New Concepts in Zonal Isolation for EGS

High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells

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Track 2, R&D

Project Overview

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- **Goal:** Develop high-temperature high-pressure zonal isolation devices compatible with the downhole EGS environment
  - Barrier H – EGS well zonal isolation
- **Timeline:** January 29, 2010 to January 31, 2013
  - Actual Start Date in May 2010
- **Budget**
  - DOE : $940,546, Cost Share: $240,000, Total Budget $1,180,546
- **Project Collaborators**
  - Brontosaurus Technologies (industrial partner)
  - AltaRock Energy, Inc. (industry collaborator)
  - Geodynamics (industry collaborator)
- **Jobs**
  - One (1) project engineering job has been created under this program
  - One (1) technician job has been retained due to this program

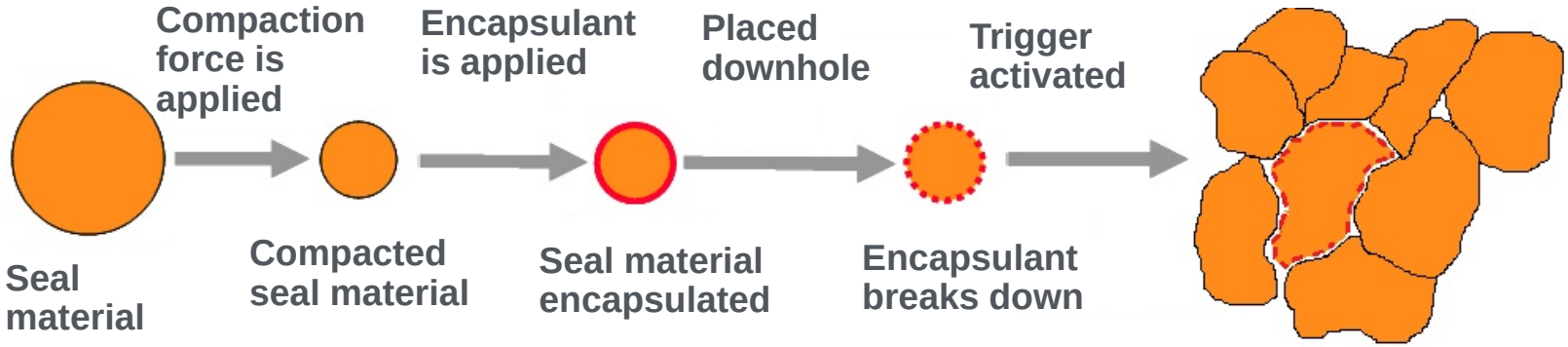
Relevance/Impact of Research

- **Innovations**
  - Expanding polymer system that will provide barrier for zonal isolation and flow control
  - Flow through porous material builds pressure
  - Seal material fills irregular spaces
  - Distributed pressure reduces unwanted fractures
- **High Temperature High Pressure (HTHP) Zonal Isolation will enable**
  - Sealing off of unwanted flow regions
  - Increased and accurate stimulation (fraccing)
  - Elimination of fluid loss
  - Identification and mitigation of short circuiting
  - Targeting of individual fractures for testing
  - Validation of reservoir models
  - All of the above will reduce the cost of EGS operations

Scientific/Technical Approach

Porous Expandable Seal (PES) capsules: High Temperature, engineered porous material packed in an expandable capsule form

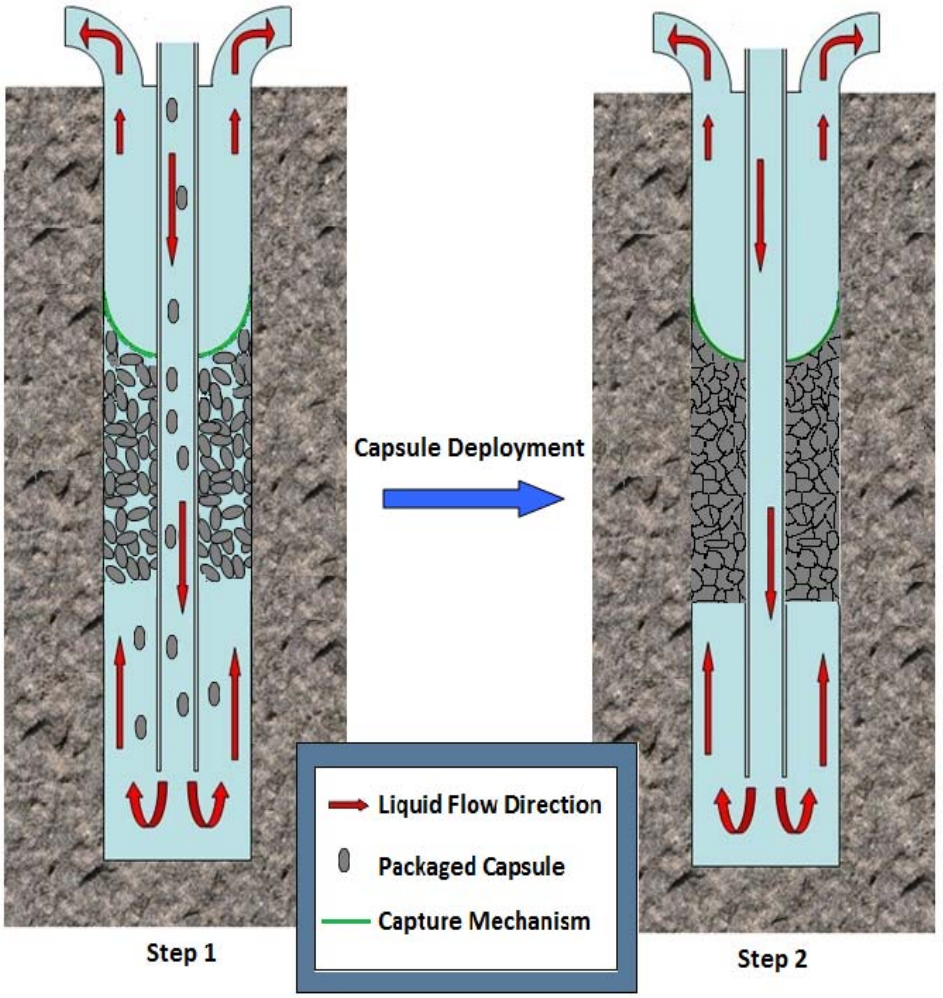
- **Capsule Production**
  - Seal material compacted
  - Encapsulate compacted seal material
- **Downhole Deployment**
  - Deliver capsules downhole
  - Encapsulant releases seal material when triggered
  - Seal material expands to original shape, creating seal in controlled manner



Patent pending

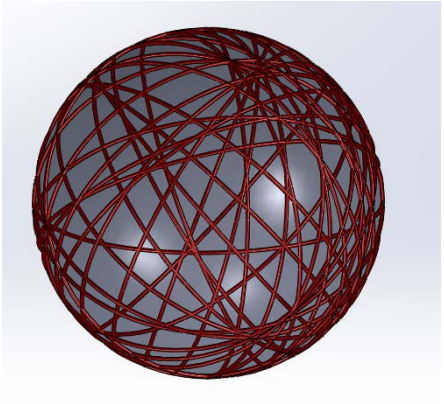
Scientific/Technical Approach

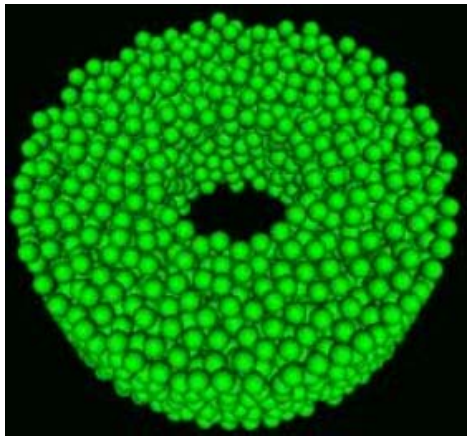
- **Downhole Applications**
  - Delivered to well site by truck
    - 20 to 100 gallon range
  - Cool Flush
  - Pumped Downhole
    - Through work pipe
  - Captured in place by catch screen
  - Pump through chemical trigger solution
  - Encapsulant released, PES capsules expand
    - Pressure rise indicates deployment
    - Plateau indicates full deployment
    - Begin fraccing operations
- **Year 1 – Concept and Design Development**
- **Year 2 – Component design and feasibility assessment**
  - Proved design can create pressure differentials matching theoretical values



Final Prototype PES Capsule Design

- Design Details
  - Capsule Design
    - 1” Spherical Capsule Shape for ease of manufacture and high random packing factor
    - Open wire frame aluminum capsule shell to mitigate hydrostatic pressures
      - Perforated thin shell coating
      - Pre-formed thin shell
      - Particulate metallic/polymer shell
      - Wire wrapped structure
  - Stage I PES material
    - Avg. 500 D hydraulic conductivity
    - Stage I PES material packaged to 63% volumetric compression
    - Multi-axial compression strain packaging
  - Encapsulant Material
    - Thin 99.8% pure aluminum wire
    - 5-7 lbs. Al for a 40’ annular section





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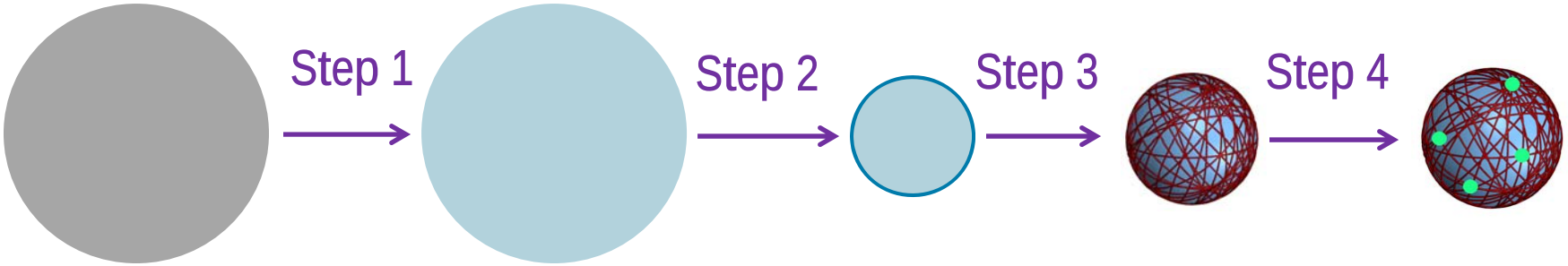
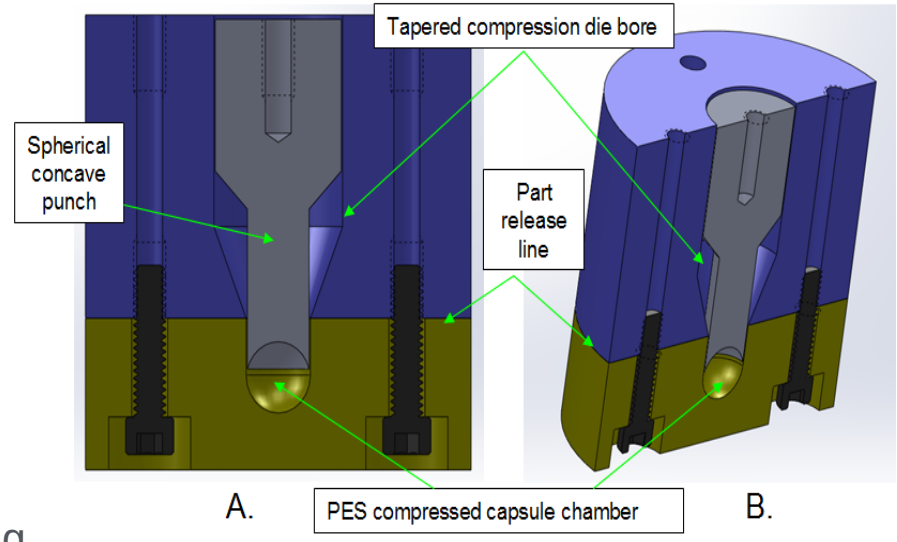
- **Manufacturing Prototype PES Capsules: Procedural Steps**
  1. Infuse PES material with water by mechanical exercise while soaking
  2. Compress PES material into spheres
     - Freezing holds the PES material in the compressed state
  3. Wrap the frozen spheres with thin gauge aluminum wire
  4. Secure multiple spots of the wire including the free end



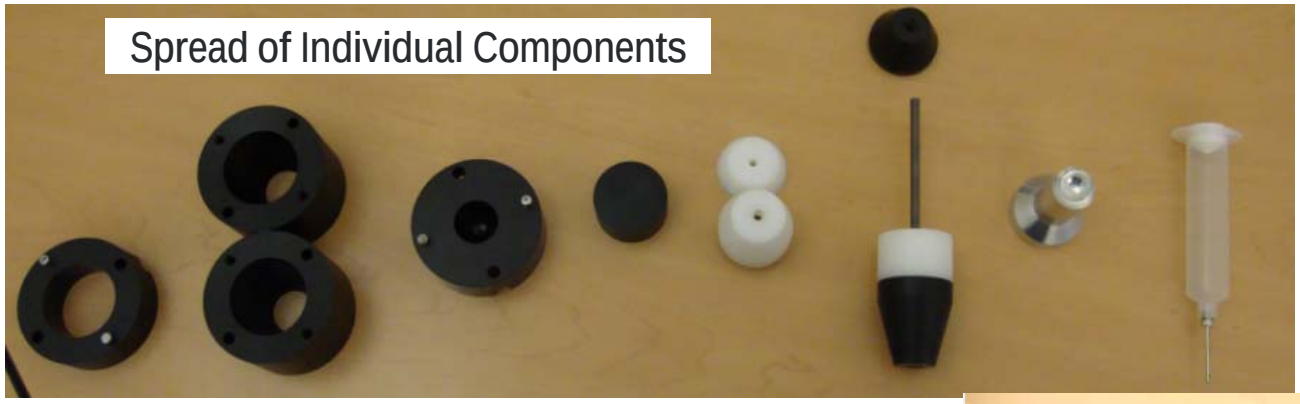
PES Material Compaction

- **Requirements**
  - Multi-axial compression packaging
  - Finished frozen PES sphere has to be a smooth in round surface
- **Primary Design Concept**
  - Die-Press tool with a plunger to compress the PES material into a spherical mold
- **1st Tooling Iteration**
  - Cylindrical plunger to press PES material into a smaller cylindrical chamber
  - The compressed, frozen cylindrical PES pieces would be shaped into spheres
- **2nd Tooling Iteration**
  - Tapered draft angles (45° & 30°)
  - Progressive set of plungers
  - Final plunger is left in and is the top half of the spherical shape
  - Final frozen PES sphere had a relatively smooth surface
  - Roundness was excellent
  - Spheres released without coatings or prying

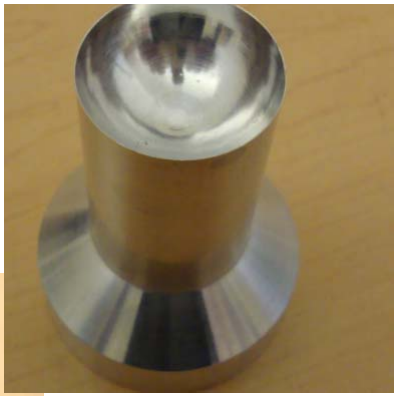


PES Compacted Spheres

Spread of Individual Components



Hemispherical Punch-Press

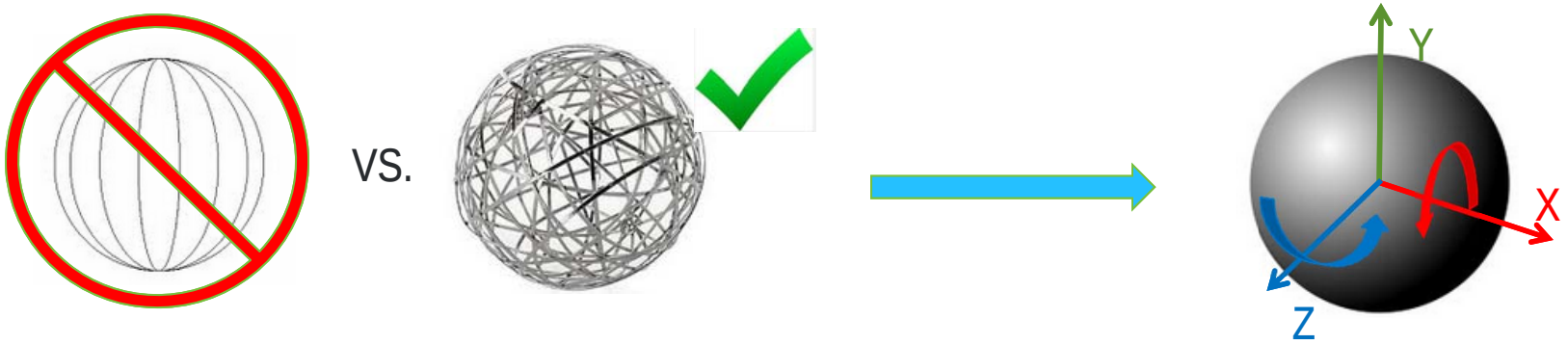


Hemispherical Chamber

Progression of Process Development on Prototype PES spheres

Wire Encapsulant Design

- **Analysis shows wire wrapping should have multiple axial variables**
  - 2 Axis rotation winding method
    - Produces the “randomly” wrapped cage
- **CTD designed equipment to quickly wind the frozen PES spheres**
  - Uses a belt drive to produce the x-axis rotation
    - The lower surface of the spheres rides on a free rollers
  - X-axis translation movement produces rotation of the spheres about the z-axis
  - Very adjustable



Random Orbit Winder

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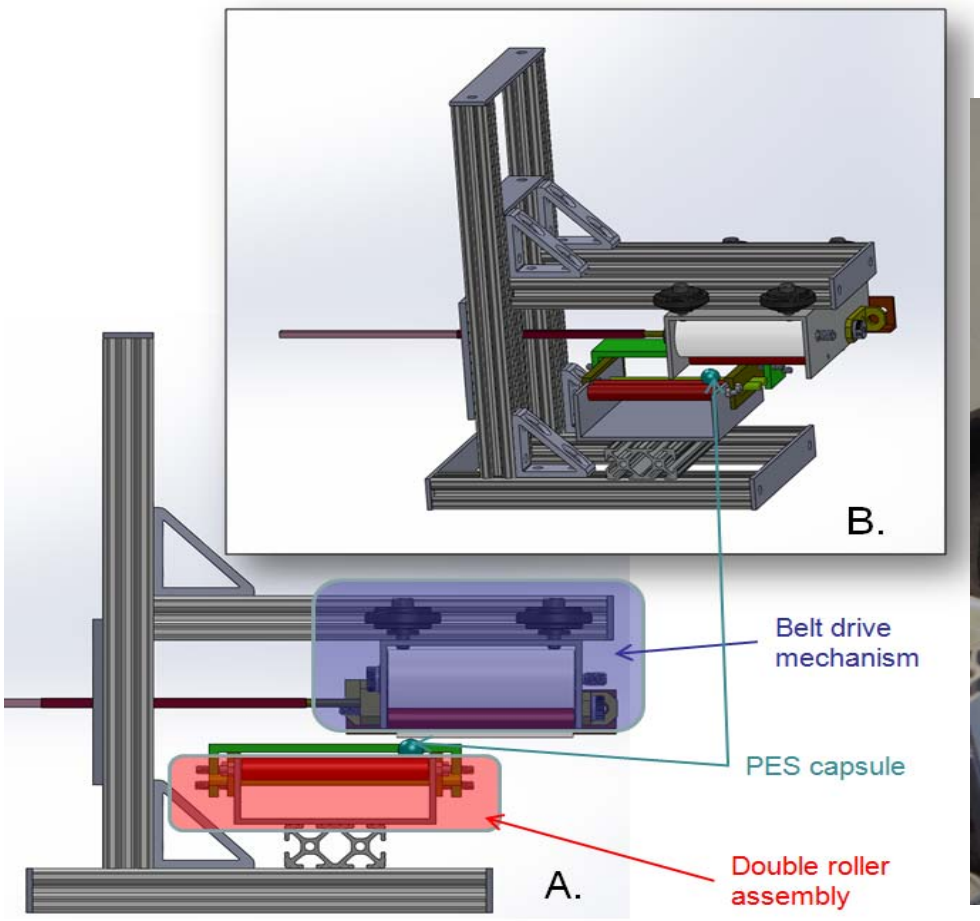
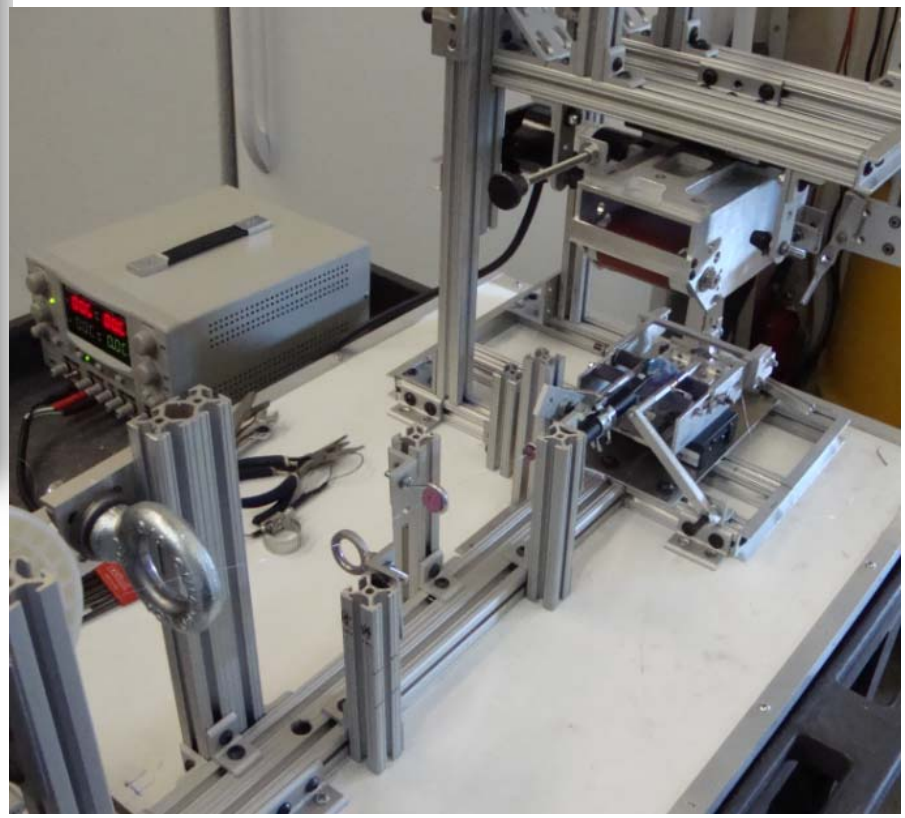
- Design and Fabrication of wire encapsulant winding equipment





Final Prototype Fabrication Process

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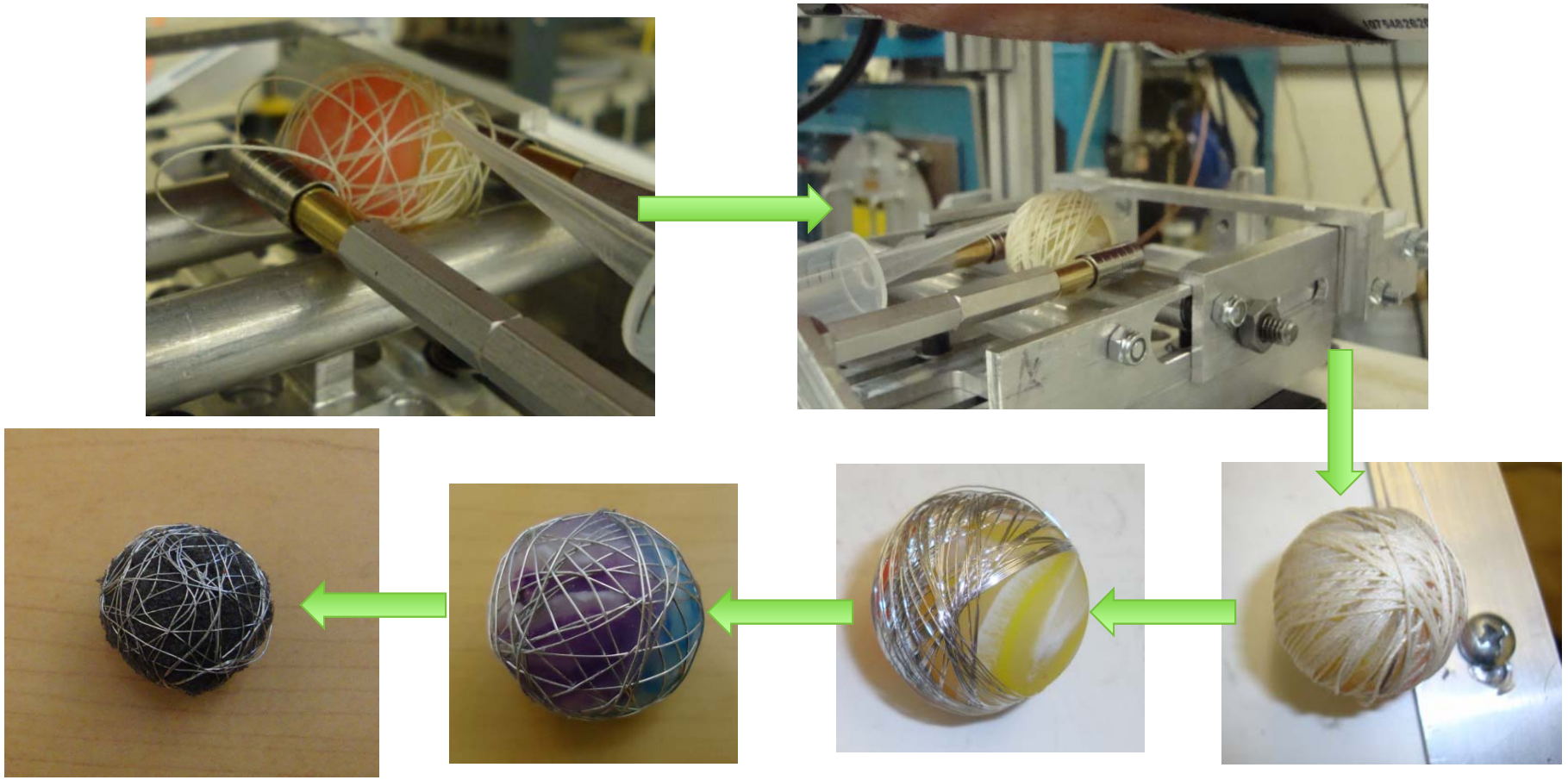
1. 1st iteration: Base adjustments and trials with rubber ball and string
2. 2nd iteration: Rubber ball and aluminum wire
3. 3rd iteration: Frozen PES sphere and wire



Summary Slide

- 2013
  - Developed final PES capsule design
  - Developed final prototype manufacturing process
  - Designed & fabricated prototype manufacturing equipment
  - Created final prototype PES capsule
- Project Completion
  - Completed all planned tasks
  - Created in-house zonal isolation demonstration
  - Full system prototype design and concept validation demonstration
  - Created 2 stages of prototype PES capsules
  - Pilot-Scale manufacturing plan for future development
  - Developed viable PES capsule manufacturing process
  - From TRL 0 to TRL 4/5

Future Directions

- **Project has been completed**
  - Project completed in January
- **Future development**
  - Develop Stage II and III PES materials based on high temperature chemistries
  - Identify large scale PES material manufacturing source
  - Develop scaled up capsule production equipment
  - Implement downhole testing
- **Commercialization efforts**
  - License technology

Project Management

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Timeline:

Planned Start Date	Planned End Date	Actual Start Date	Actual /Est. End Date
1/29/2010	12/31/2012	5/3/2010	1/31/2013

Budget:

Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
$940,546	$240,000	$1,180,545	$1,180,545	$1,180,545	$0

- **Project management activities**
  - Oversight of technical work
  - Establish priorities of technical support staff
  - DOE reporting and documentation requirements
  - Budget management
- **Coordination of work with collaborators and vendors**
  - Communication and meetings with Brontosaurus Technologies and DOE offices
  - Meetings with potential industrial partners for downhole trials