Radial Deconsolidation of Irradiated AGR-3/4 Compacts at Idaho National Laboratory

HOTLAB 2018

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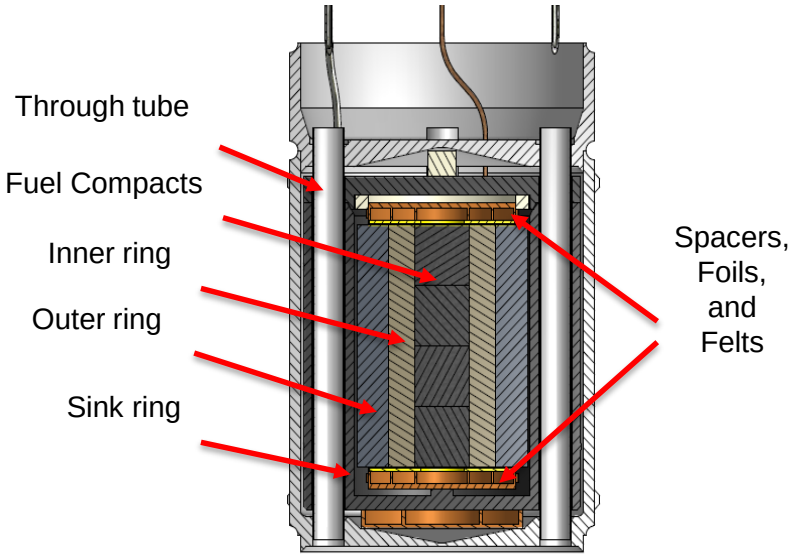
AGR-3/4 Experiment

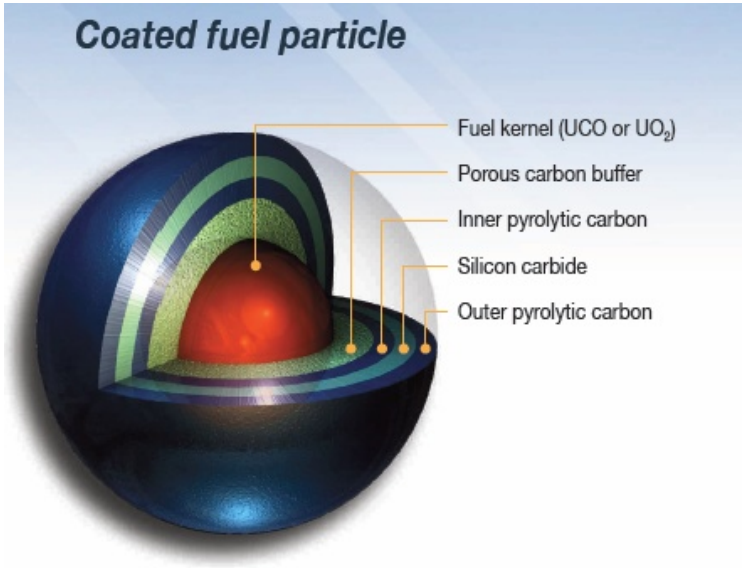
- TRISO Fuel – HTGR
  - PyC/SiC clad particles, UO_2/UC2 fuel, He cooled, not UO_2, stainless clad CO_2 cooled
- Study Fission Product Transport in graphite and graphitic material
- Normal Coated TRISO particles have minimal Fission Product release
- AGR-3/4 incorporated 80 DTF (designed to fail) particles among 7500 particles in each experiment capsule
- Capsule contains series of graphite or graphitic annuli (rings) through which FP diffuse

- Capsule
- Stainless Steel external
- Fuel in 4 compacts on axis
- Graphite/graphitic diffusion rings
- Different materials, temperatures

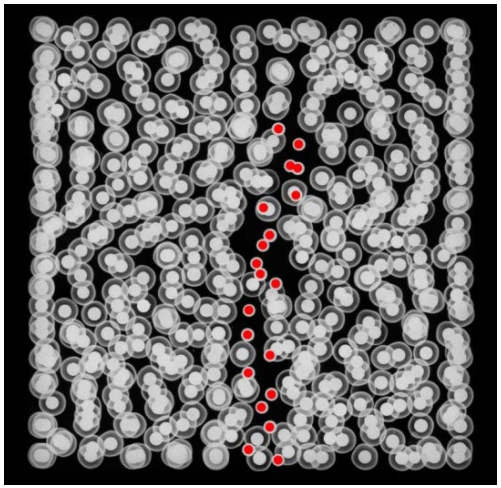


Designed To Fail Particles

- Each compact ~1875 intact particles
- Normal coating
  - OPyC 41 µ
  - SiC 33.5 µ
  - IPyC 40 µ



- 20 UCO kernels arranged on compact axis, coated with only 20 µ of pyrocarbon
- Each compact 12.3 mm OD × 12.3 mm long
- Particles held together in compact by graphitic matrix material



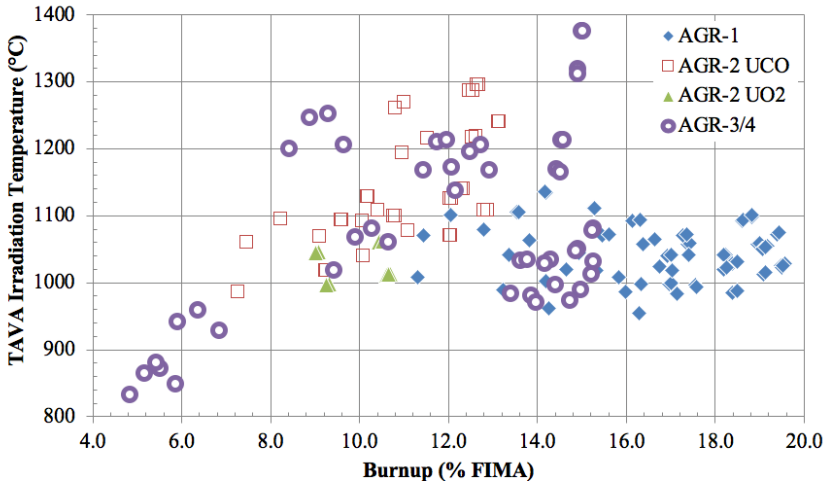
Irradiation AGR-3/4

Initial Enrichment 15%

Maximum TAVA ~1350

Maximum Burnup 15%
(Essentially all initial fissile material)

Time Averaged, Volume Averaged Temperature (TAVA)



Post Irradiation Separation

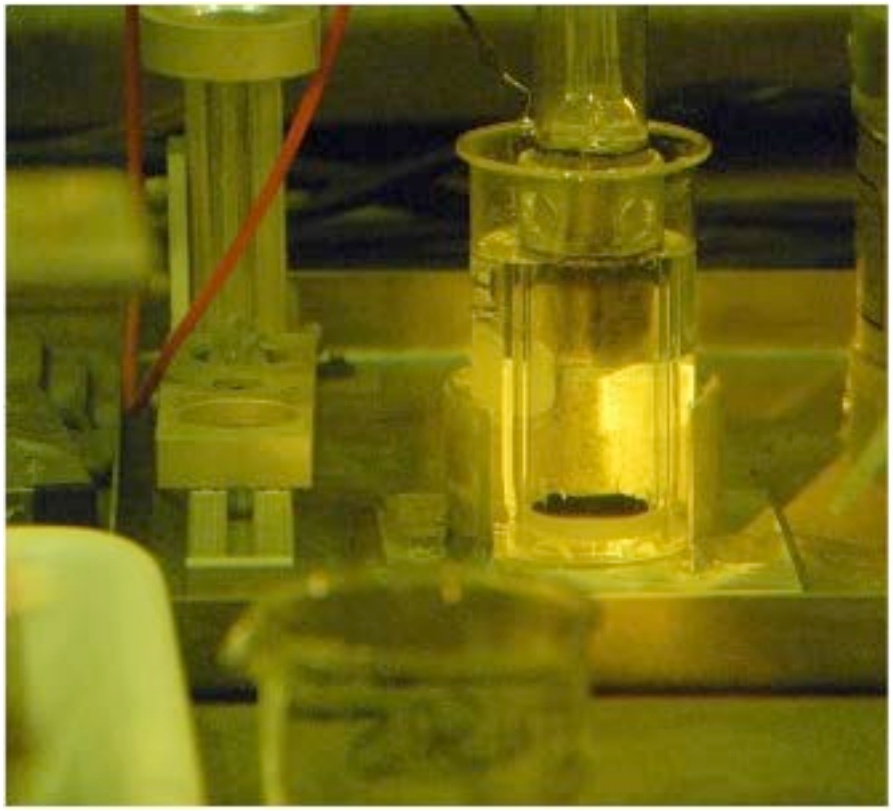
- Deconsolidation – Electrochemical decomposition of matrix
- Leach – 2-24 hour leaches in boiling concentrated HNO_3
- Oxidize – OPyC 72 hours in air at 750C
- Leach – 2-24 hour leaches in boiling concentrated HNO_3

- Chemical analysis
  - Gamma Spectrometry
    - Gamma emitting fission product concentration
  - Mass Spectrometry
    - U/Pu, selected isotopes
  - Sr separation – beta emitter by gas proportional counting

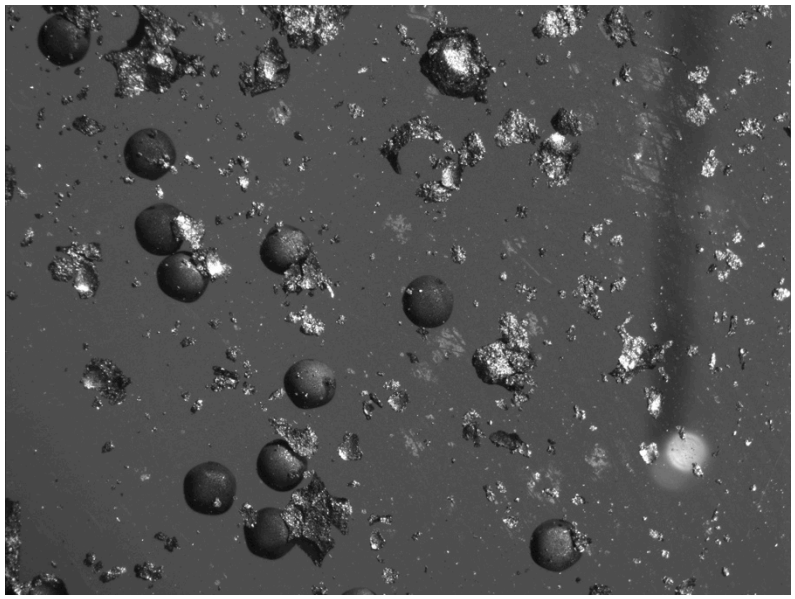
Deconsolidation

Breaking down compact matrix to release particles

- Matrix Deconsolidation
  - Electrolytic <10 W and 4 M HNO_3



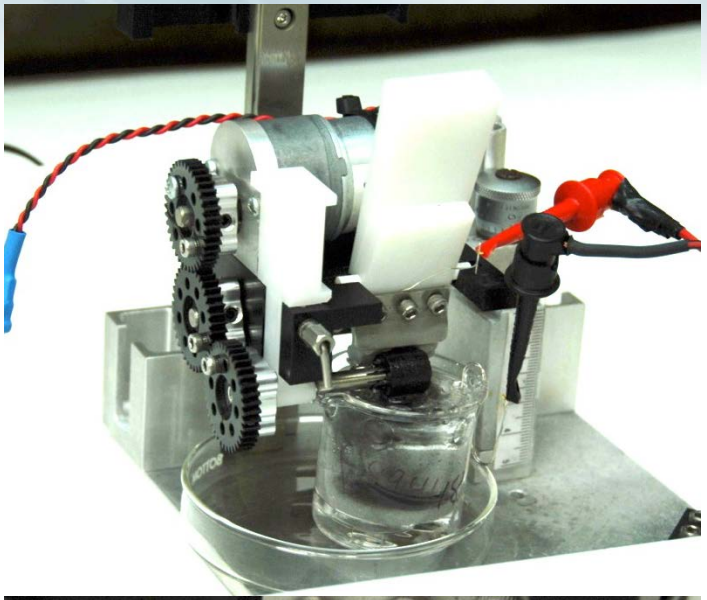
- Cathode (reduction):
- $HN(V)O3 + e^- \rightarrow 2\ N(IV)O_2 + OH^*$
- Anode (oxidation):
- $C(0) + 4\ OH^* \rightarrow C(IV)O_2 + 2\ H_2O + 4\ e$



Radial Deconsolidation

- Rotating compact in contact with electrode and acid
- Remove ~1 mm layer from circumference
- Repeat until shaft is contacted
- Complete axis deconsolidation by conventional complete dissolution

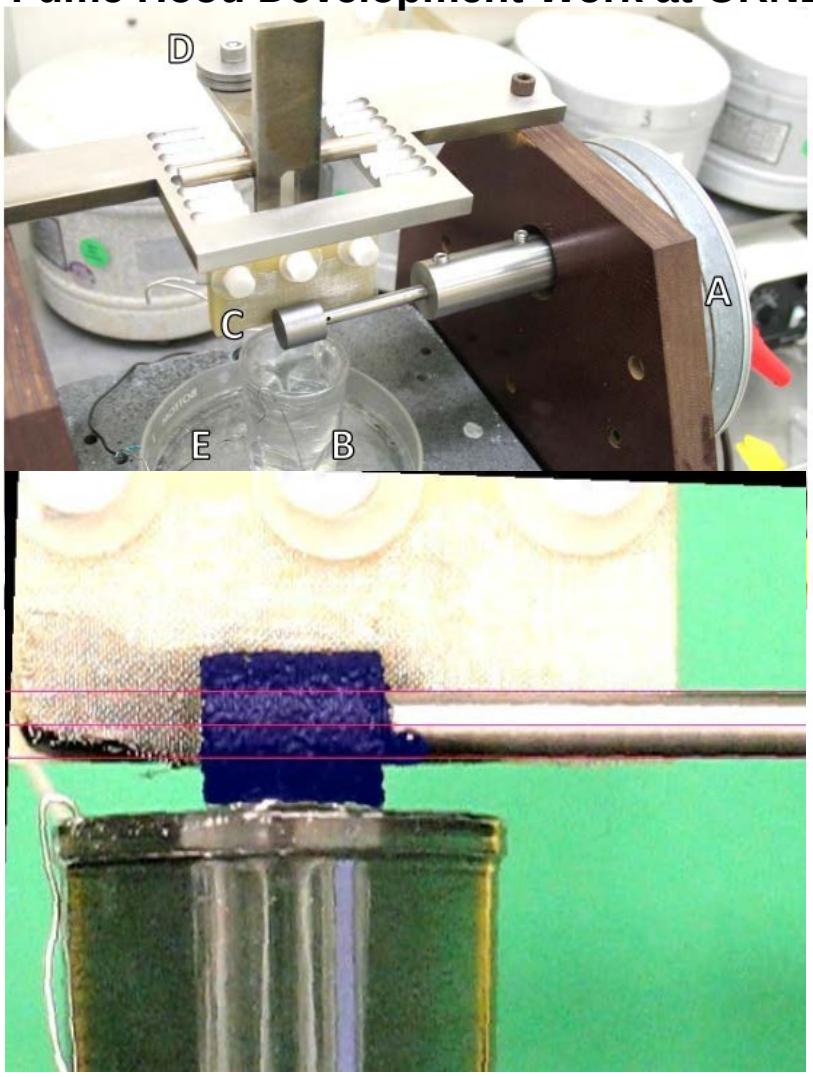
- Purpose – Measure gradient of fission product concentration in matrix
  - Determine if gradient of particle burnup exists



Development work by Grant Helmreich, ORNL

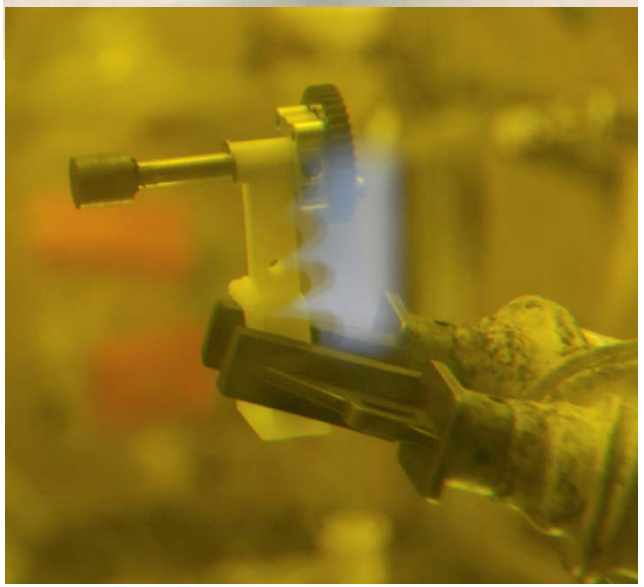
- Determined that conductive epoxy was an effective way to mount the compact to the rotating shaft
- Determined that using direct current through the shaft resulted in asymmetric breakdown of compact
- Determined that 4 N HNO_3 most effective
- Developed MatLab video imaging technique for non-contact measurement of compact diameter

Fume Hood Development Work at ORNL



INL Development

- Scale down system to work in small hot cell
- Develop remote method for gluing compact to rotating shaft
- Test and confirm MatLab FrameGrabber routine for determining diameters through hot cell window



INL Scaled Unit

- Use 12 V DC 10 rpm gearmotor
- Drive gears 1:1 ratio
- Shaft-compact-gear mounted on handle for manipulator operation
- Main structure Delrin
- Contact components Pt-Rh anode, screen Pt cathode
- Handling components HDPE

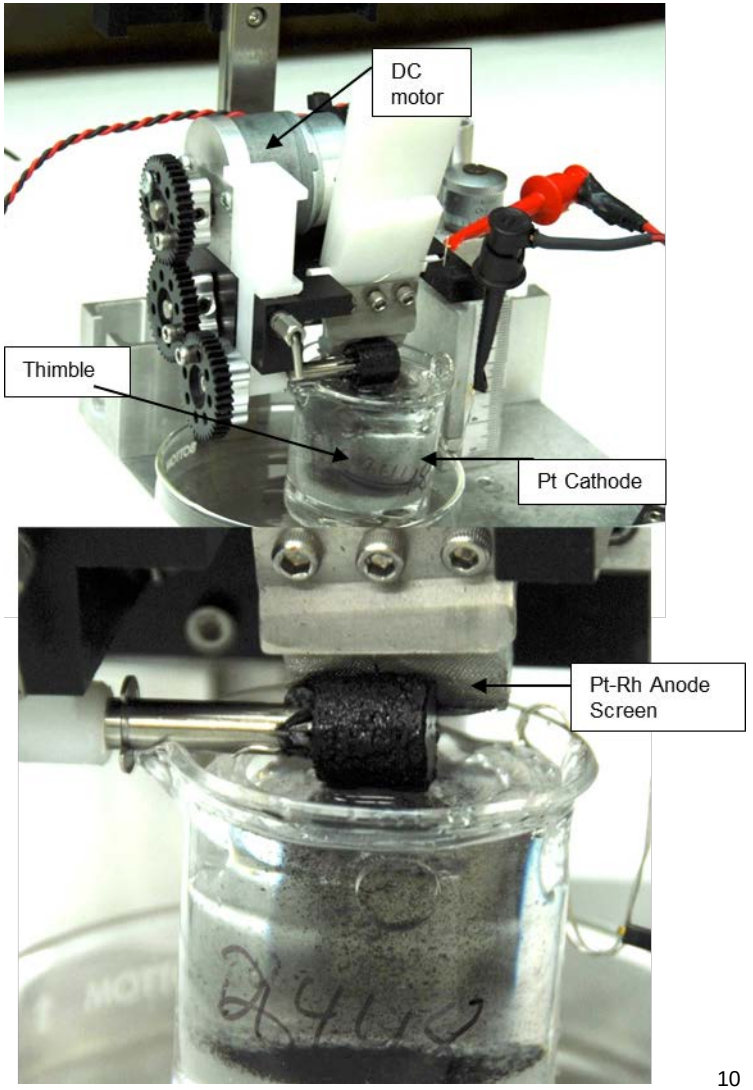
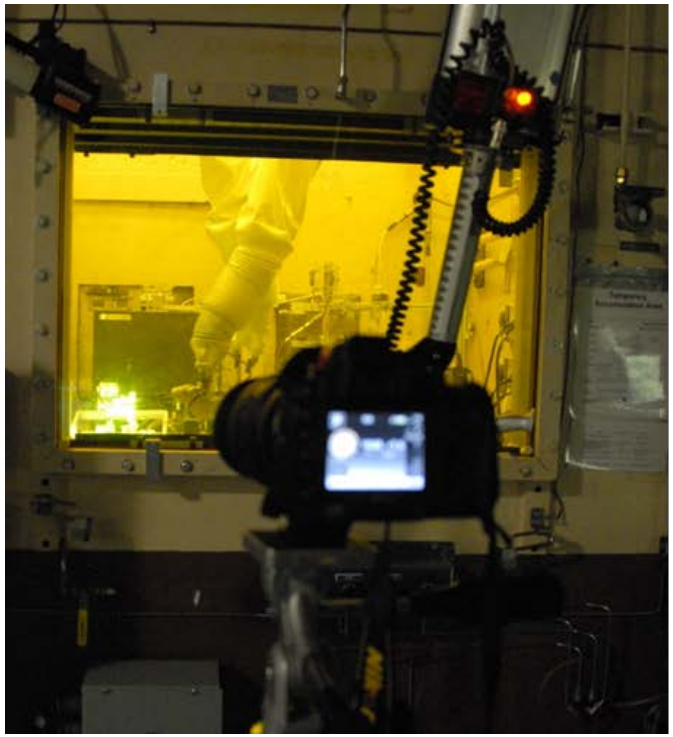
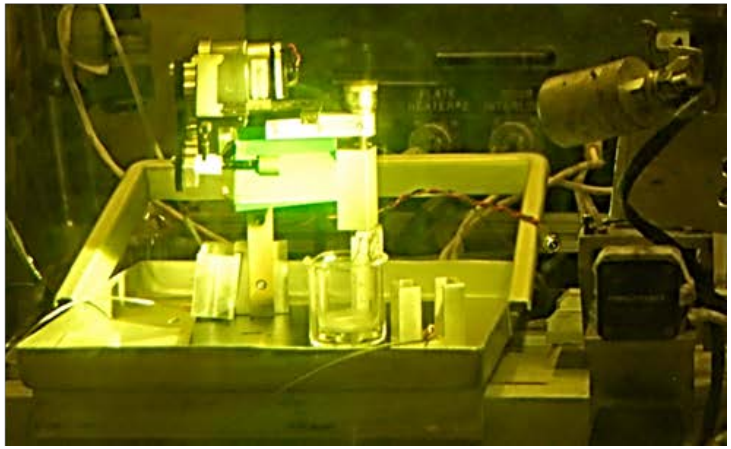


Image Analysis Joint Effort J. Stempien, INL and Grant Helmreich, ORNL

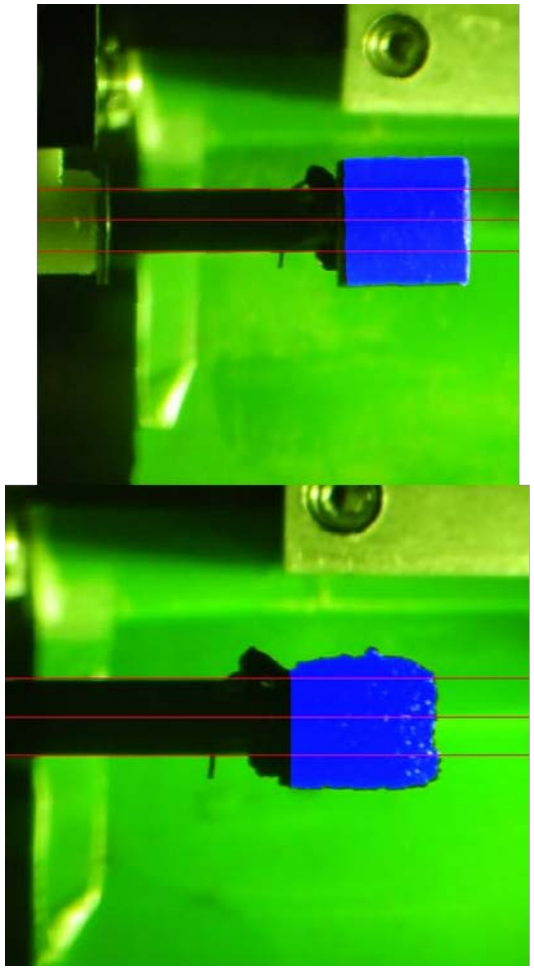
- Using Nikon D5000 DSLR with Nikkor 80-400 mm telephoto
  - Full 400 mm zoom magnification
- Working approximately 2 m from window





Frame Grabber Measurement

- Direct through window
- Video of rotating shaft/compact
- Uses green background to distinguish object of interest
- Uses known 6 mm diameter of rotated shaft as reference standard
- Compacts manually measured prior to shipment to AL Hot Cell



Pre-deconsolidation compact

Post deconsolidation compact

Observations

- In hot cell environment where electronics are at risk due to radiation, and custom modified measurement systems are expensive and operationally problematic, external video interpretation is an effective alternative.

- HDPE lacks the precision for tightly fit machined parts. Despite not being rated for high radiation, Delrin machines well and has held up in most operations.

References

- Stempien, J. D., Radial Deconsolidation of AGR-3/4 Compacts 3-3, 12-1, and 12-3, INL/EXT 17-43182 September 2015.
- Helmreich, Grant, Fred C. Montgomery, and John D. Hunn, Development of a Radial Deconsolidation Process, ORNL/TM 2015\699, December 2015.

Thanks for your kind attention

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