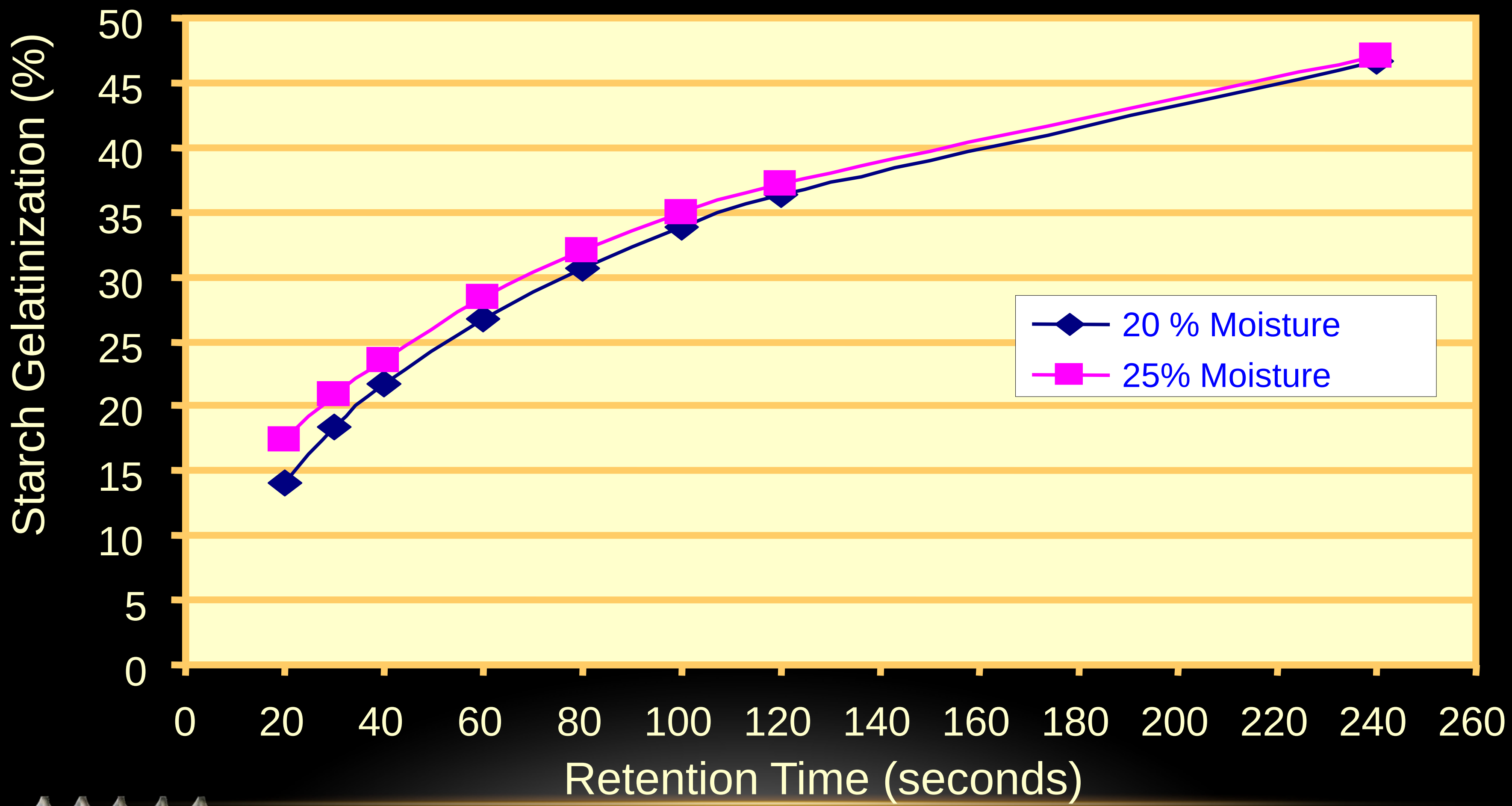


Dead stop all preconditioner functions, then empty and measure the material retained in the preconditioner.

Preconditioner Operation Management
Calculating Retention Time

$$\bar{t} = \frac{\text{Density X Fill Factor X Volume}}{\text{Feed Rate}}$$

Preconditioner Operation Management
Factors of Retention Time



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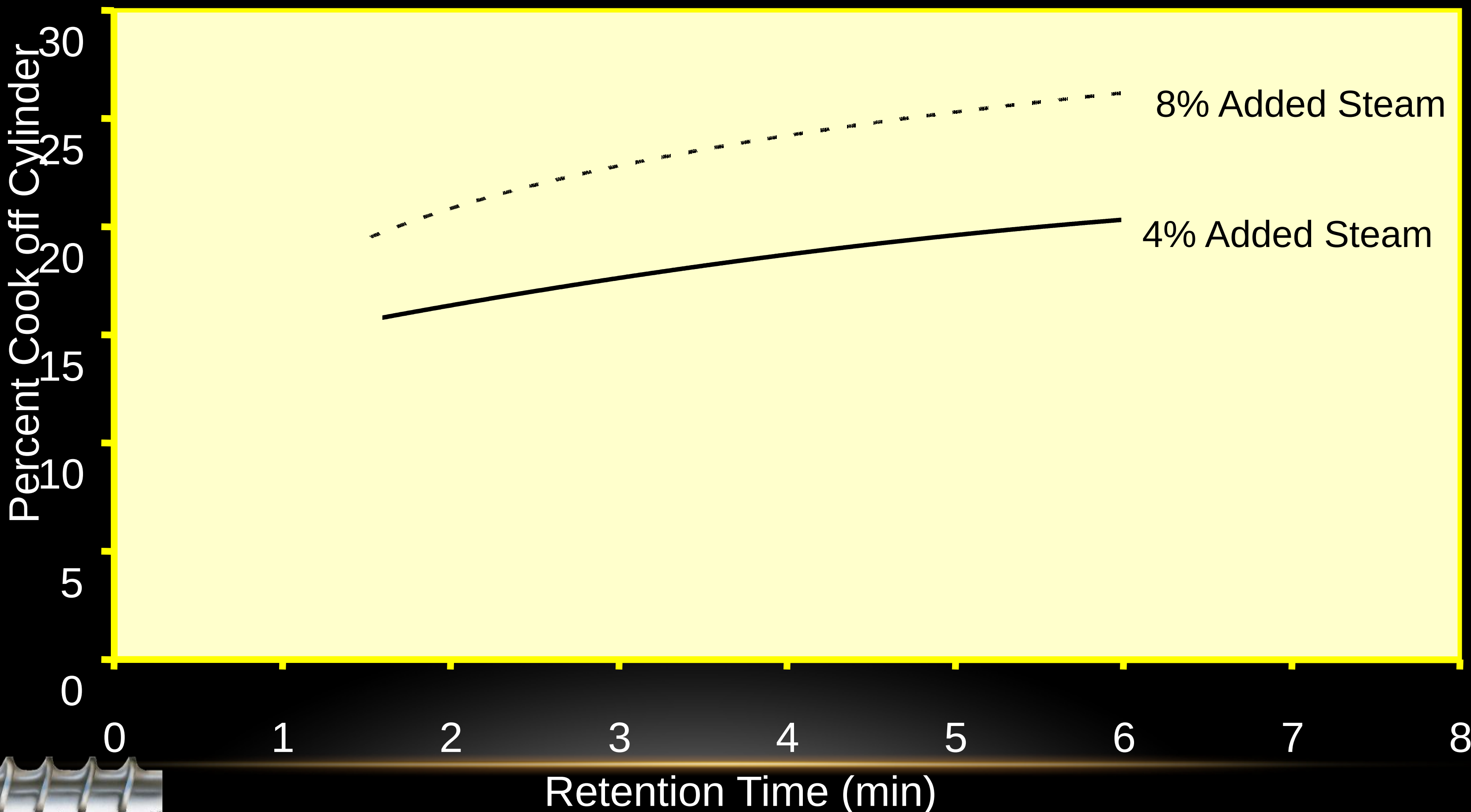
Preconditioner Operation Management
Factors of Retention Time



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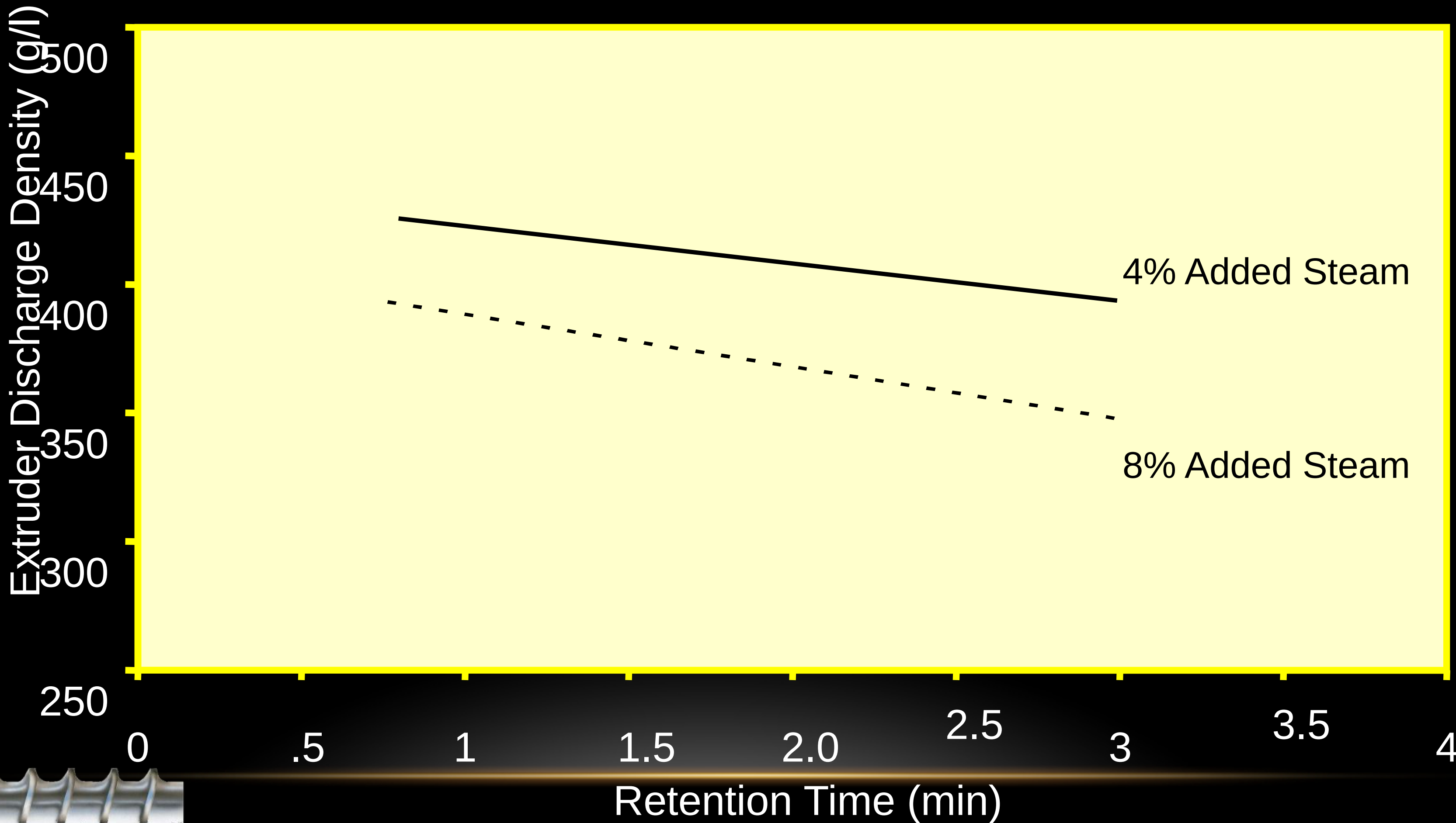
Preconditioner Operation Management
Factors of Retention Time



Preconditioner Operation Management Residence Time Distribution (RTD)

A measure of the retention time uniformity among the raw material particles as a whole.

FIFO – First In, First Out

The product that enters the preconditioner first, will be the first product out the discharge.

Defined and controlled by the mechanical setup of the hardware, except in cases where shaft speeds are controlled independent of each other.

Proper FIFO Action

6

5

4

3

2

1

Bin / Feeder

30 **Seconds of Retention Sample #6**

30 **Seconds of Retention Sample #3**

30 **Seconds of Retention Sample #1**

Preconditioner

Improper FIFO Action

6

5

4

3

2

1

Bin / Feeder

60 **Seconds of Retention Sample #5**

20 **Seconds of Retention Sample #3**

80 **Seconds of Retention Sample #1**

Preconditioner

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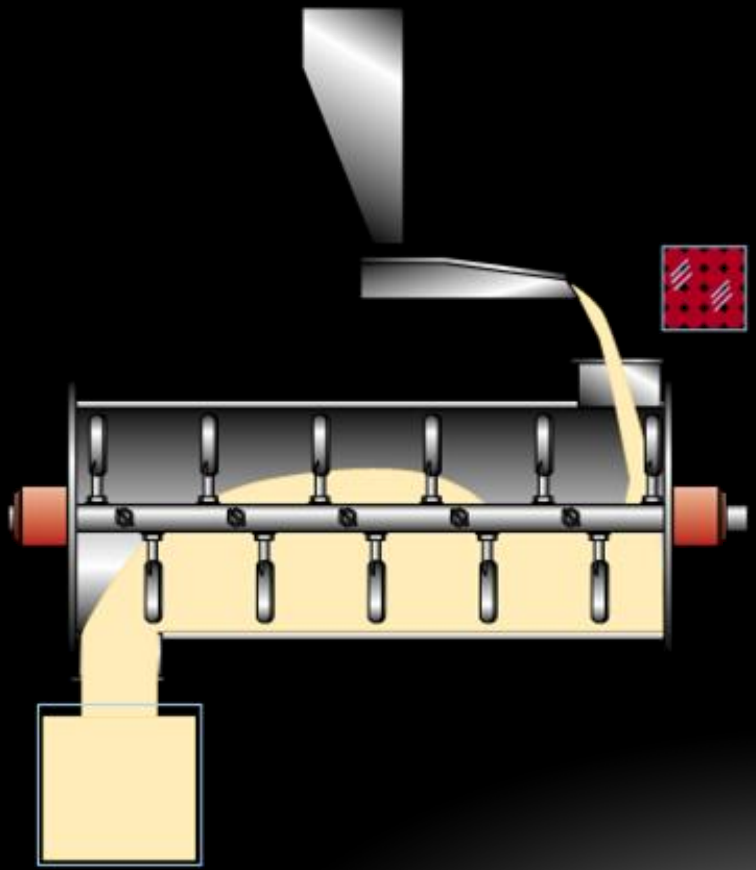
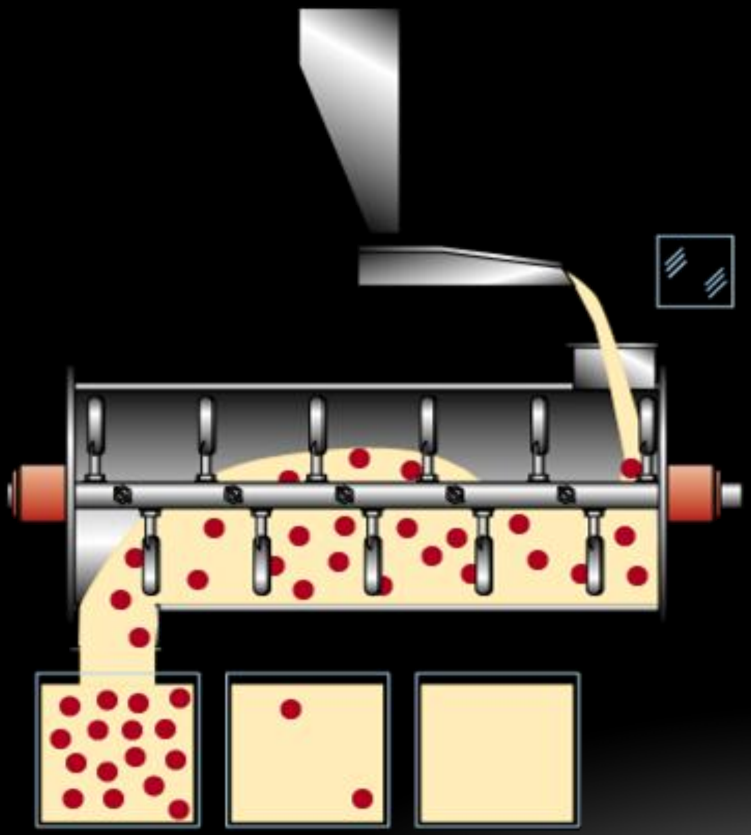
Preconditioner Operation Management
Residence Time Distribution



Operate preconditioner at steady state for some time.

Preconditioner Operation Management
Residence Time Distribution



At time zero, add a tracer and start collecting samples at specific intervals of time.

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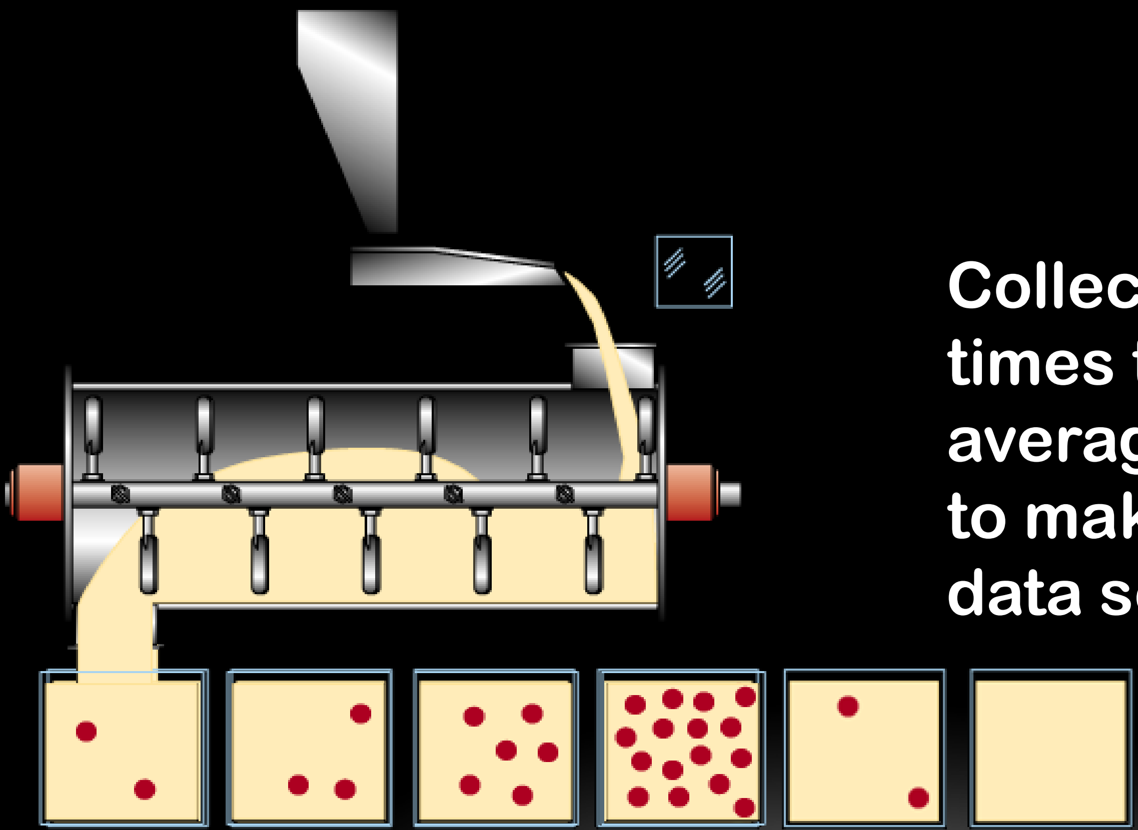
Preconditioner Operation Management
Residence Time Distribution



Collect samples for 2-3 times the expected average retention time to make sure a good data set is recorded.

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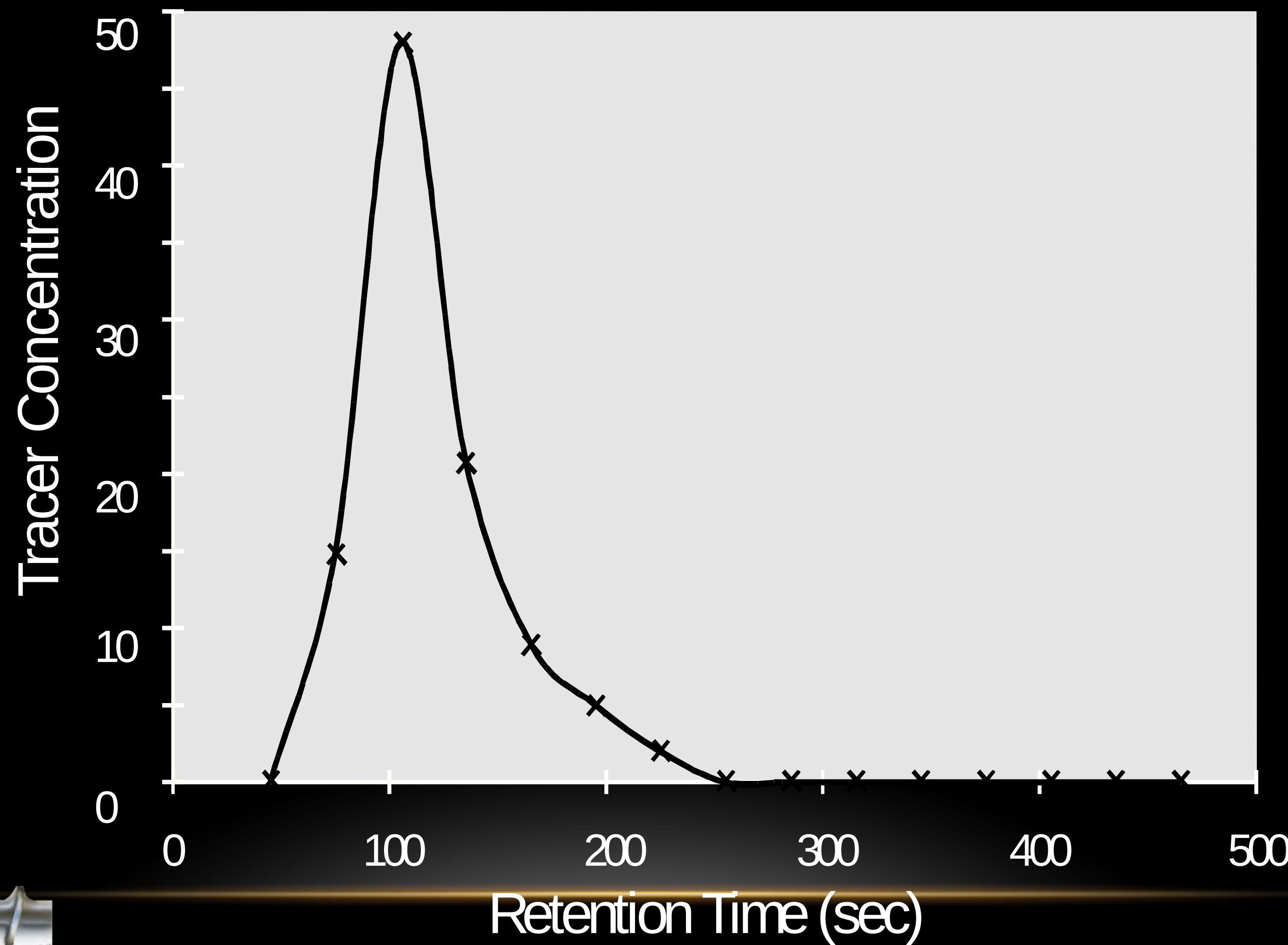
Preconditioner Operation Management
Residence Time Distribution Curve



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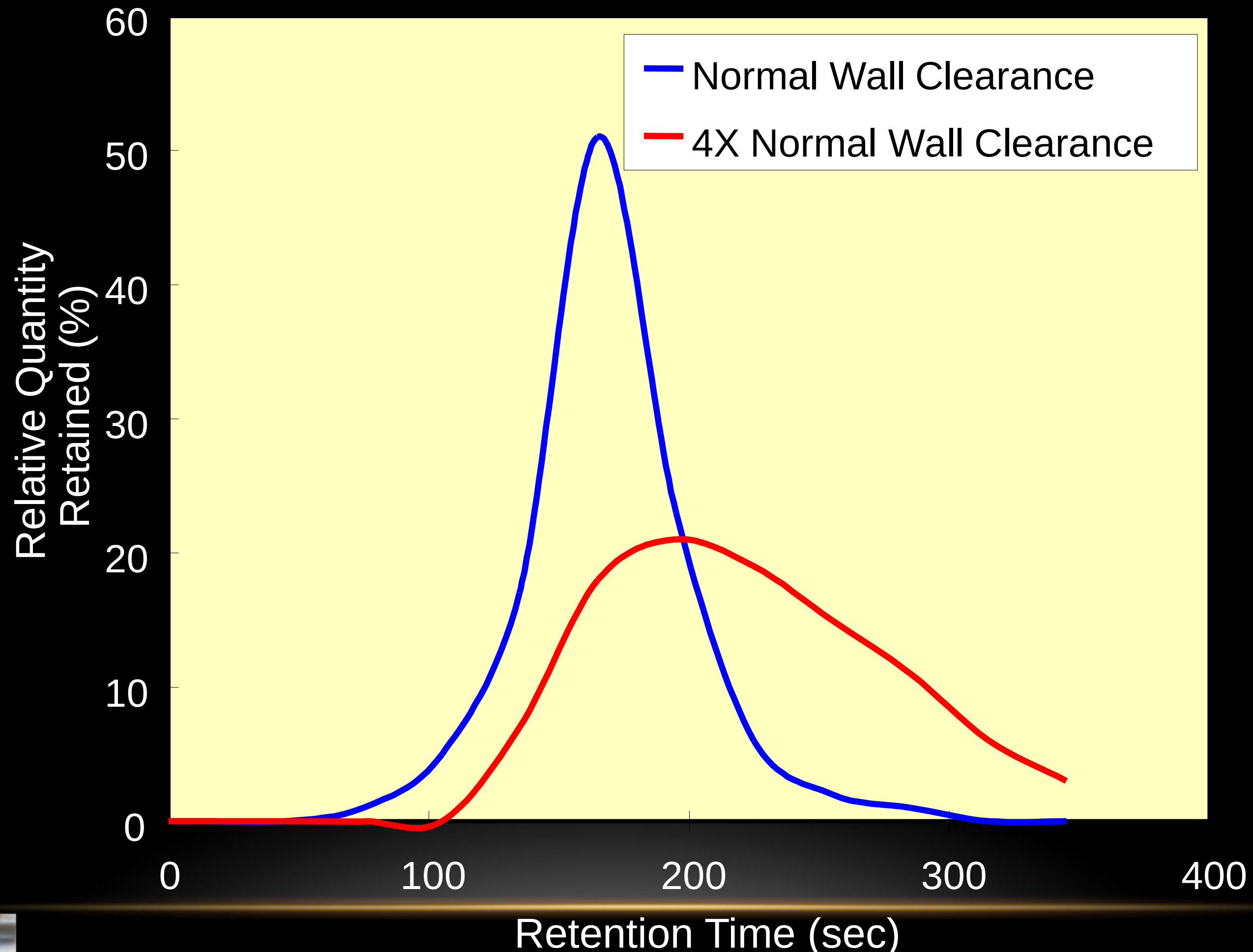
Preconditioner Operation Management
Effect of Wall Clearance on RTD



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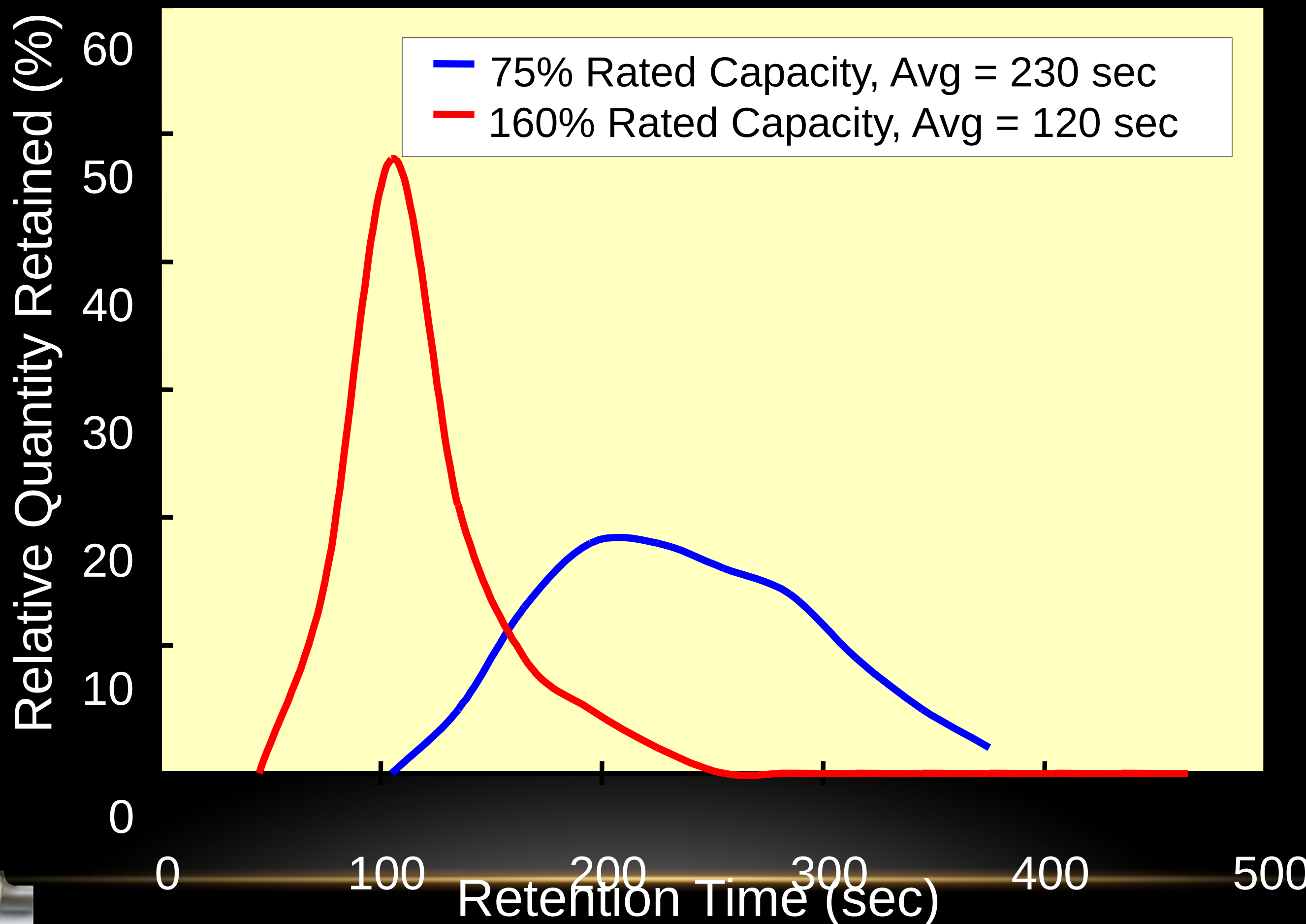
Preconditioner Operation Management
Effect of Capacity on RTD

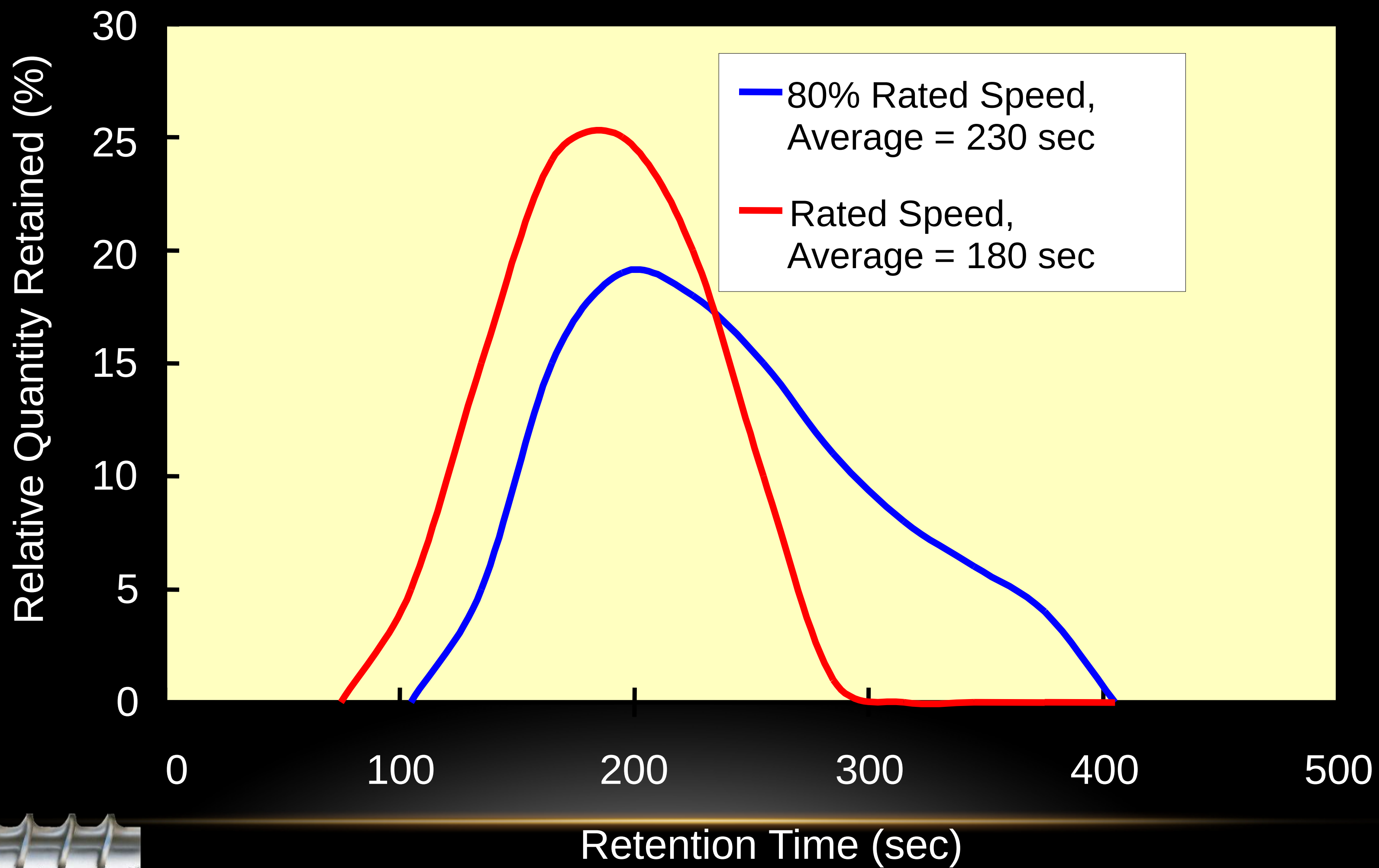


Preconditioner Operation Management
Effect of Speed on RTD

- Reduced speeds decrease mixing intensity
- Reduced speeds will broaden the Residence Time Distribution (RTD) curves.

Note: Reduced speeds will increase Average Retention Time.

Preconditioner Operation Management
Effect of Speed on RTD



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Performance and Efficiency Factors

- Ingredient size, shape, and density
- Sequence and ratio of ingredient additions
- Preconditioner fill level
- Preconditioner design
- Beater design and contacts/time (speed)
- Retention time and residence time distribution
- Mixing energy (power and duration)
- Component wear
- Feed Rate

Measuring Performance

Mean (Average)

- The expected result of any one particular sample.
- Sum of all the data points, divided by the number of data points

Standard Deviation

- The measure of the spread in a set of data points
- How widely spread are the values from the Mean

Coefficient of Variance

- The degree to which a set of data points varies
- How close are the data points to one another

Benefits of Proper Preconditioning

- Higher level of gelatinization (cook)
- Destruction of Pathogens / Growth Inhibitors
- Improved moisture penetration
- Improved heat transfer
- Improved mixing of solid-liquid ingredients
- Decreased extruder friction/wear
- Higher extruder capacities
- Lower extruder loads
- Improved digestibility / palatability of product

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Effect of Preconditioning on Microbial Populations

Microbe	Raw Recipe	Post Preconditioning
TPC (CFU/g)	240,000	9,300
Coliform	22,600	<10
Mold count	54,540	<10
Clostridium	16,000	<10
Listeria	Positive	Negative
Salmonella	Negative	Negative

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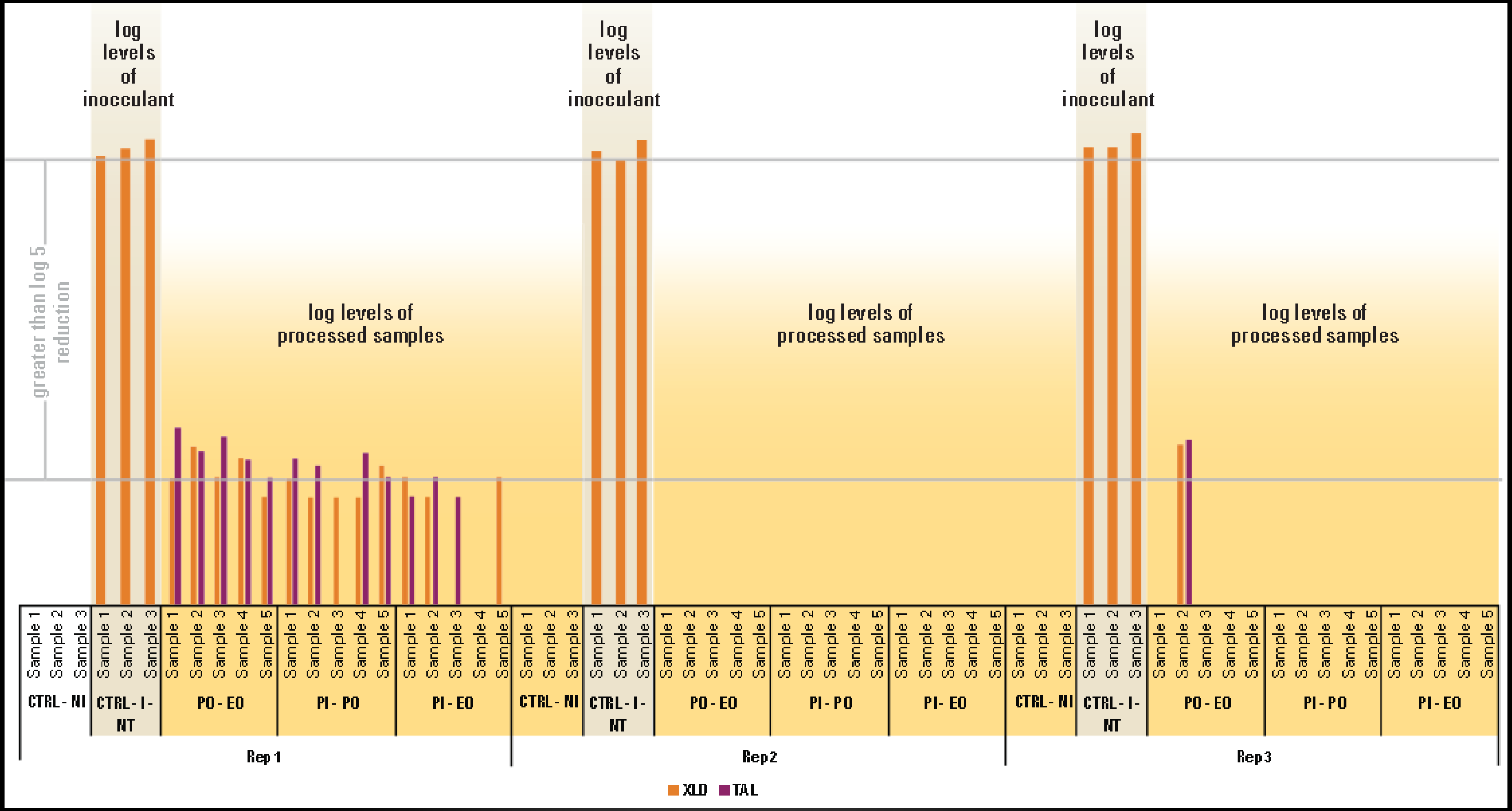
Effect of Preconditioning on Microbial Populations



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Preconditioning and Extruder Wear Cost

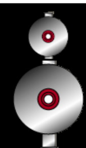
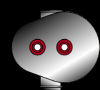
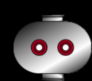
System	Wear Cost ($/Ton)	Screw Life (Hours)
w/o Preconditioning	0.9358	3,000
w/ Preconditioning	0.4319	6,500

AT 11 TONS/HR ---- $40,000 (USD) PER YEAR SAVINGS

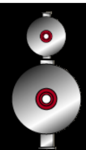
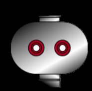
Preconditioner Design Comparison

Type	Actual Free Volume (m^3)	Silhouette Size (m^3)	Access Doors	RTC
Dual Stage	1.0	8.0	2	No
DDC/HIP	1.3	6.4	6	Yes
ADP	1.52	7.0	2	Yes
SCC	.5	7.0	2	Yes

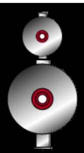
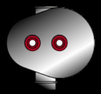
Preconditioner Design Comparison

Type		Mixing Intensity Hits/120 sec	Product Build-Up	Mixing Design
Dual Stage		14,784	Excessive	Single Shaft
DDC/HIP		36,000	Negligible	2 Diff. Speed/Diameter Inter-meshing Shafts
ADP		35K – 57K	Negligible	2 Var. Speed Inter-meshing Shafts
SCC		17K – 28K	Negligible	Single Var. Speed Shaft

Preconditioner Design Comparison

Type		Pros	Cons
Dual Stage		•High Retention •Simple Design	•Higher Cost •Poor Mixing •Sanitation •Higher Maintenance
DDC/HIP		•Good Mixing •Good Retention •High Capacity	•Highest Cost •Highest Maintenance •Complex Design
DCC		Low Maintenance •Good Mixing •Good Retention •High Capacity •Simple Design	•Medium Cost
SCC		•Lower Cost •Lower Maintenance •Simple Design	•Short Retention Times •Low Mixing

Preconditioner Design Comparison

Type		Specifications
Dual Stage		•Up to 5 minutes retention •Up to 4% fat •Limited levels of fresh meat
DDC/HIP		•1.5 – 3 minutes retention •Up to 20% fat •Up to 40% fresh meat
DCC		•1 - 2.5 minutes retention •Up to 16% fat •Up to 20% fresh meat
SCC		•30 seconds retention time •Up to 4 % fat •Limited levels of fresh meat

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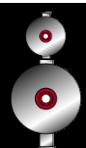
Preconditioner Design Comparison

Type		Specifications
Dual Stage		No Data Available
DDC/HIP		•Standard and specialty pet foods/treats •Most floating/sinking aquatic feeds •TVP •High meat/fat injection
DCC		•Standard and specialty pet foods/treats •Most floating/sinking aquatic feeds •TVP •High meat/fat injection
SCC		•Some low fat floating/sinking aquatic feeds •Pelleted feeds •Limited ingredient flexibility

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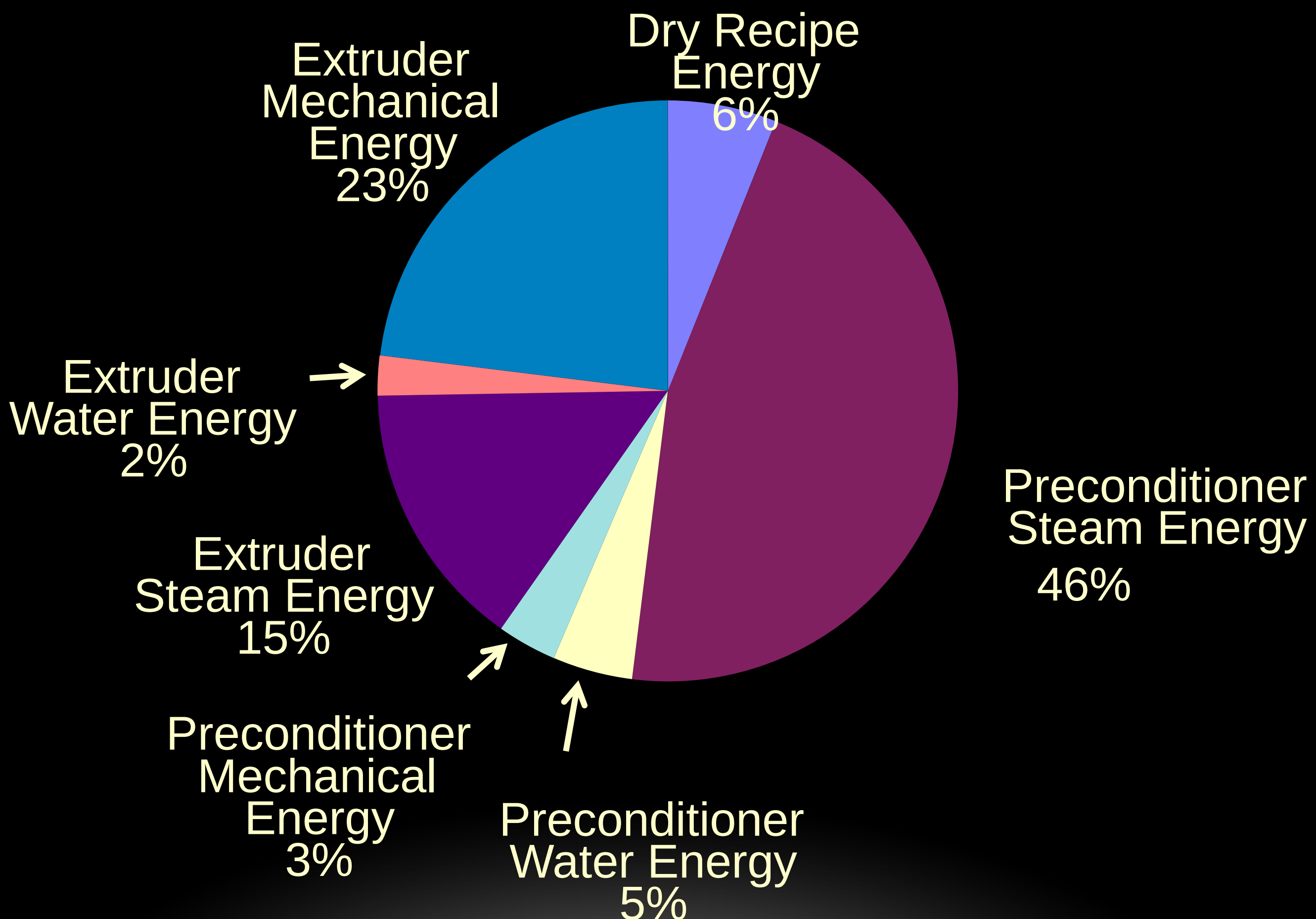
System Energy Analysis



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Questions?

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