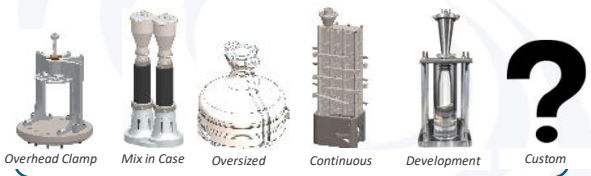
Modal Design Envelope for RAM Mixing

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Engineering Manager
Resodyn Corporation

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Problem Statement

The RAM5 Pedestal is a highly versatile platform for MIC and other mixing configurations



This versatility increases the risk of machine or vessel failure when designing for the RAM environment!

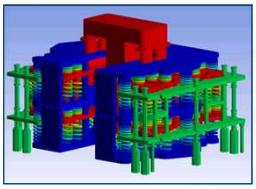


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2

Most Significant Risk: Off-Axis Modes

- **A Resonant Mode is the type of motion a vibrating body undergoes on its natural frequency**
- **The primary Resonant Mode for RAM Technology is vertical displacement**
- **RAM Equipment is designed for 100g operation on this mode**



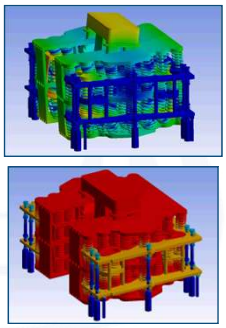
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Most Significant Risk: Off-Axis Modes

- Several Off-Axis Resonant Modes in addition to the Primary Mode
  - 7 Unique body combination
  - 6 Degrees of Freedom per body

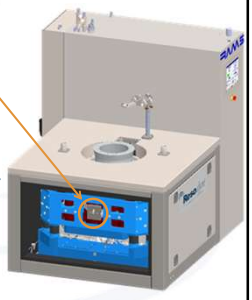
  42 Degrees of Freedom!
- Each Degree of Freedom creates its own Mode at a specific frequency
- Three Factors determine each Natural Frequency
  - Mass
  - Stiffness
  - Rotational Inertia



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Most Significant Risk: Off-Axis Modes

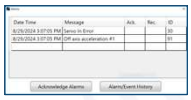
- RAM5 & OmniRAM includes 2 sensors that shutdown the Resonator if off-axis limit is exceeded
- These sensors cannot capture all off-axis modes!
- Outcomes of operating too near Off-Axis Modes
  1. Resonator will shut down
  2. Resonator will fail
  3. Vessel or Vessel holder will fail

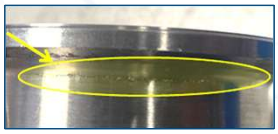


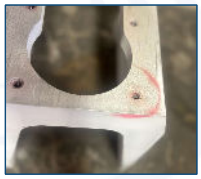
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Most Significant Risk: Off-Axis Modes

- Outcomes of operating too near Off-Axis Modes
  1. Resonator will shut down
  2. Resonator will fail
  3. Vessel or Vessel holder will fail







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Pedestal Design Envelope

- Because of the complexity in designing for RAM environments, Resodyn recommends the use of Resodyn Vessels, Vessel Holders, and MIC Holders
- Resodyn provides limited support for Customer Designed Vessels and Holders in the form of a design envelope
- Three parameters set the design envelope; limits provided in the Modal Test Report

Design Parameter
Starting Frequency
Max Acceleration
Avoid Off-Axis Modes

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Generating the Modal Test Report

- Limits for each design parameter is determined by testing each fixture on the RAM it will operate with
- Simulated system with adjustable mass and center of gravity used when fixturing is not available



Fixture Testing

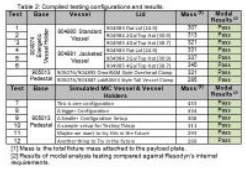


Simulated Testing

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Reading the Modal Test Report

- Typical Modal Test Report includes:
  - Results from vessel specific testing

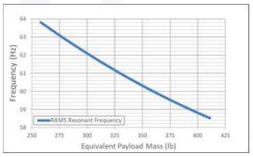




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Reading the Modal Test Report

- Typical Modal Test Report includes:
  - Results from vessel specific testing
  - Starting frequency calculation



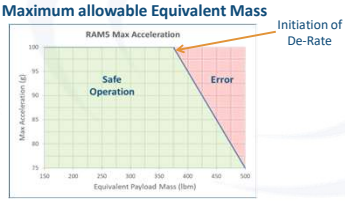


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Reading the Modal Test Report

- Typical Modal Test Report includes:
  - Results from vessel specific testing
  - Starting frequency calculation
  - Maximum allowable Equivalent Mass





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Reading the Modal Test Report

- Typical Modal Test Report includes:
  - Results from vessel specific testing
  - Starting frequency calculation
  - Maximum allowable Equivalent Mass
  - Modal Map



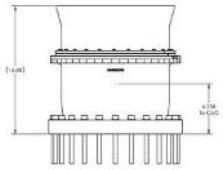


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Reading the Modal Test Report

- Typical Modal Test Report includes:
  - Results from vessel specific testing
  - Starting frequency calculation
  - Maximum allowable Equivalent Mass
  - Modal Map
  - Vessel specific CoG information





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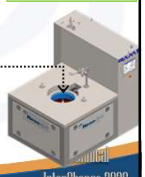
How to Measure: Mass

- **Tooling Mass**: Mass of fixed equipment attached to the payload plate
- **Coupled Material Mass:** Portion of Mix & Coolant mass that doesn't absorb energy
- **Uncoupled Material Mass:** Portion of Mix & Coolant mass that absorbs energy
- **Equivalent Payload Mass**: Tooling Mass + Coupled Mix Mass



Tooling
- Pedestal
- Vessel Holder
- Vessel / MIC Vessels
- Lids / MIC Hoppers
- RTDs / Fittings
- Fasteners

Does Not Include
- Mix Material
- Coolant
- Hoses / Cables



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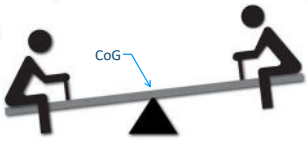
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How to Measure: Center of Gravity (CoG)

- **Point around which mass of a rigid body is balanced**
  - **Found for each component and the system**

$$CoG = \frac{\sum Mass_i * Distance}{Mass_{Total}}$$



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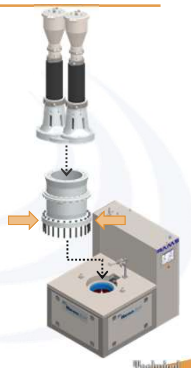
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How to Measure: Center of Gravity (CoG)

- Mass Weighted average used to find the CoG_{total}

$$CoG_{total} = \frac{\sum Mass_i * (CoG_i + Offset_i)}{Mass_{Total}}$$

- Offset requires a consistent reference
  - Resodyn will always measure CoG_{total} from the top of the Payload Plate (bottom of the pedestal)

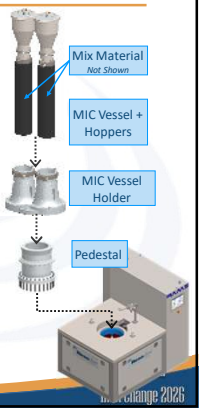


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Pedestal Design Envelope Example

- Evaluate twin MIC vessel holder with additional top feeders that is mixing Paste with a Coupling Coefficient of 0.4
- This example utilizes sample data provided by Resodyn on a Modal Test Report

Design Parameter	Result
Starting Frequency	?
Maximum Acceleration	?
Avoids Off-Axis Modes	?

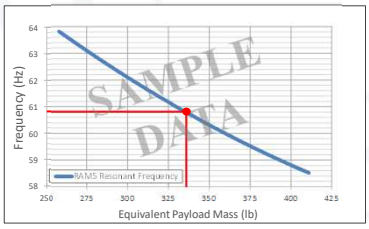


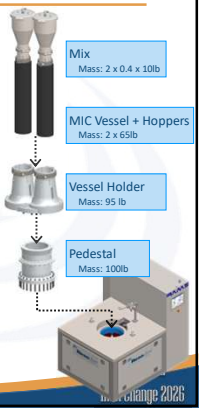
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Example: Starting Frequency

Use the Natural Frequency vs Equivalent Mass Table

Equivalent Payload Mass = 334 lb



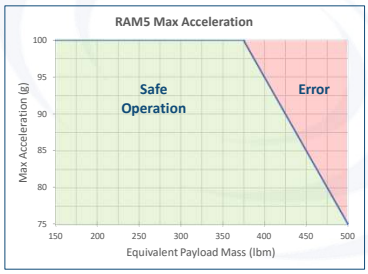


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Example: Maximum Acceleration

334 lb equivalent mass requires no acceleration de-rate

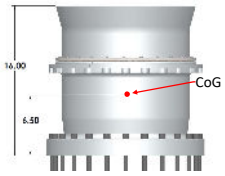
Equivalent Payload Mass = 334 lb

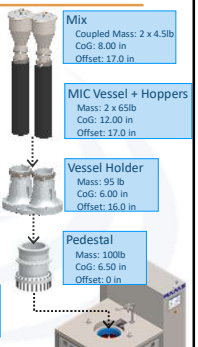


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Example: Calculating Center of Gravity

Center of Gravity & Offset Calculated for each component





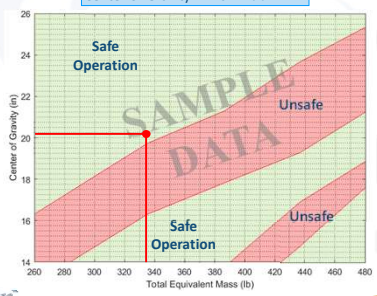
$$CoG = \frac{\sum Mass_i * (CoG_i + Offset_i)}{Mass_{Total}} = 20.17$$

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Example: Avoiding Off-Axis Modes

Mass and Center of Gravity Compared To the Modal Map

Equivalent Payload Mass = 334 lb
Center of Gravity = 20.17 in



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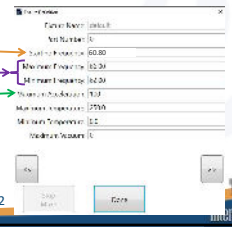
Example Review

- Twin MIC vessel holder example meets design envelope requirements

Starting Frequency	✓ 60.8 Hz
Maximum Acceleration	✓ Up to 100g
Avoids Off-Axis Modes	✓ 20.17 in

- Design parameter information embedded in Fixture File

Design Parameter
Starting Frequency
Avoid Off-Axis Modes
Max Acceleration



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RAM Family

- All *Omni*RAM Vessel's attach above the Resonator similar to a RAM5 Pedestal
- *All Omni*RAM's include an Off-Axis motion sensor on the resonator



	LabRAM I	LabRAM II	OmniRAM	RAM5	RAM55
Configurations	Pedestal	Pedestal	Pedestal	Pedestal & Internal	Pedestal & Internal
Maximum Equivalent Mass at 100g	4.0 lb	5.5 lb	80 lb	375 lb	3,100 lb
Off-Axis Sensors	No	No	Yes	Yes	Yes

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Summary

- Recommend use of Resodyn Vessels & Vessel Holders
- Detail of Design Envelope depends on Customer Requirements
- Customer Designed Pedestal Fixtures will need to comply with their RAM5 & Pedestal Design Envelope, and will receive limited support from Resodyn

Resodyn Will Provide
- ✓ Pedestal Mounting Geometry
- ✓ Configuration Files
- ✓ Remote support for Generic Modal Testing
- ✓ Starting Frequency vs Mass Table
- ✓ Acceleration De-Rate Table
- ✓ Modal Map Chart [1]

Resodyn Will NOT Provide
- ✗ Guidance on how to design Customer Supplied Vessel Holders
- ✗ Comprehensive Modal Testing once the system leaves Resodyn
- ✗ Advice on how to correct Bad Modes on Customer Supplied Vessel Holders

- Resodyn's warranty for any system Resonator does not cover operation with client supplied custom Vessel, MIC Vessel, or Vessel Holders

[1] Must be completed before the machine leaves Resodyn

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Thank you for your time and attention.



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