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# Continuous ResonantAcoustic® Production of Energetic Material

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*Process Development Engineer*



Building Value through  
Discovery and Innovation®

# Project Overview

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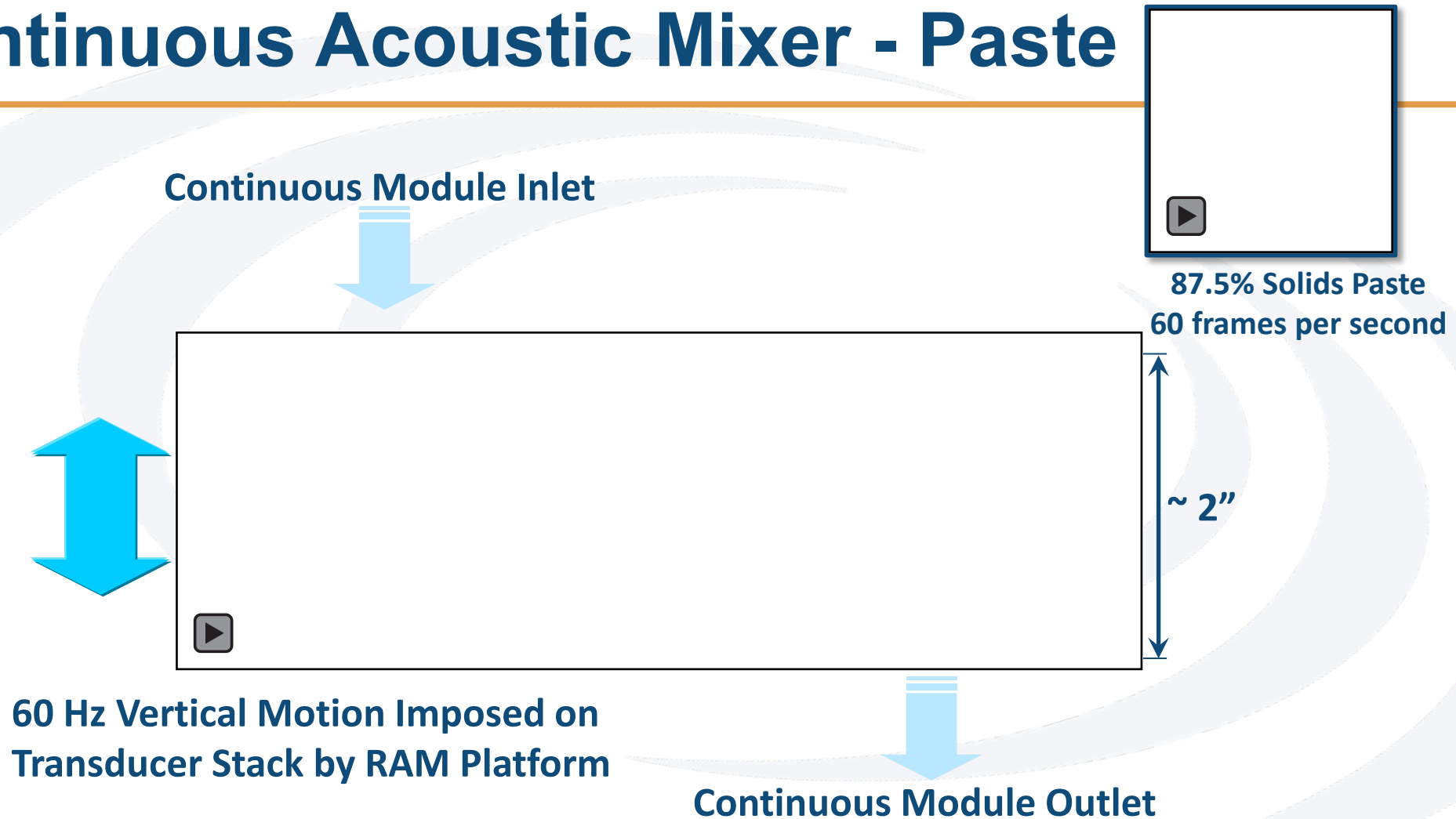
## Objectives

- **Design, Fabricate and Test an Energetics Rated Continuous Acoustic Mixing – Clean In Place (CAM-CIP) system**
- **Demonstrate Energetic PBX Production at NAWCWD China Lake Using the Energetics Rated CAM-CIP system**

## Results

- **CAM-CIP Module Completed and Tested**
- **Testing of Energetics Rated Ancillary System Ongoing**
- **Expect to Produce Energetic PBX Material once set up at China Lake**

# Continuous Acoustic Mixer - Paste



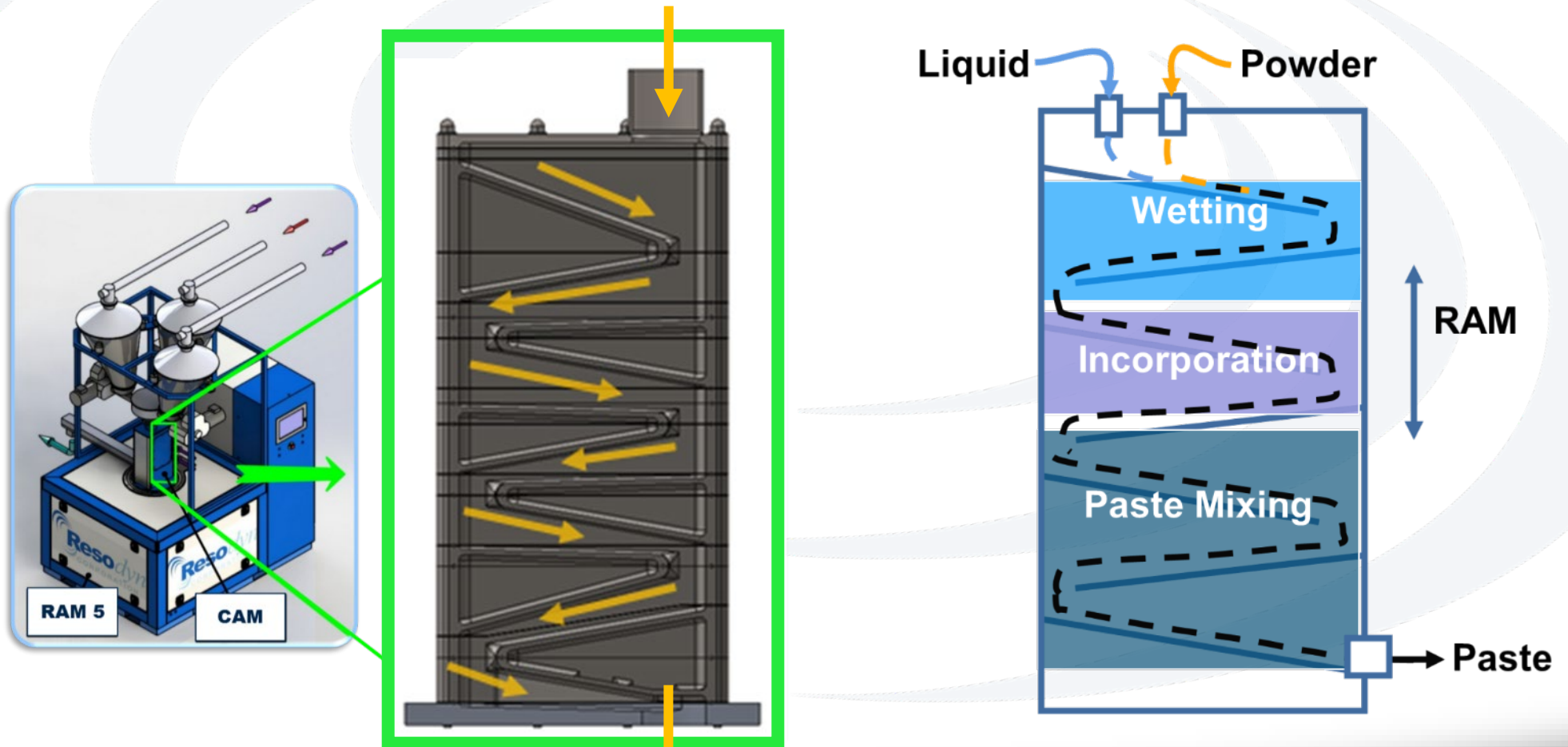
60 Hz Vertical Motion Imposed on Transducer Stack by RAM Platform

Upper and Lower Acoustic Transducers Continuously work on the Materials being Mixed

Unclassified. Distribution Unlimited.

# Continuous Mixing Schematics

## Continuous Acoustic Mixer (CAM)



Unclassified. Distribution Unlimited.

# Mixing Pastes Continuously

## CAM-CIP for RAM 5

- Paste Viscosities:  $>1,000,000$  cP at Room Temperature
- Tested at: 3.0 kg/min or 180 kg/hr



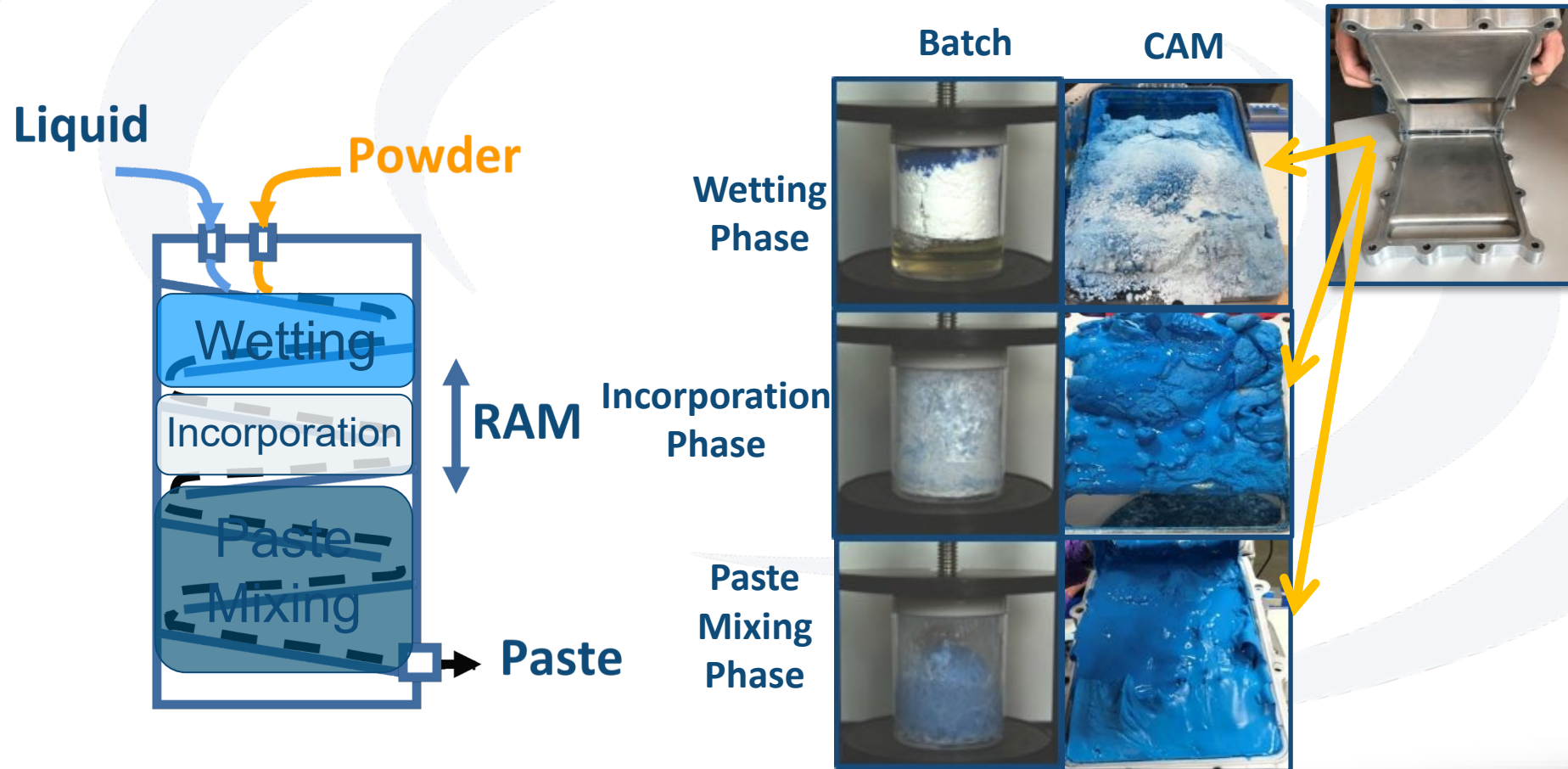
## Continuous Mixing System



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# Continuous Module Mix Regimes

Mix Regimes are the Same within the CAM as in Batch



# Characterization of the CAM-CIP

Test	Solids Loading %	Acceleration G	Flow Rate gm/min	Solids Loading Range %
1	92.6	60	932	0.4097
2	92.6	80	932	3.175
3	88.6	70	535	1.044
4	89.0	60	970	0.5808
5	89.0	80	970	0.6595
6	86.0	70	1,500	0.00989
7	87.5	60	1,760	0.1824
8	89.0	70	2,500	0.1230
9	87.5	80	2,500	0.5012
10	86.0	60	2,500	0.4531
11	87.5	70	1,250	0.1617

# Plastic Bonded Surrogate Explosive Paste

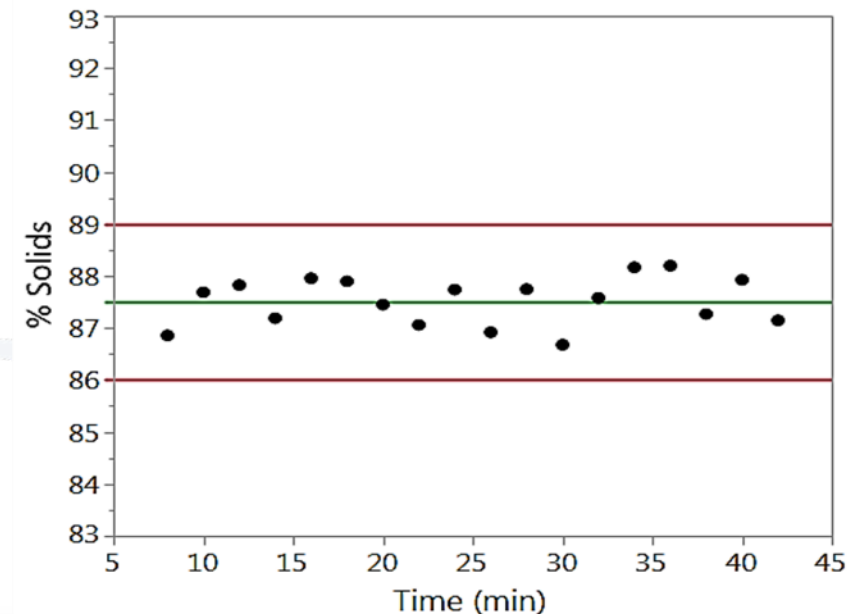
## Regression Analysis:

- JMP Software was utilized
- All source interactions are statistically significant
- The interaction between solids loading and acceleration is the most significant

## Mixed material was tested for consistency using:

- Thermal Gravimetric Analysis

Source Interactions	p-value
Solids Loading (%)	0.0233
Acceleration (g)	0.0408
Flow Rate (gm/min)	0.0150
Solids Loading (%), Acceleration (g)	0.0016
Solids Loading (%), Flow rate (gm/min)	0.0236
Acceleration (g), Flow Rate (gm/min)	0.0264

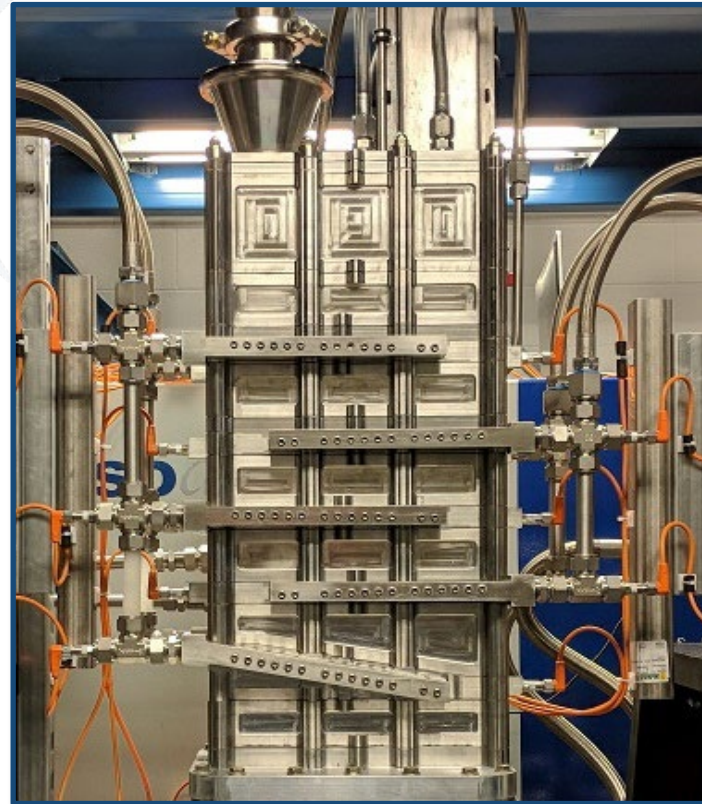




# Temperature Control – Heating or Cooling

## Embedded Heat Transfer Channels within CAM Modules

Through Plate Channels  
For Cooling, or Heating  
Fluids

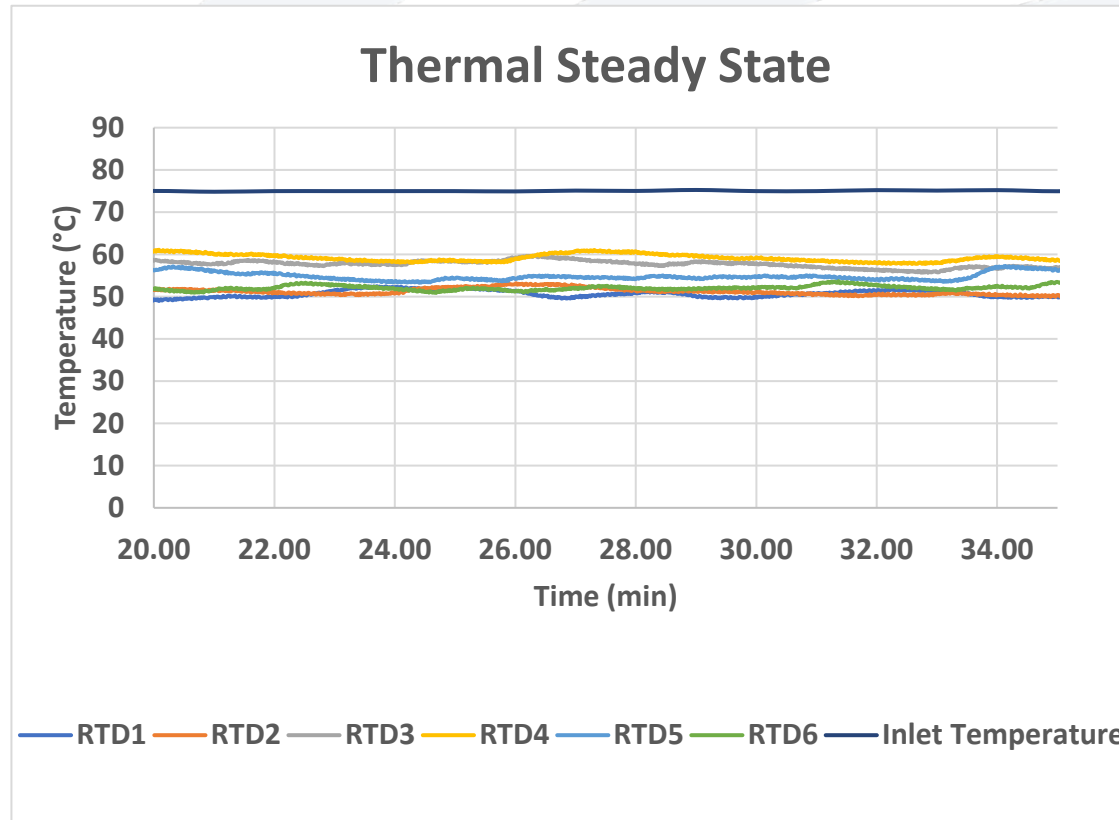


Temperature  
Control Manifolds

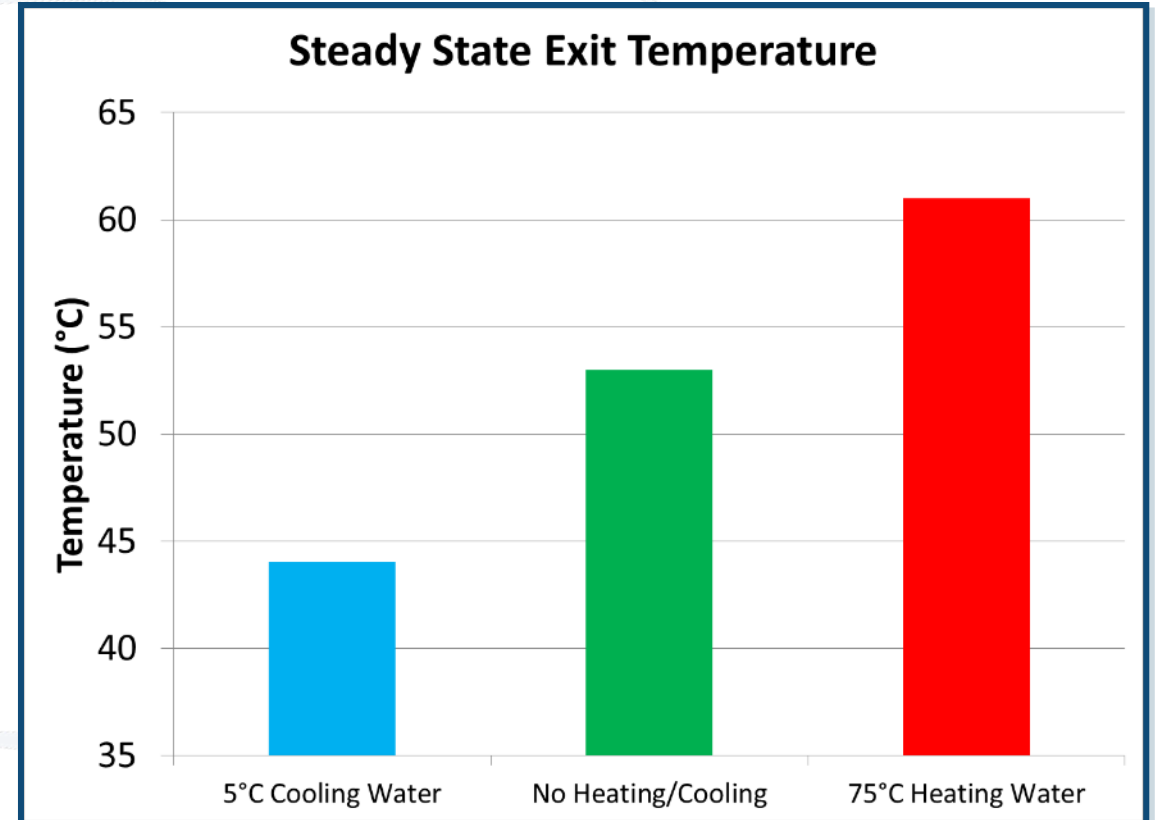
Thermowells  
Several Plate  
Locations to Measure  
Mix Temperature Progress  
Through the Stack

# CAM-CIP Temperature Control

## Thermal Steady State



## Steady State Exit Temperature



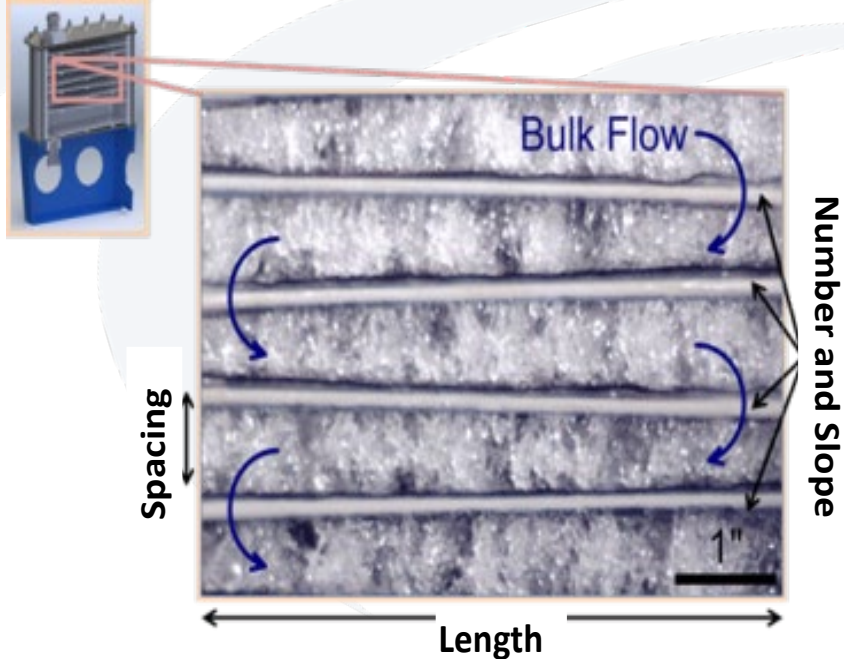
# Clean-in-Place (CIP)

## Current Typical Batch Cleaning

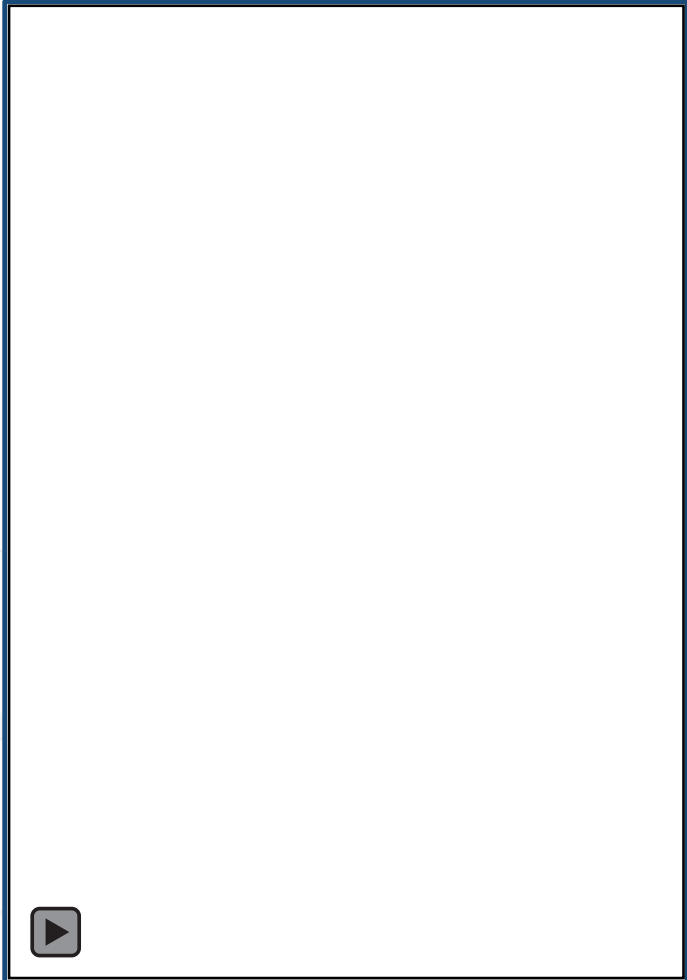
- **Uses Organic Solvents**
  - **Hazardous Air Pollutants (HAP)**
  - **Exposure source for workers**
- **Creates Waste**
  - **Residual material  $\approx$  5% by mass**
  - **Cleaning supplies and PPE  $\approx$  10% by mass**



# Clean-in-Place (CIP)



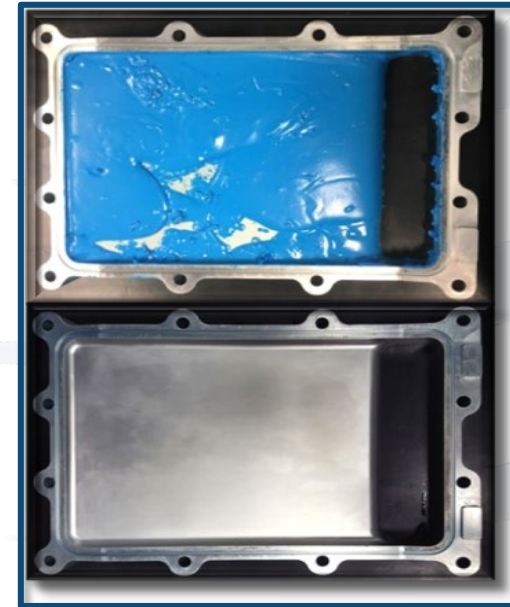
**Prototype CAM Processing  
Water and Air**



# CAM Clean in Place (CIP)

- Cleaning Inert PBX Surrogate from CAM using Clean-in-Place
- 5 kg of Material Wasted
- Less than 9 L of Aqueous Waste
- 100% Removal Efficiency Achieved

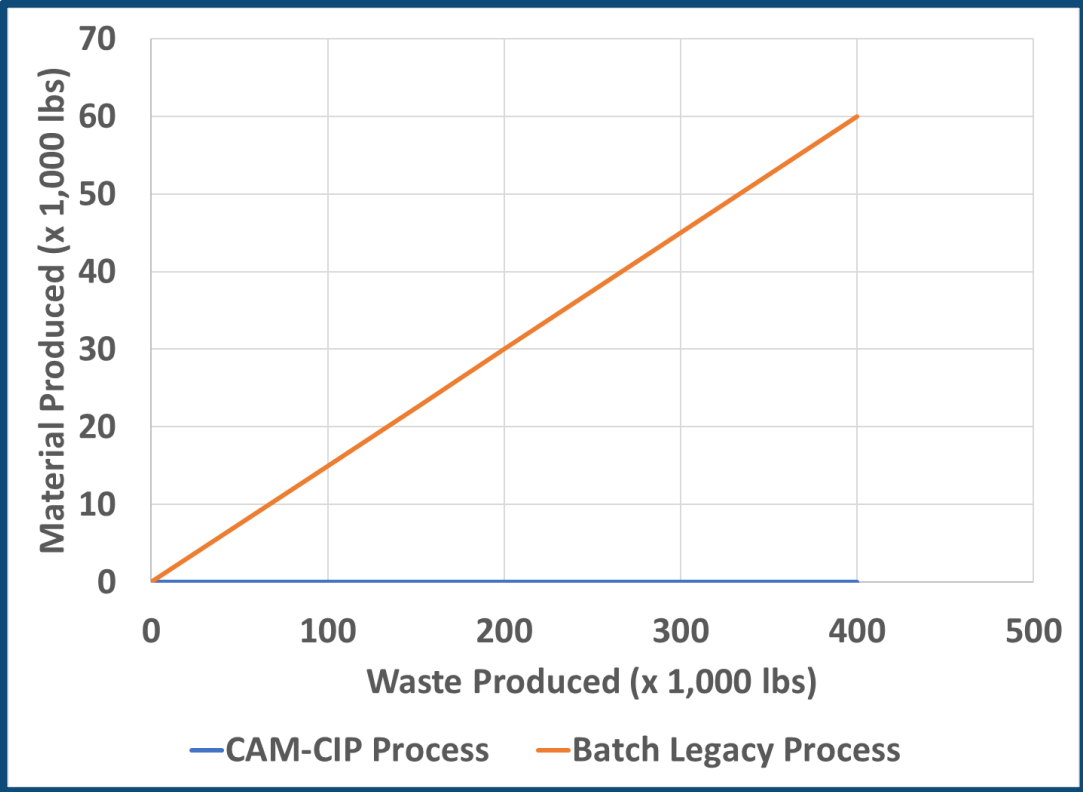
After Runout  
Before Cleaning



After Clean-in-Place

# RAM CIP Results in Less Waste

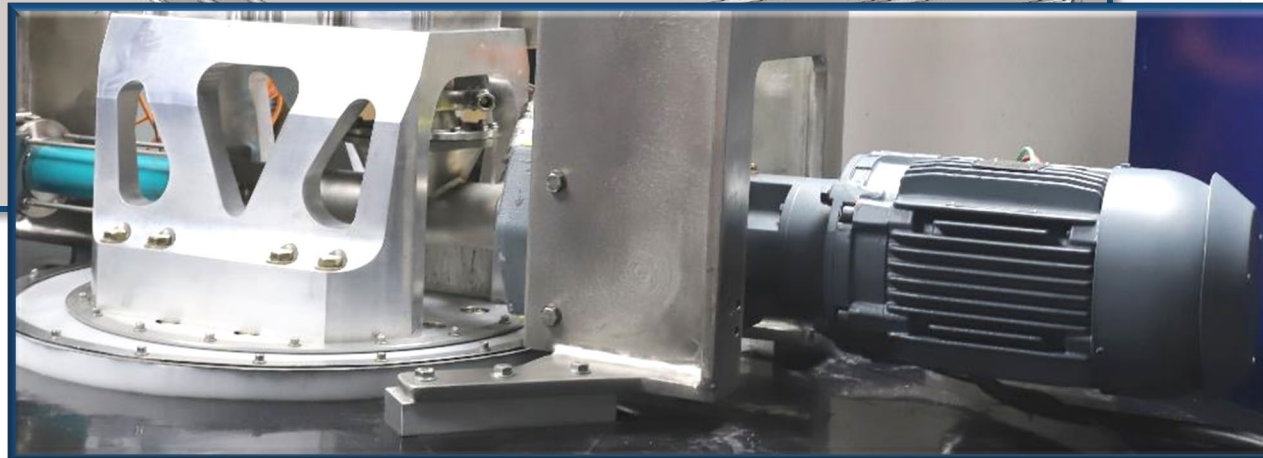
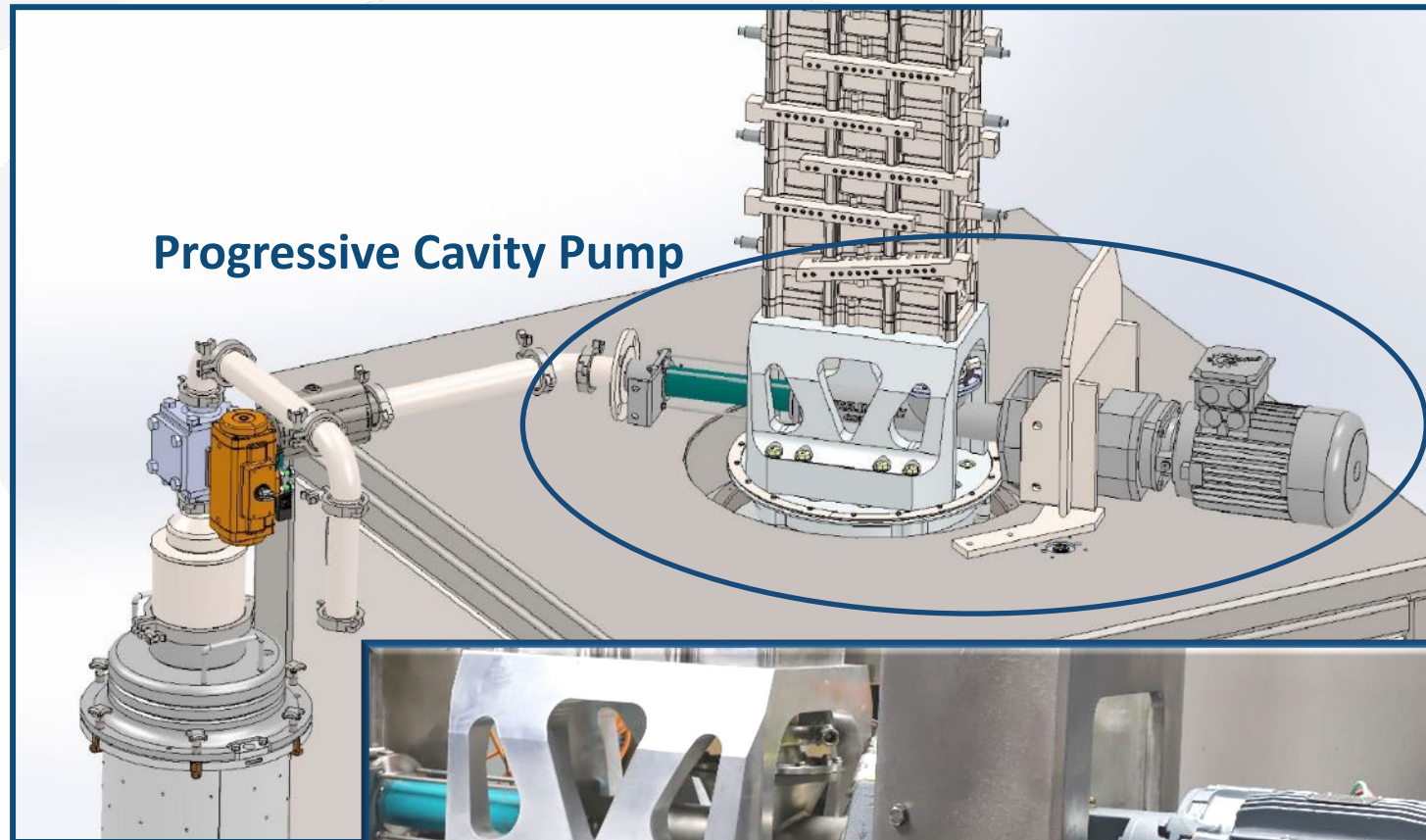
- Waste Produced is Independent of Run Time
- No Material is Wasted Due to Batch Overrun



# Transition to an Operational Environment



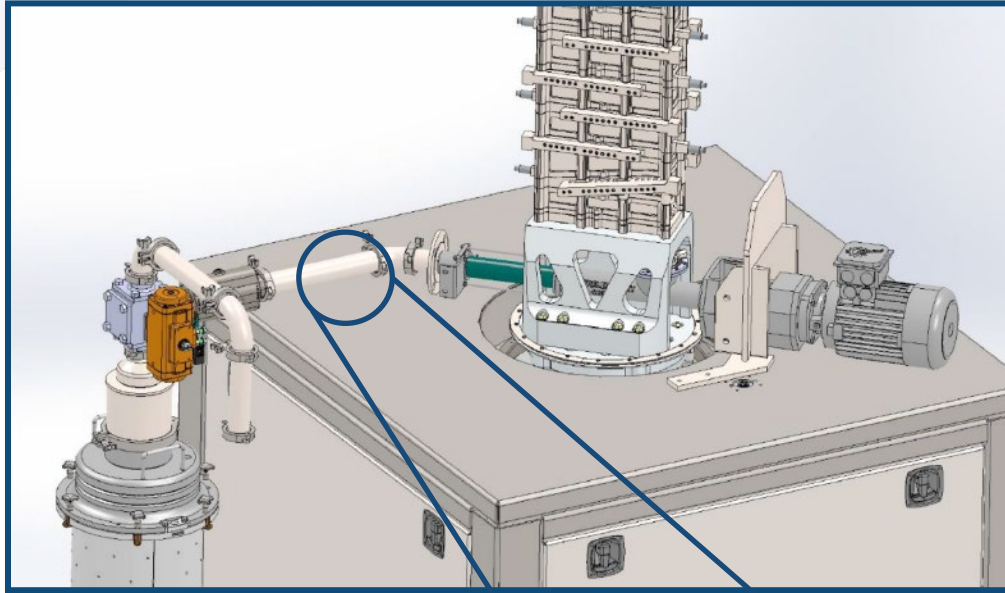
# Material Transport



Unclassified. Distribution Unlimited.

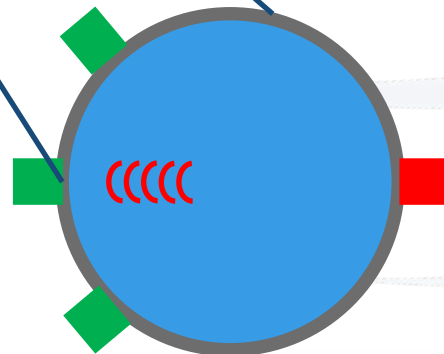


# Mixedness Sensor



One Transmitter and One Receiver can Measure Composition and Mixedness by analyzing the Time of Flight Against a Standard and to Each Other

Ultrasonic Receiver

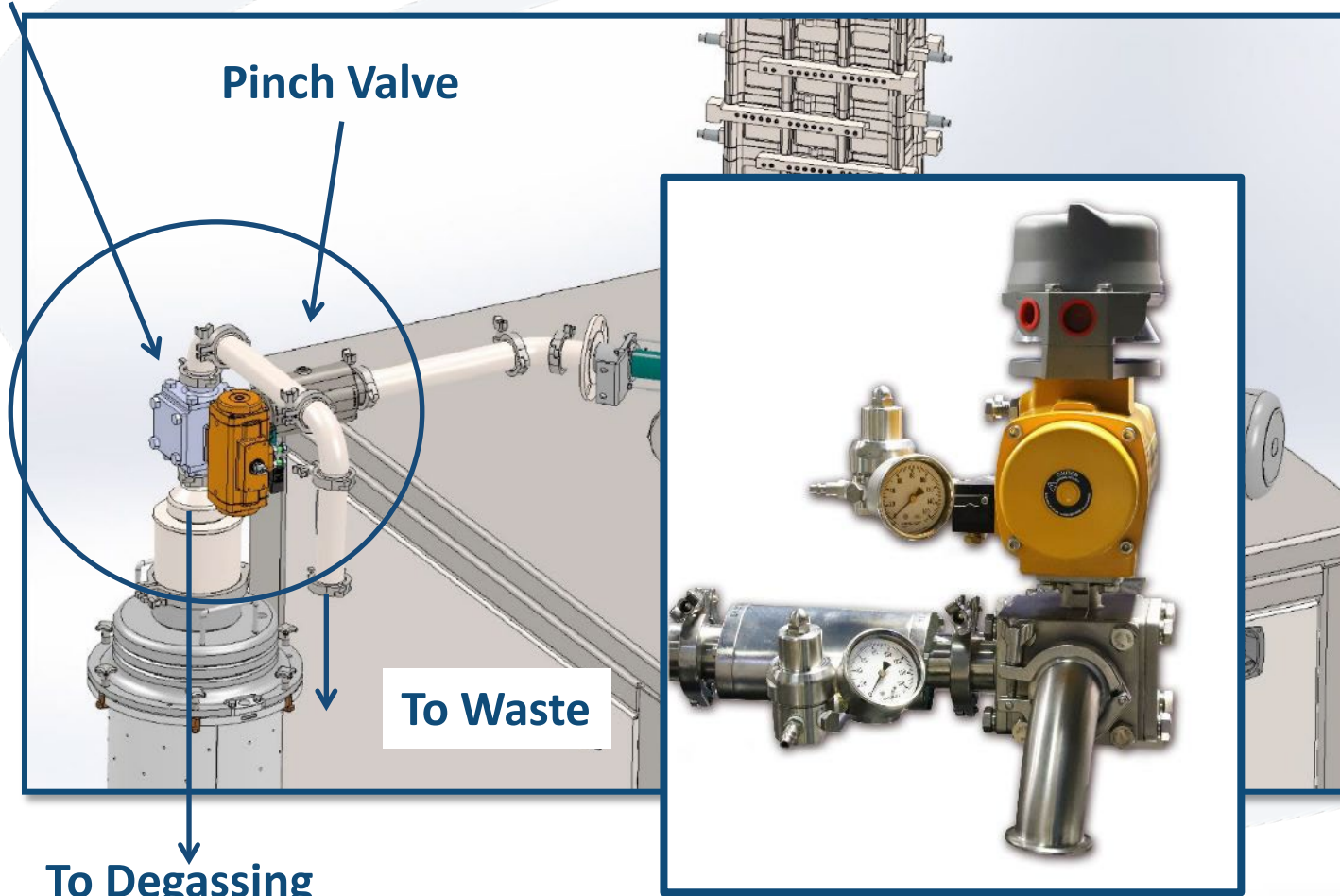


Ultrasonic Transmitter

# Automatic Diversion System

3-Way Valve

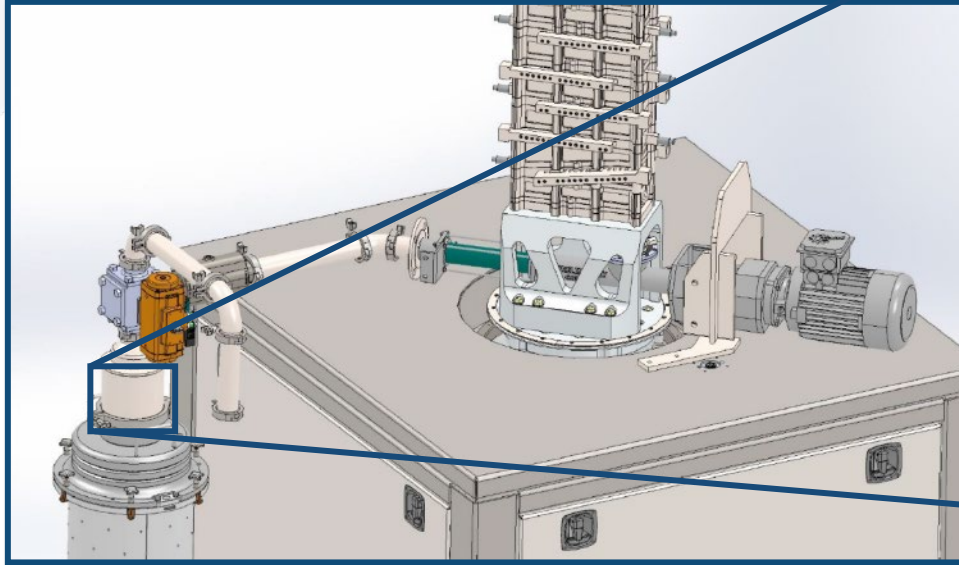
Pinch Valve



To Waste

To Degassing

# Continuous Degassing System



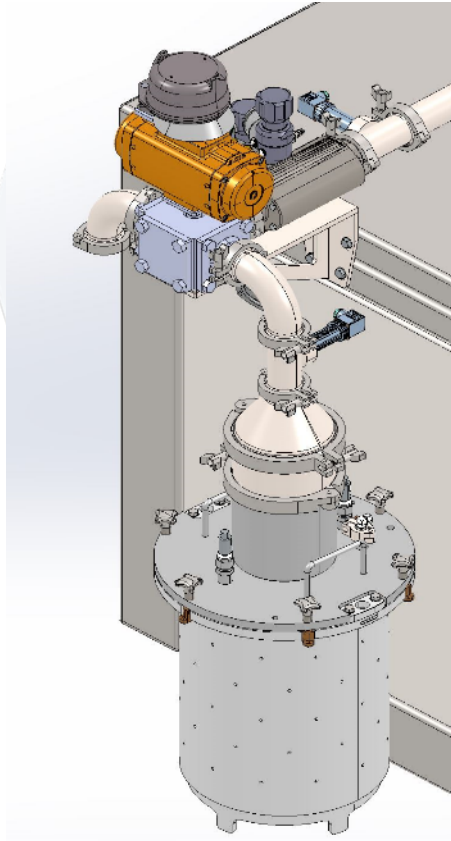
**Adequate Surface Area  
for Production Rate**

**Spacing to Allow Strand  
Expansion**

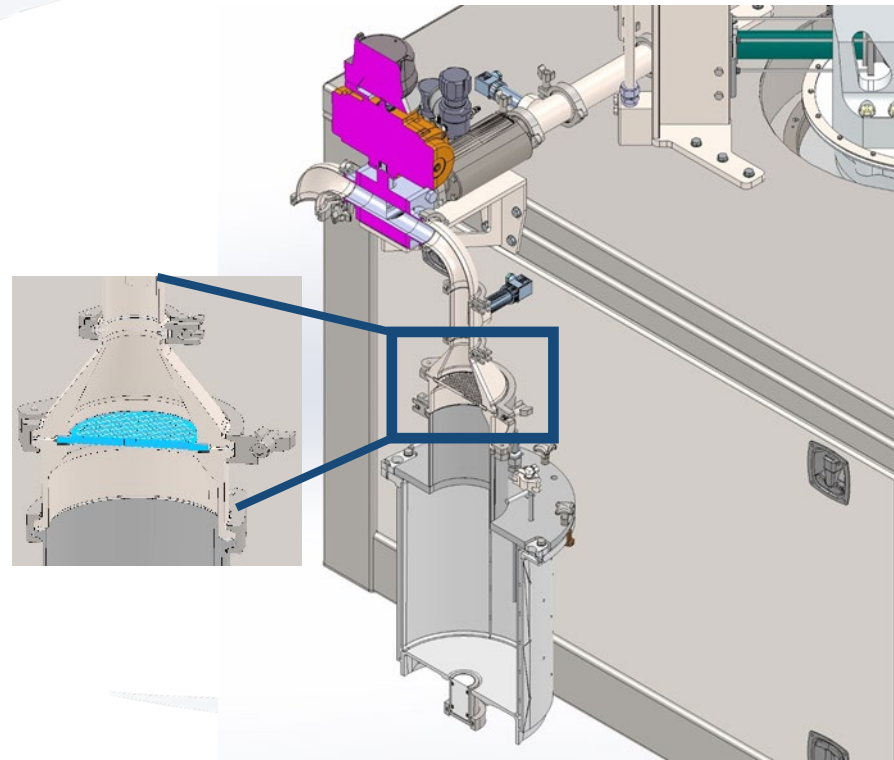


# Continuous Degassing System Assembly

## View of Degas Assembly



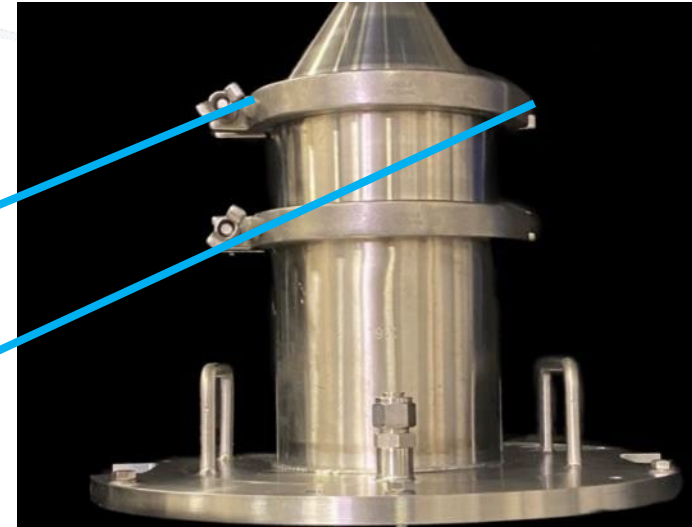
**Degassed Mix Material  
Collection Vessel**



**Cross-section View of Degas  
Assembly**

# Continuous Mixed Material Degassing System in Operation

Degas Strainer Assembly



Degas System in Operation

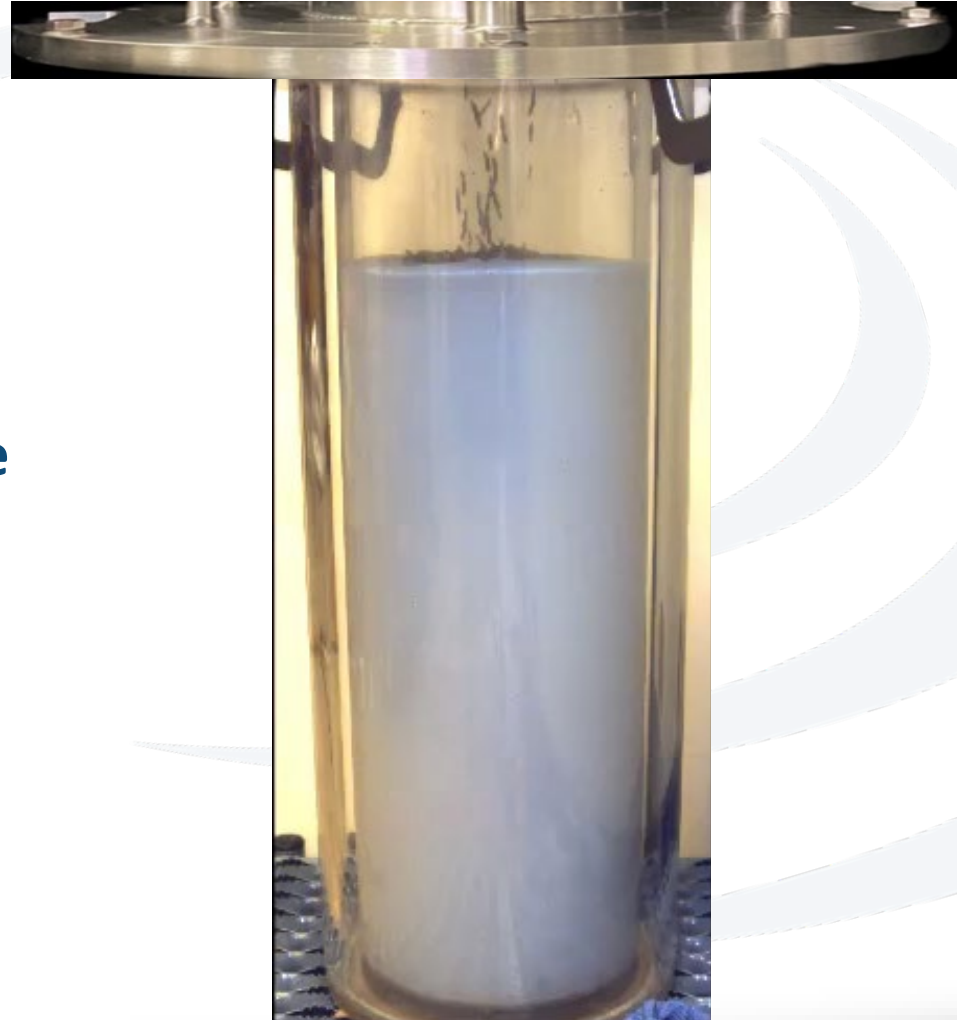
Acrylic Cylinder Inside  
Diameter 7.5 inches



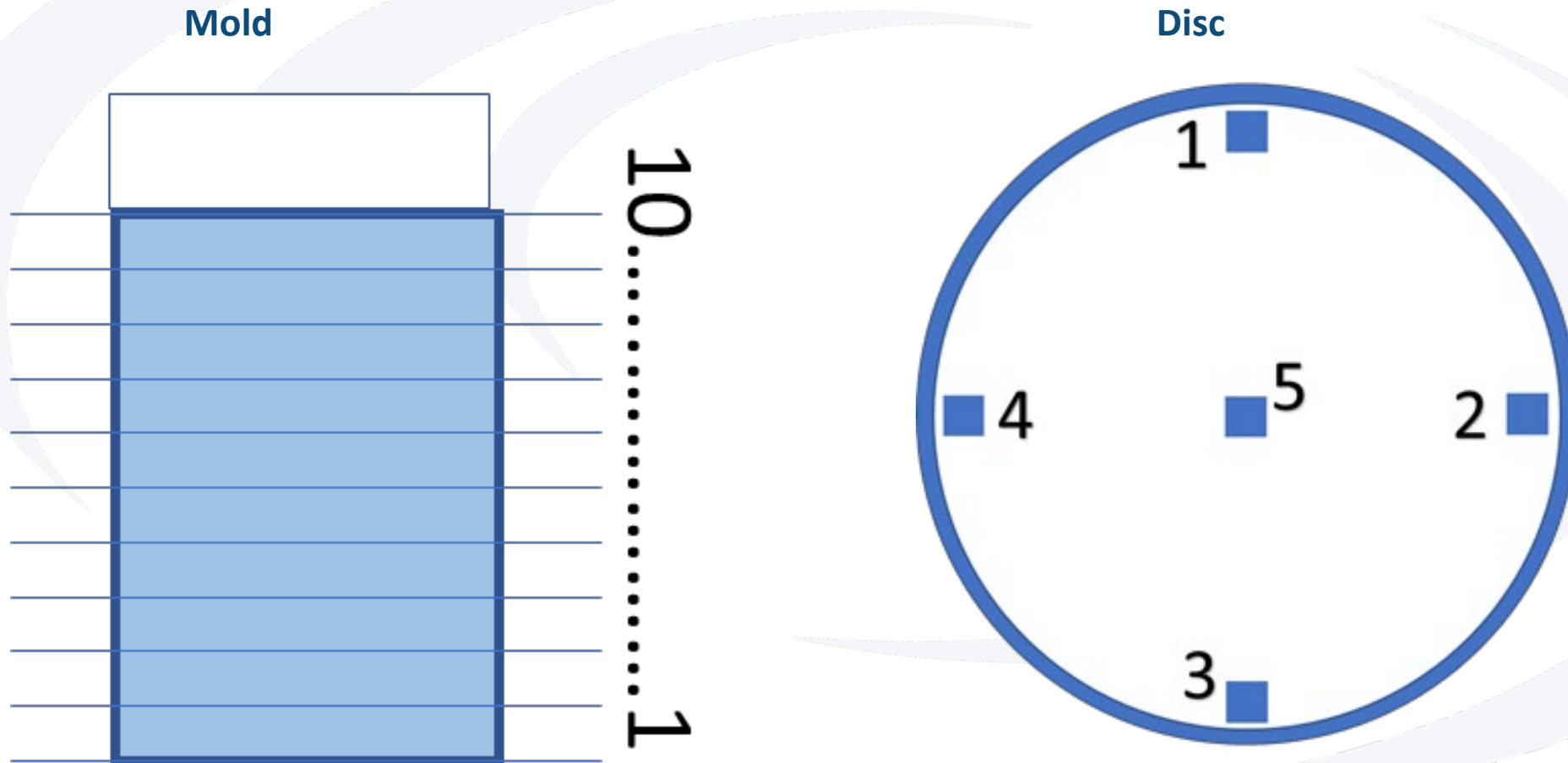
# Degassed Mixed Material Collection at End of Run

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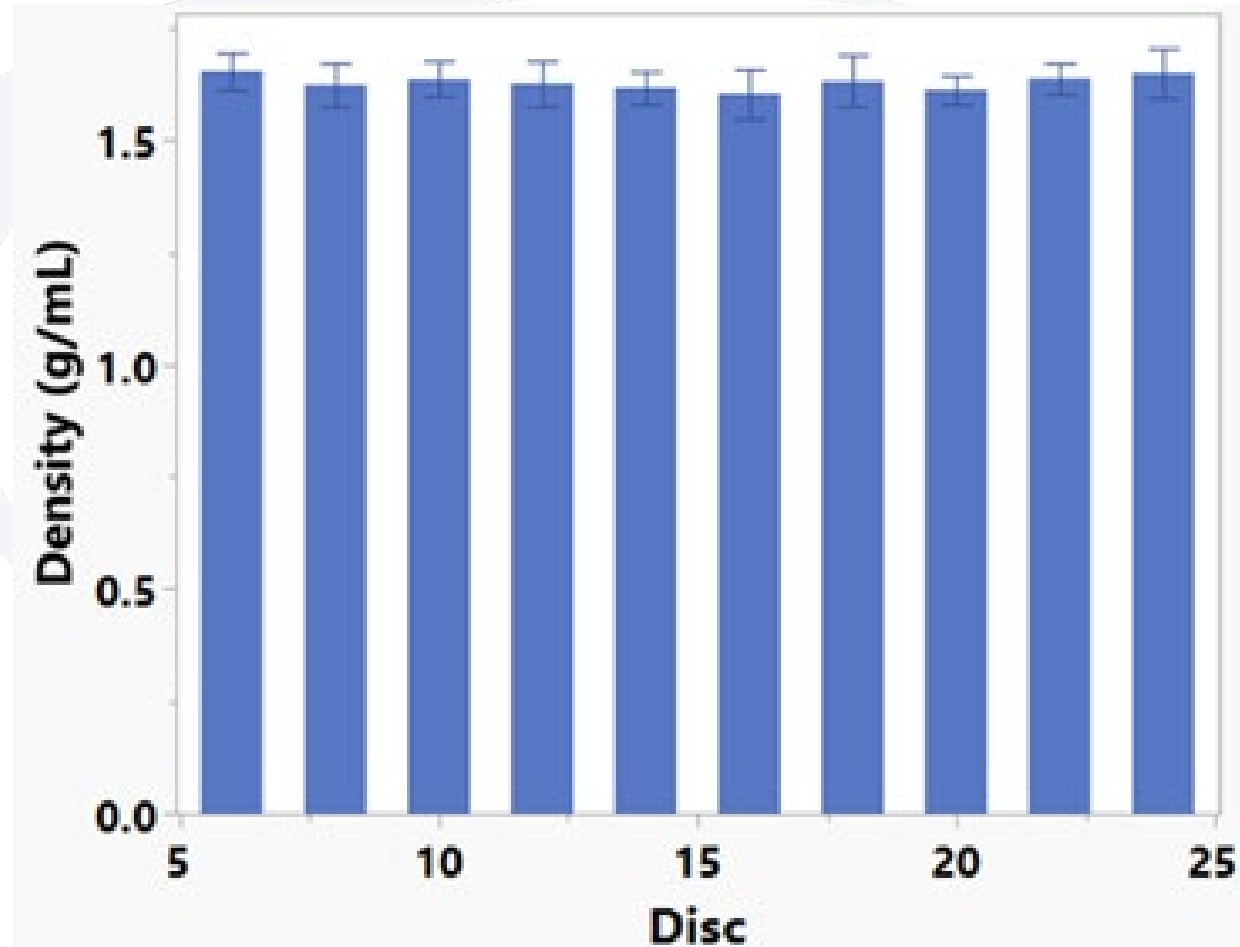
**Mixed and Degassed  
Material Production Rate  
60 kg/hour**



# Energetic Rated System Testing



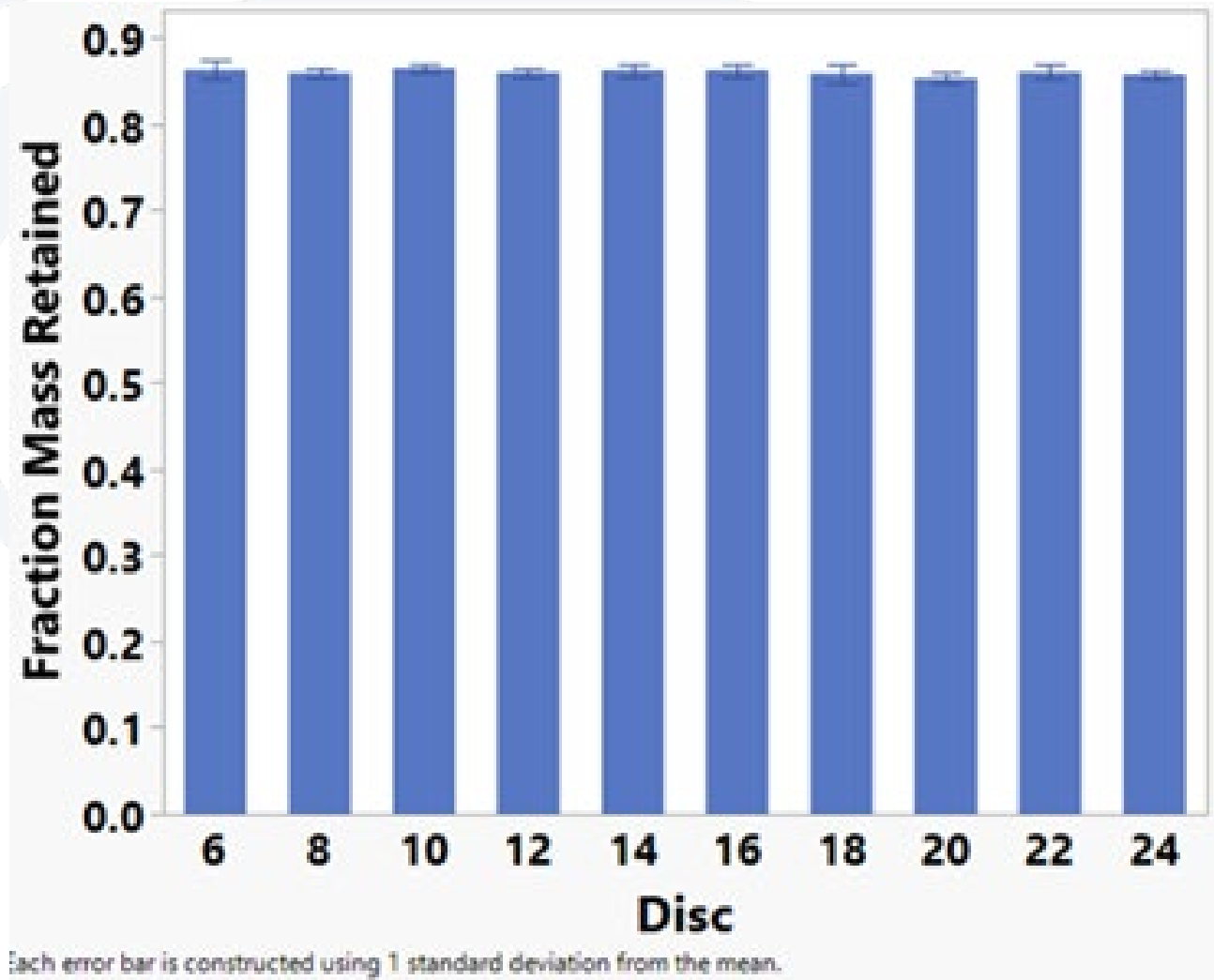
# Energetic Rated System Testing



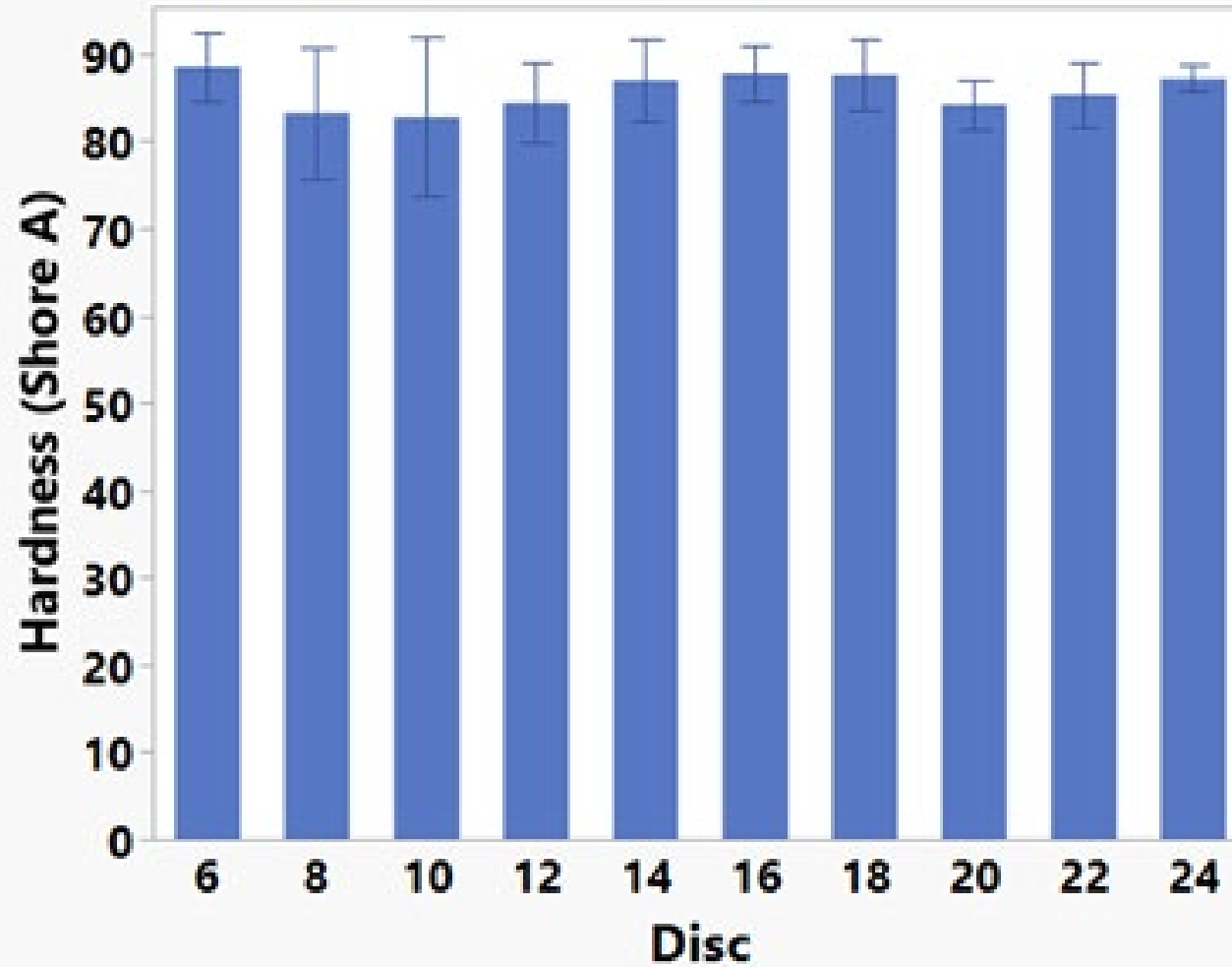
Each error bar is constructed using 1 standard deviation from the mean.



# Energetic Rated System Testing

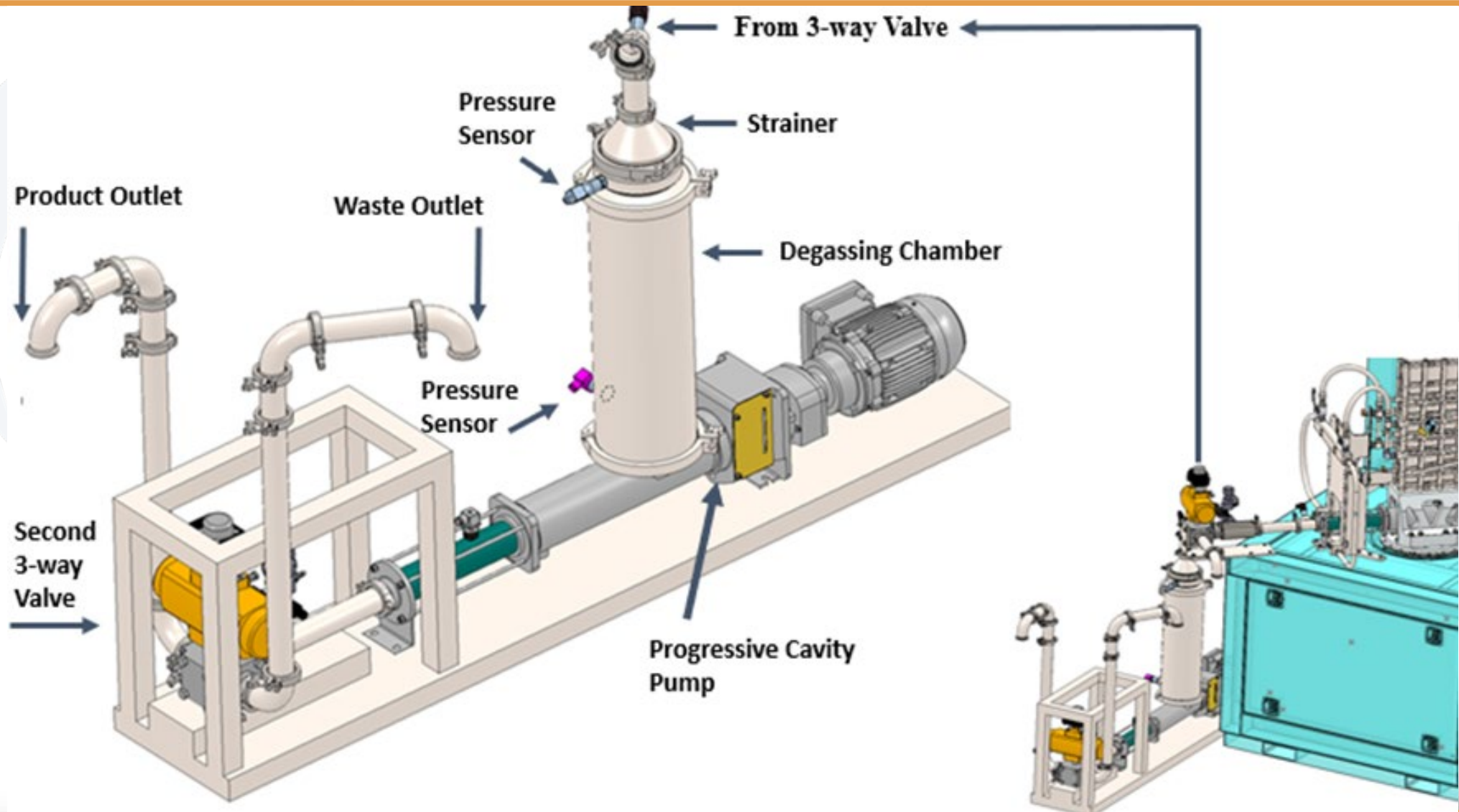


# Energetic Rated System Testing



Each error bar is constructed using 1 standard deviation from the mean.

# Continuous Mixed Material Degassing System for Continuous Filing





# Summary

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## Accomplishments

- Energetics Rated CAM-CIP Ready for Energetics Testing
- CAM-CIP Demonstrated with 100% Efficiency
- Temperature Control, Degassing

## Next Steps

- Production of Mixed Energetic Material from this System at NAWCWD China Lake
- Development of Inline Mix Quality Sensor
- Development of a Continuous Degassing System

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**Thank you for your time and attention.**

