Resodyn Acoustic Technology Universal Processing Platform and Mix Material Considerations

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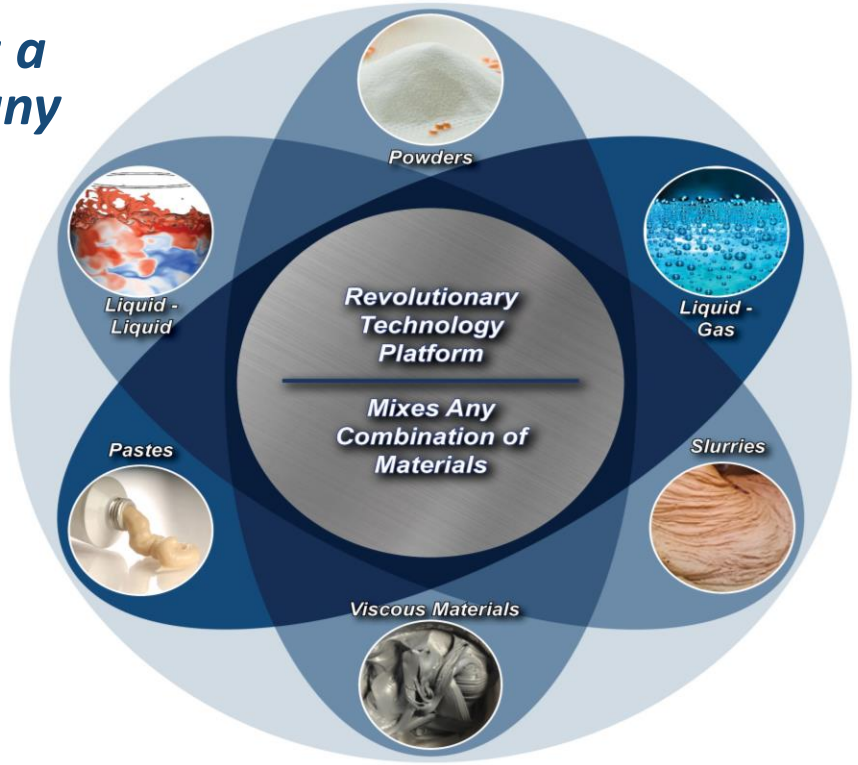
Resodyn Acoustic Technology and Processing Methods Overview from 10,000 feet

UNIVERSAL PROCESSING PLATFORM

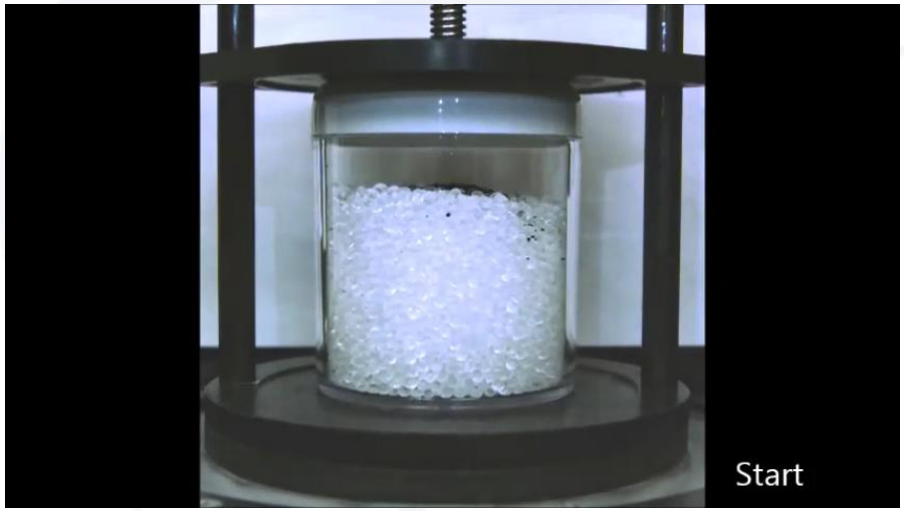
ResonantAcoustic® Technology

Acoustic Resonator Technology Platform Uniquely Enables

- *Versatility and Flexibility as a **Universal Platform** to mix any Combination of Materials*
- Use Over a Broad Range of Industrial Applications
- New Product Discovery
- Rapid Product Evolution
- Seamless Scalability from Bench-to-Production-to-Continuous



Example Mixing/Processing Regimes



High-Speed Video of sub-millimeter
Beads of micron sized Carbon Black
being milled/mixed and coating millimeter
sized polymer beads – 4 seconds duration

Top View
Realtime Video of 3-million Cps viscous paste
Being mixed in RAM55 system

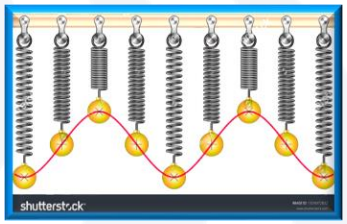
RAM Processing Capabilities

- Modes of Mixing and Processing
  - Batch
  - Semi-Continuous Batch (automated)
  - Continuous
- In addition to being a Universal Mixing Technology, RAM is used for many Advanced Processing Methods
  - Sieving
  - Grinding
  - Coating
  - Degassing
  - Cleaning
  - Deburring
  - Polishing
  - Chemical Reactions
  - Bioprocessing
  - Continuous Chemical Reactions
  - Continuous Crystallization
  - Mechanochemistry
  - Others

Resodyn Acoustic Mixer as a Universal Mixing and Processing Platform

- The RAM Technology **Employs a Single Platform** to Mix and/or Process a Broad Range of Materials

- The Underlying Foundation for the RAM Technology is the Use of an **Oscillating Resonant Driver System** to Transfer Energy to a Platform that Shakes a Mix Vessel, or Processing Container



- The Resodyn Acoustic Mixing (RAM) and Processing Technology is **Arguably the Most Universal Mixing/Processing Technology** of any Type Developed to Date

ResonantAcoustic® Technology Core Features

- The ResonantAcoustic® Mixing and Processing Technology has one Common Element -- “Resonator”

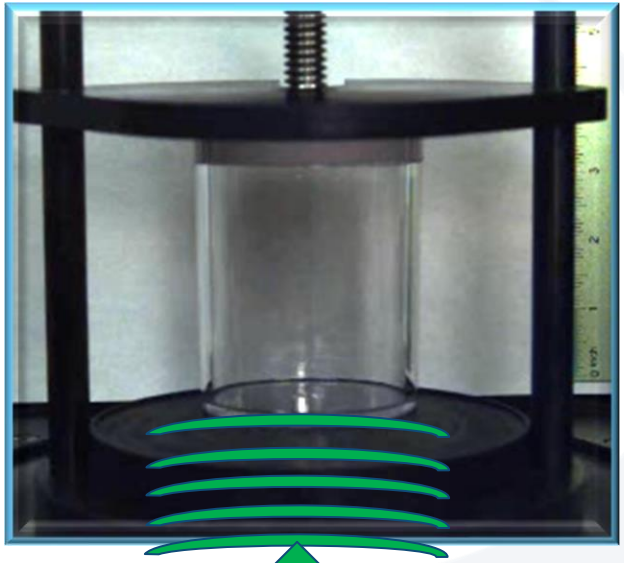
- The ResonantAcoustic® Technology Embodies 3 Core Features
  1. Sound Generator
  2. Operates at Large Displacements and at Modest Frequencies
  3. Operates at Mechanical Resonance

- ResonantAcoustic® Mixing and Processing Technology Requires one to 

Mindsets on Several Fronts

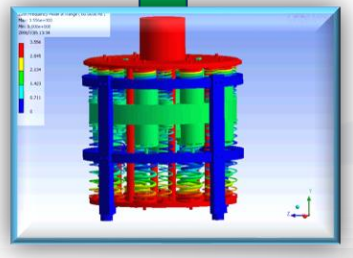
ResonantAcoustic® Technology Core Feature Number 1 -- Vibration Generator

A Sub-Woofer is an acoustic energy generator designed to produce low-frequency sounds by vibrating



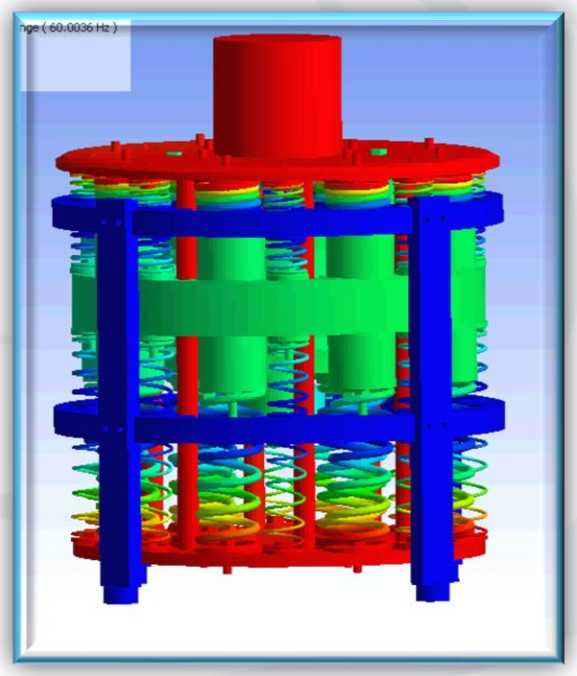
Empty container at 100 *g* of acceleration 3,600 fps

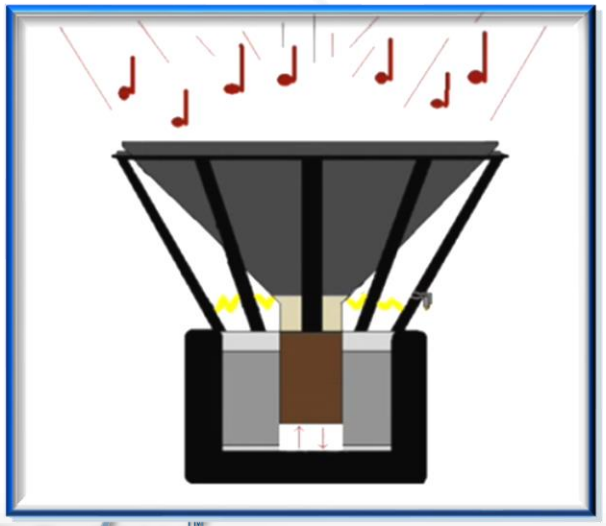
VIBRATION ENERGY



The “Driver” Applied for all RAM Phenomena
All Systems Use the Same Vibrating Platform Concept

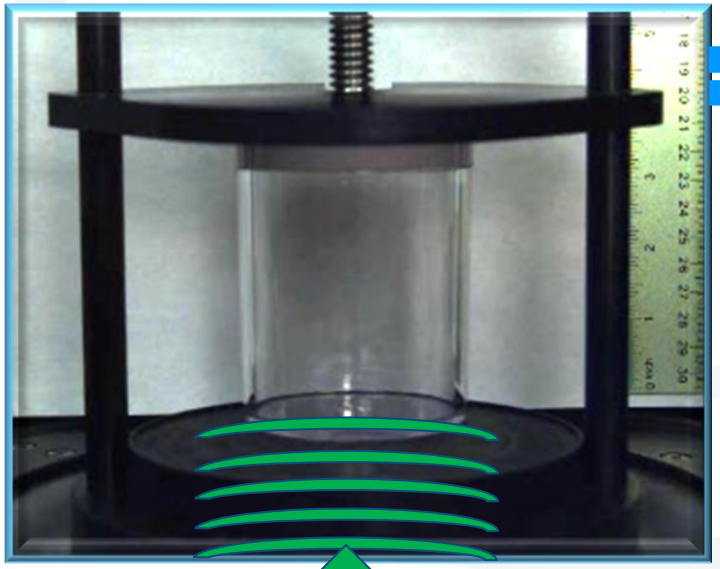
ResonantAcoustic® Platform





ResonantAcoustic® Technology
Core Feature Number 2
Operates at Substantial Displacements

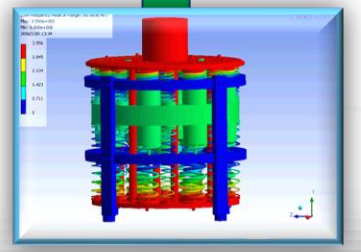
ResonantAcoustic® Mixers Create Up to 0.55 Inch Oscillating Displacements at ~60 Hz and at 100 *g* of Acceleration



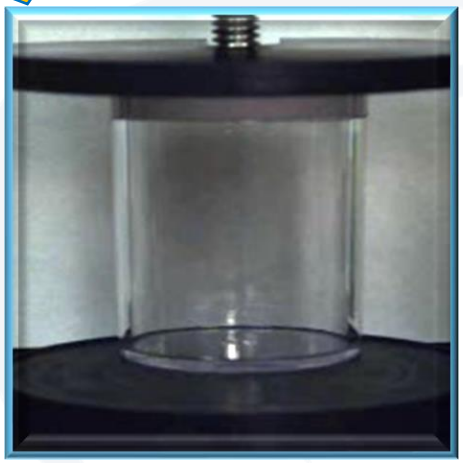
0.55 inch Peak-to- Peak Displacement at 100 g

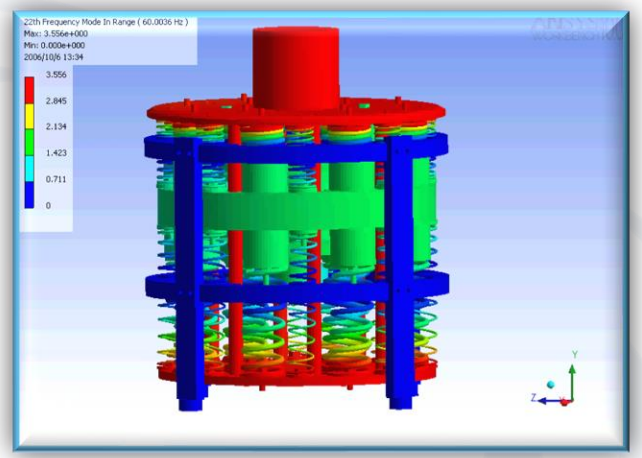
Empty container at 100 *g* of acceleration 3,600 fps

VIBRATION ENERGY

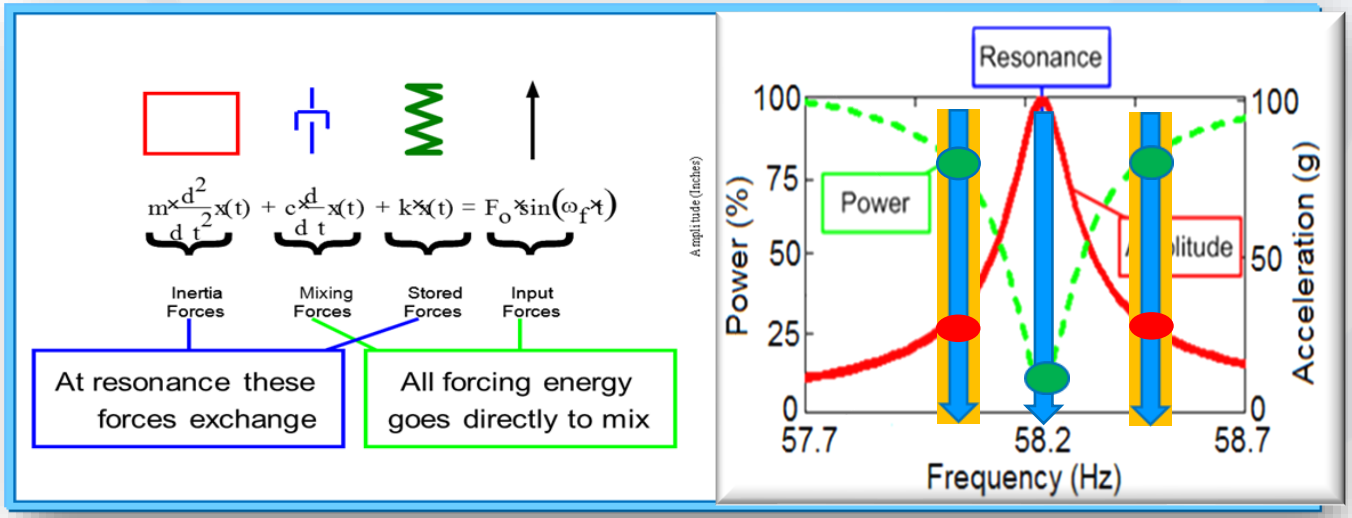


ResonantAcoustic® Technology Core Feature Number 3 – Operates Mechanical Resonance





Resonator Platform and Dynamics



Maximum Resonator Amplitude at Minimum Power

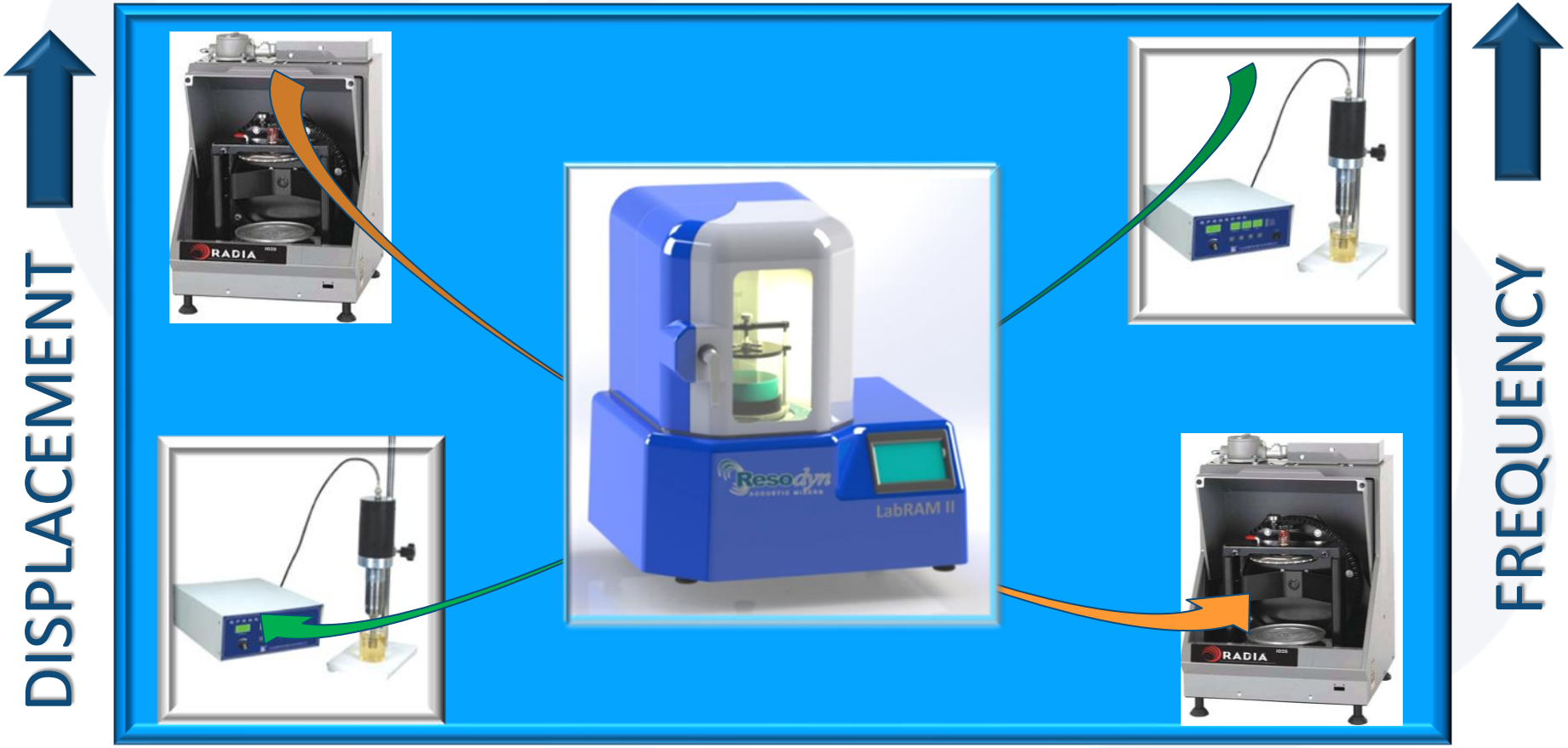
Attributes of 3-Core Features

- These 3 Core Features are the Basic Building Blocks for each ResonantAcoustic® Platform
  - Bench Scale
  - Pilot Scale
  - Industrial Scale
  - Continuous

- These 3 Core Feature Commonalities Enables Seamless Scalability from
  - Bench Batch through Industrial Batch
  - Batch to Continuous
  - Bench Continuous through Continuous Industrial

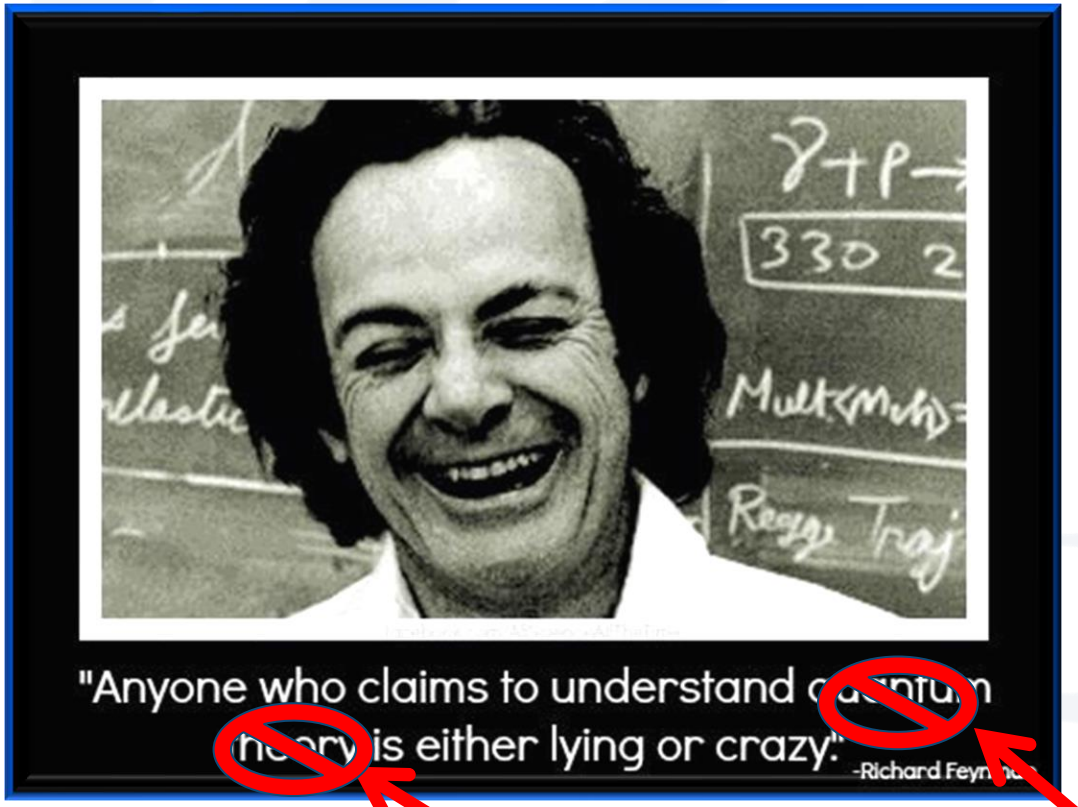
- These 3 Core Features Enable Mixing, Chemical Reactions, Crystallization, etc., all on the Same ResonantAcoustic® Platform

ResonantAcoustic® Technology Enabling Operational Features



Not a Paint Shaker, nor an Ultrasonic Technology
Modest Frequency and Substantial displacements

Resodyn is Neither Lying nor Crazy -- Just Still Discovering

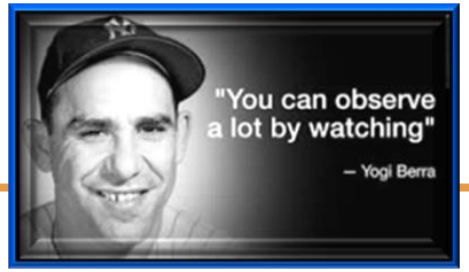


ResonantAcoustic® Mixing

Take Home Messages

- Headway in the Understanding of ResonantAcoustic® Mixing Process is Continuously being made by Resodyn and by the RAM Users Community
- More Effective Means of Explaining the use of the ResonantAcoustic® Mixing Processes for Client Applications are always being Developed
- How Does This work?

Observed Mixing Regimes



- Physics of Mixing and Processing Underlying the Resodyn Acoustic Resonator Technology are Primarily Driven by Highly Dynamic and Interactive Phenomena

- These Highly Dynamic and Interactive Phenomena are
  - Faraday Instabilities
  - Acoustic Wave Forces
  - Bubbly and Froth Mixing
  - Interfacial Area Creation Dynamics
  - Particle Collision and Interaction Mechanisms
  - Vapor Cavity Creation and Dynamics

Same Acoustic Resonator Platform is used for all of the Mixing/Processing Regimes. However, the Physics Driving each Regime are Different

1. 

2. 

3. 

Successful Mixing with RAM is a Multistep Process

1. Identify the Dominant **Material Mixing Properties** (This important aspect of ResonantAcoustic® Mixing is Presented in Upcoming Sessions)

2. One must Select the **Mixer Operating Conditions that Align with the Materials Mixing Properties** Throughout the Mix Cycle (Note: Properties of the Mixture Often Change from Start to Finish Sometimes Requiring Adjustment in the Following Settings)
   - Acceleration
   - Pressure (vacuum)
   - Temperature
   - Use of both top and bottom transducer is often essential
   - Time at specific operating conditions
   - Power into the mix

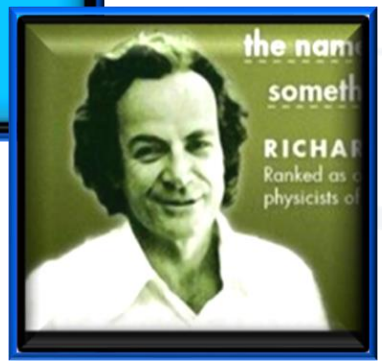
3. Identify when and how the **Materials Mixing Properties Transition** during the Mixing Process

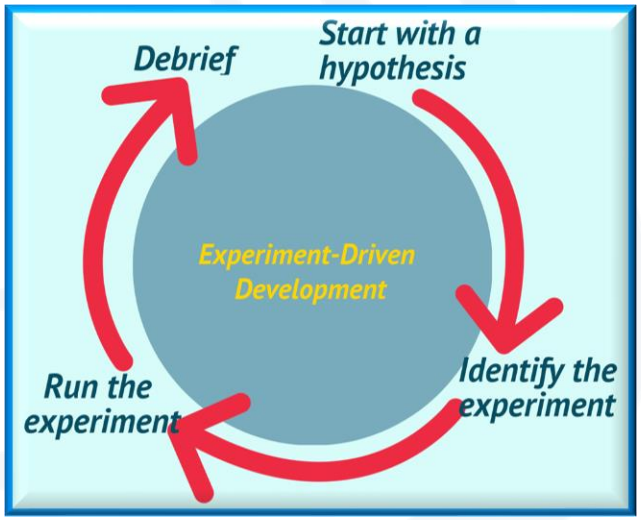
RAM Mixing and Processing Developments

- **Automated Vessel Handling**
  - Status: Implemented
- **Continuous Resonant Acoustic Mixing**
  - Status: Implemented and in Further Development to address specific client requirements
- **Continuous Resonant Acoustic Chemical Reactor**
  - Status: In Mid-Stage Development – Anticipated Product Launch 2027
- **Continuous Resonant Acoustic Crystallizer**
  - Status: In Mid-Stage Development – Anticipated Product Launch 2027
- **Continuous Resonant Acoustic Microreactor**
  - Status: In Mid-Stage Development – Anticipated Product Launch 2027+
- **Continuous Resonant Acoustic Mechanochemical Reactor**
  - Status: In Mid-Stage Development – Anticipated Product Launch 2027+

Resodyn Acoustic Mixers Technology and Processing Knowledge are a

It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong. Richard P. Feynman





WHERE NO MIXER HAS GONE BEFORE

Thank you for your time and attention.