LA-UR- 09-03321

Approved for public release; distribution is unlimited.

Title: Ratchet Growth in PBX 9502

Author(s): Darla Graff Thompson, Geoff W. Brown, Joseph T. Mang, Brian Patterson, Bart Olinger, Racci DeLuca, Stephanie Hagelberg, Los Alamos National Laboratory

Intended for: Society for Experimental Mechanics, Annual Conference, Albuquerque, NM, 1 - 4 June 2009.

Los Alamos NATIONAL LABORATORY EST.1943

Ratchet Growth in PBX 9502

Darla G. Thompson

Geoff W. Brown, Joseph T. Mang, Brian Patterson, Bart Olinger,
Racci DeLuca, Stephanie Hagelberg

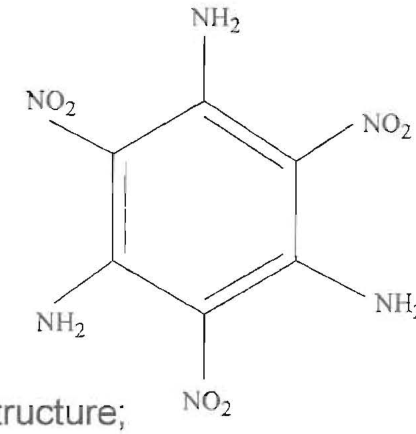
DE-1, DE-6, WT-5, MST-7
Los Alamos National Laboratory
Los Alamos, NM 87545

SEM Annual Conference, 1 - 4 June 2009
Albuquerque, NM

Funded by Weapons Surety, Los Alamos National Laboratory.

PBX 9502 (plastic bonded explosive composite)

5 wt% binder (Kel-F or chlorotrifluoroethylene/vinylidine fluoride copolymer)
95 wt% TATB (triaminotrinitrobenzene)



TATB

Recycled vs. Virgin Processing

- an insensitive high explosive with sheet-like H-bonding and graphitic crystal structure;

- anisotropic CTE for 3 directions of single-crystal TATB (similar to graphite and boron nitride)

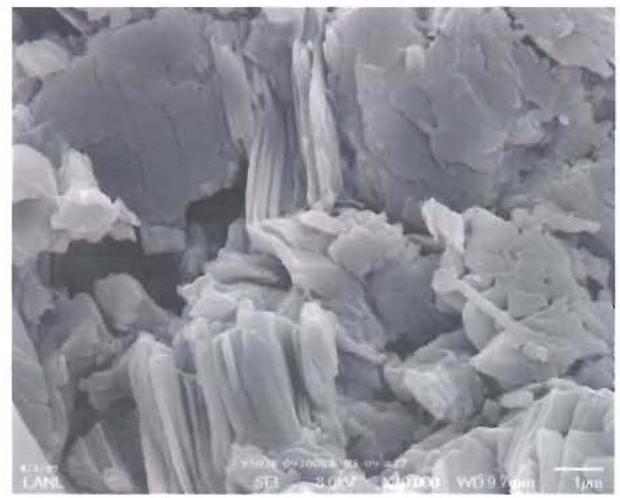
  $a = 8.3\text{ e-6 } K^{-1}$
  $b = 20.9\text{ e-6 } K^{-1}$
  $c = 248\text{ e-6 } K^{-1}$

- pressed TATB composites undergo irreversible volume change (ratchet growth) upon thermal cycling;

- ratchet growth is asymptotic for repeated cycles over a given thermal range, and begins anew if range is increased;

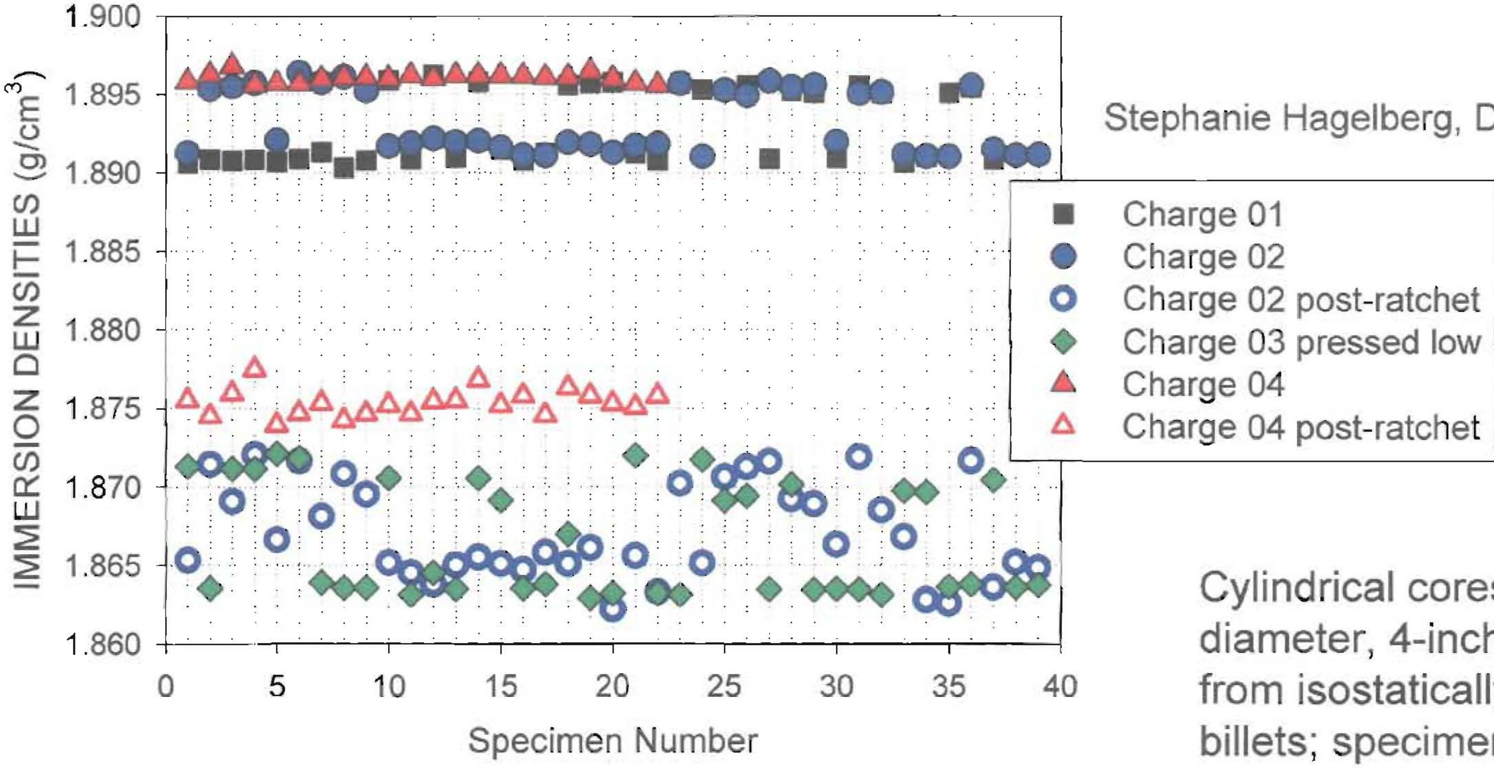
- ratchet growth magnitude is effected by binder properties, however, pressed TATB with no binder shows effect;

- mechanism of ratchet growth is unknown but likely related to high CTE anisotropy in the crystal;



PBX 9502, SEM
Ed Roemer
DE-1, LANL

Specimen Densities: As-Pressed and Post Ratchet Growth

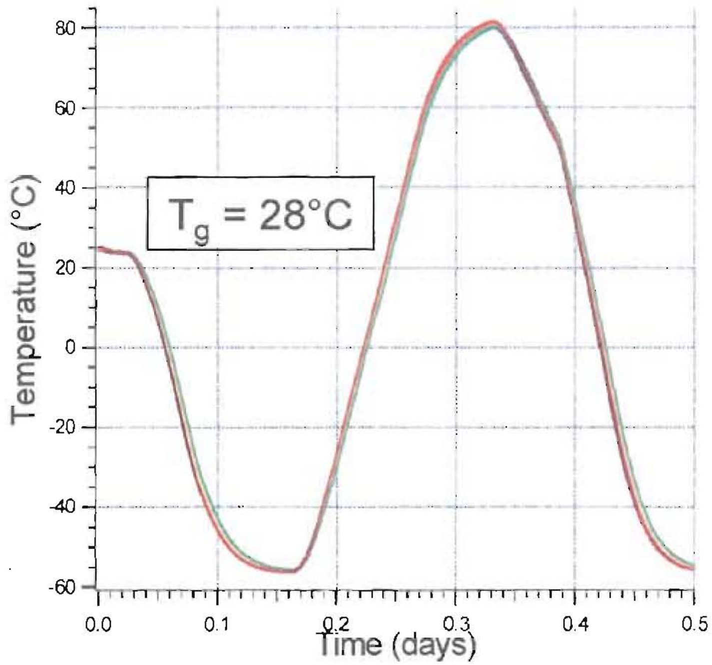


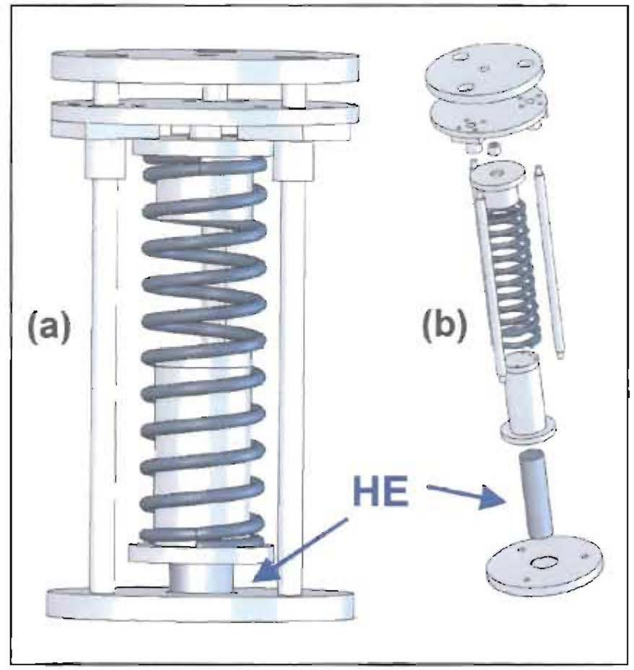
Stephanie Hagelberg, DE-3

Cylindrical cores (1-inch diameter, 4-inch long), cut from isostatically-pressed billets; specimens cut from these cores.

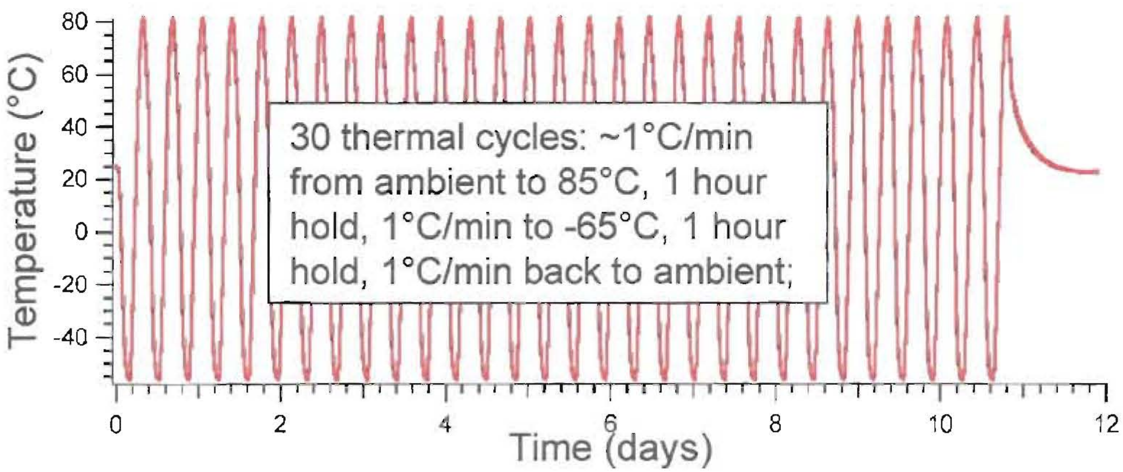
Charge 01: high-density (nominal) pressed, 20 kpsi;
Charge 03: low-density pressed, 10 kpsi;

Charge 02 cores, high-density (nominal) pressed, 20 kpsi; thermal cycled w/ no load
Charge 04 cores, high-density (nominal) pressed, 20 kpsi; thermal cycled w/ 100 psi axial load



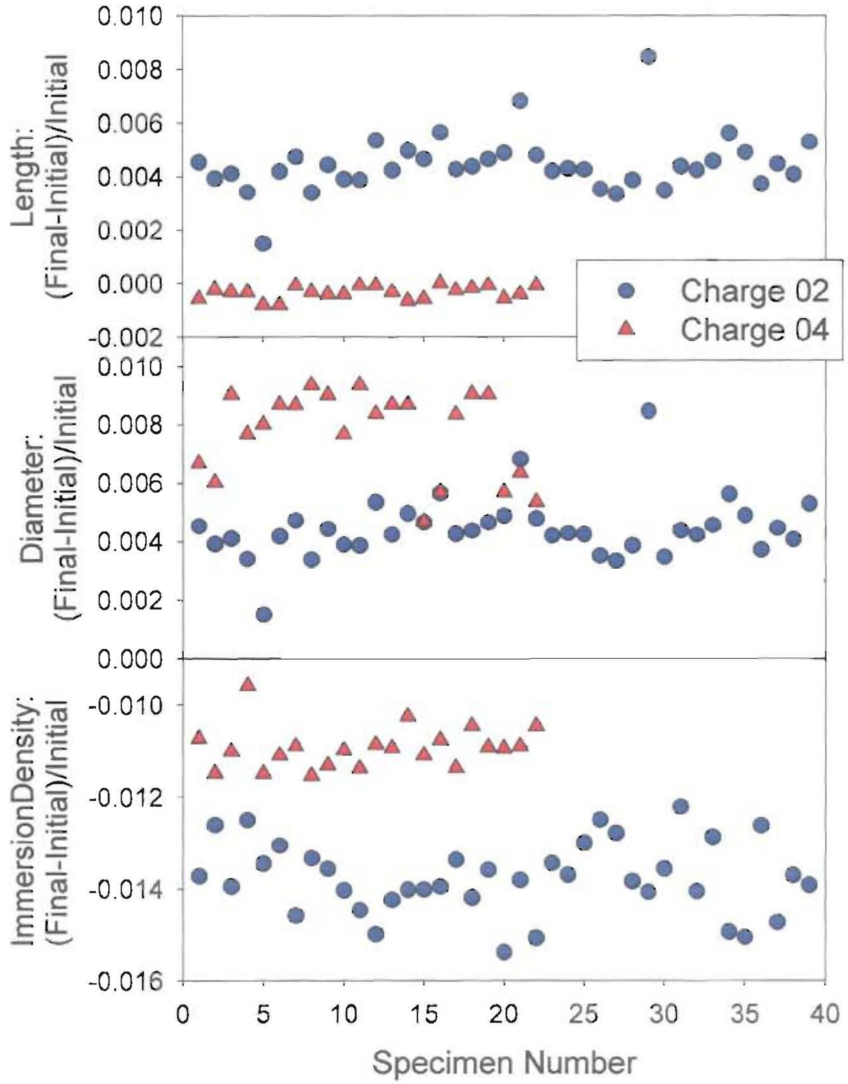


Spring rig used to apply 100 psi axial load to **HE core**; load varied +/- 5% through thermal range.



Geoff W. Brown, DE-1

Relative Core Dimension Changes Due to Ratchet Growth



Charge 02: thermal cycling with no axial load

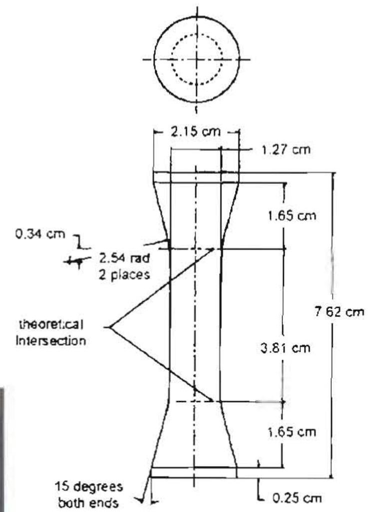
Charge 04: thermal cycling with 100 psi axial load

100 psi of axial load on Charge 04:

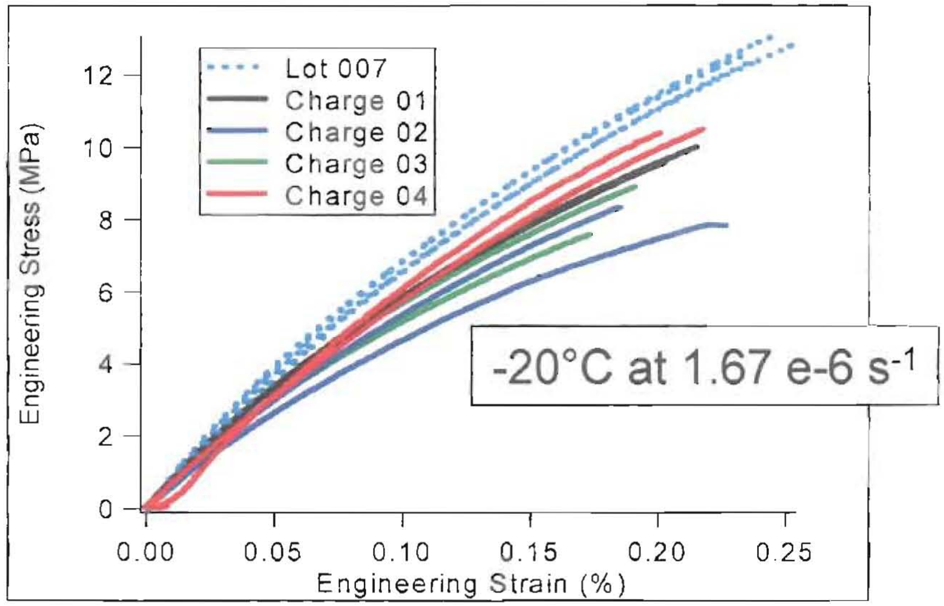
- stops all growth in length
- increases growth in diameter relative to Charge 02
- decreases overall density change from ~1.4 to ~1.1%.

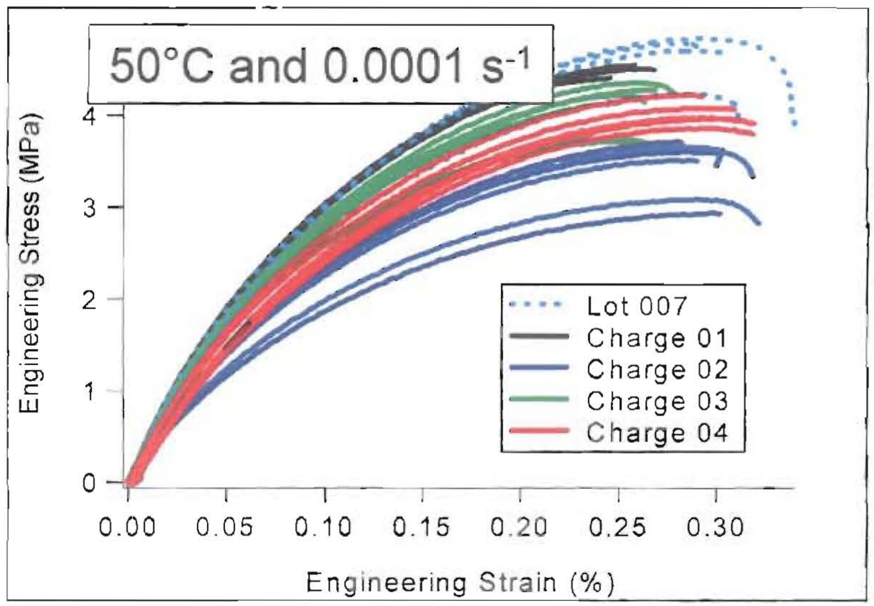
Quasi-Static Uniaxial Tension

Instron 5567 w/ MTS Renew/E Controller
Bemco Environmental Chamber

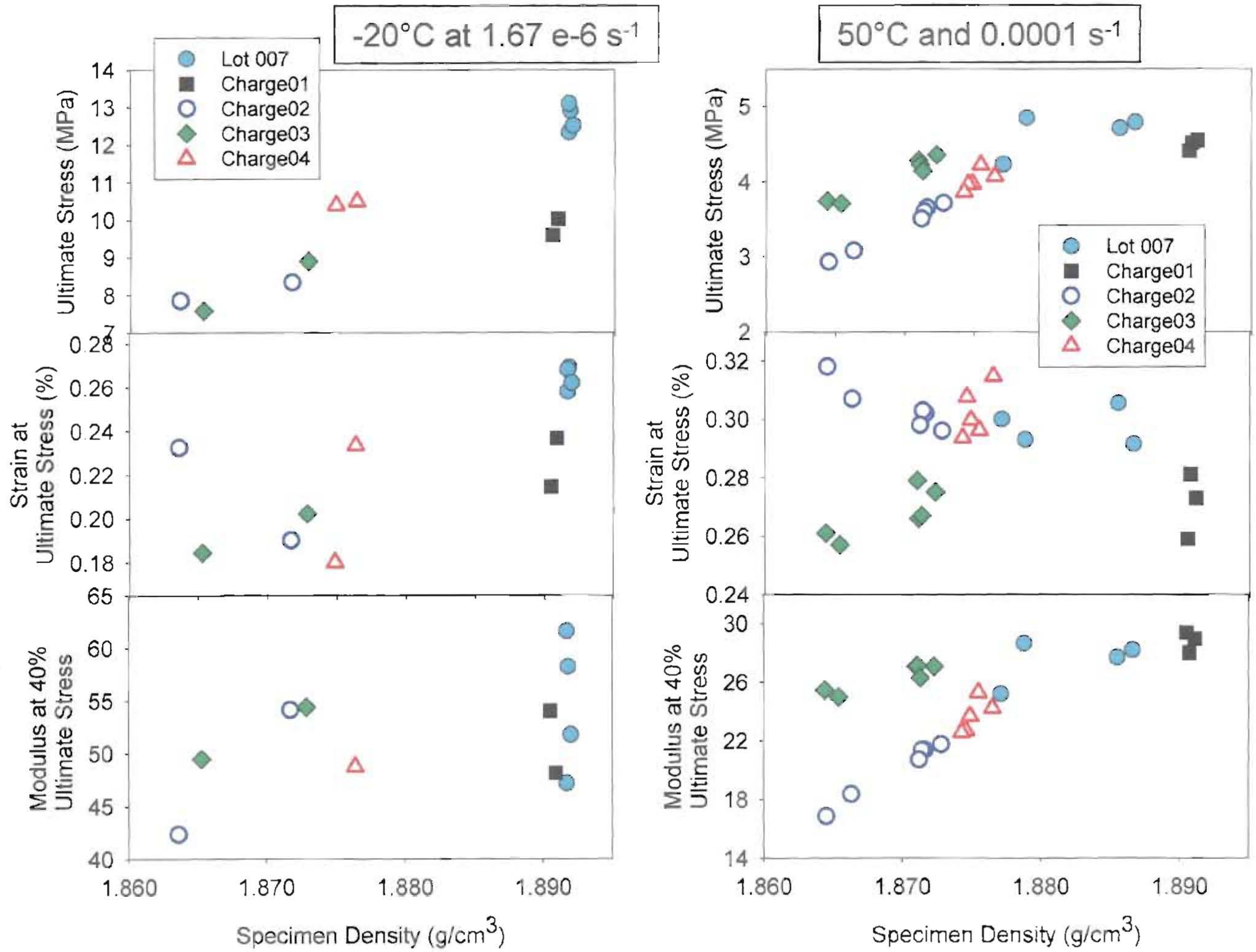


Racci DeLuca, DE-1





PBX 9502 Tensile Parameters as a Function of Density: As-Pressed (solid) and Ratchet Grown (open)



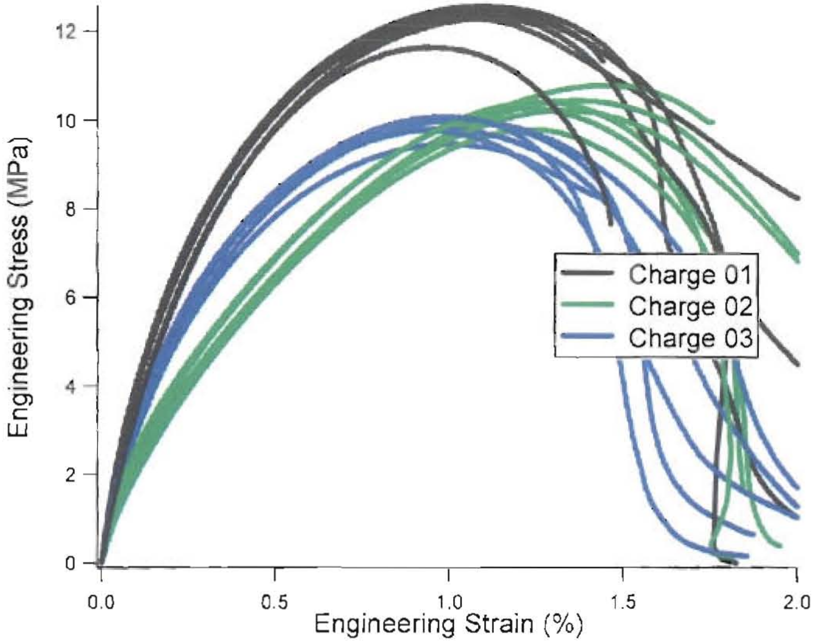
-20°C tensile failure is brittle and does not distinguish as-pressed from ratchet grown specimens;

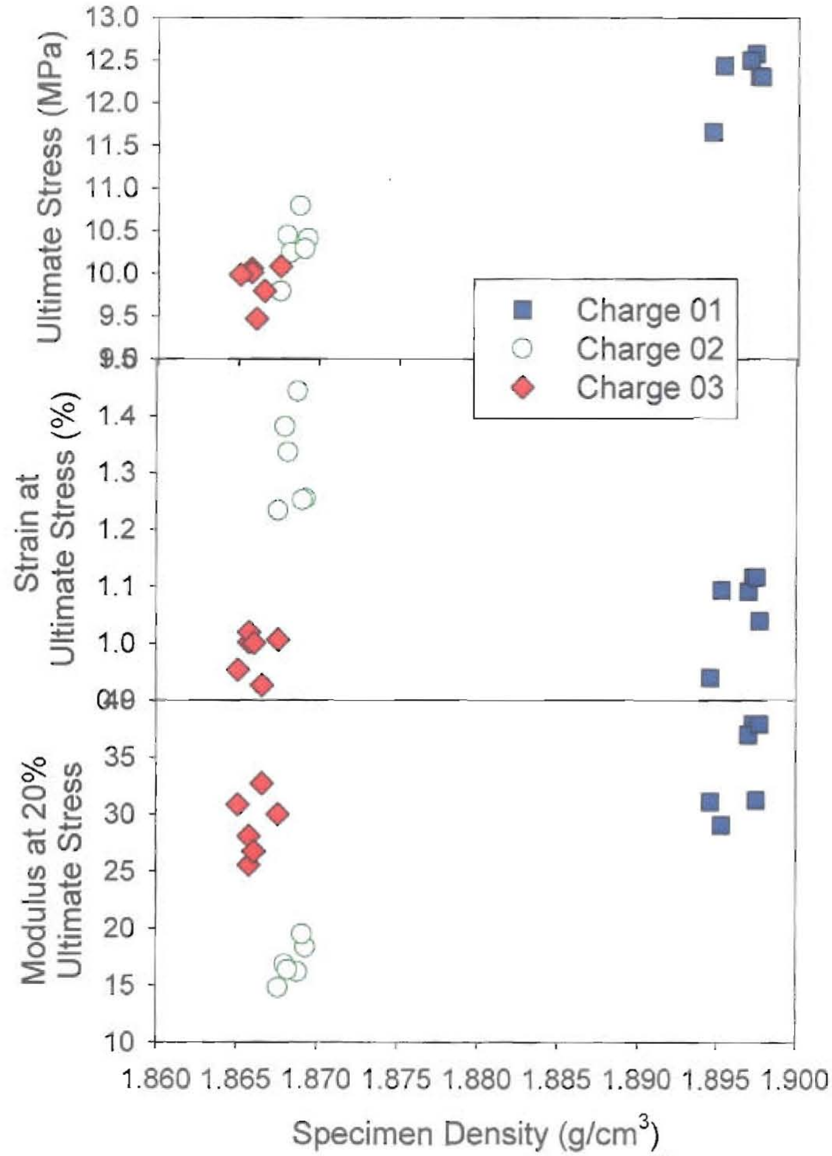
50°C tensile parameters for ratchet grown specimens show a significant decrease in strength and modulus, with an increase in strain at failure when compared with their pressed, equivalent-density counterpart specimens.

The effect of uniaxial ratchet growth confinement on tensile response is not distinguished (trend similar to unconfined).

Quasi-Static Uniaxial Compression:

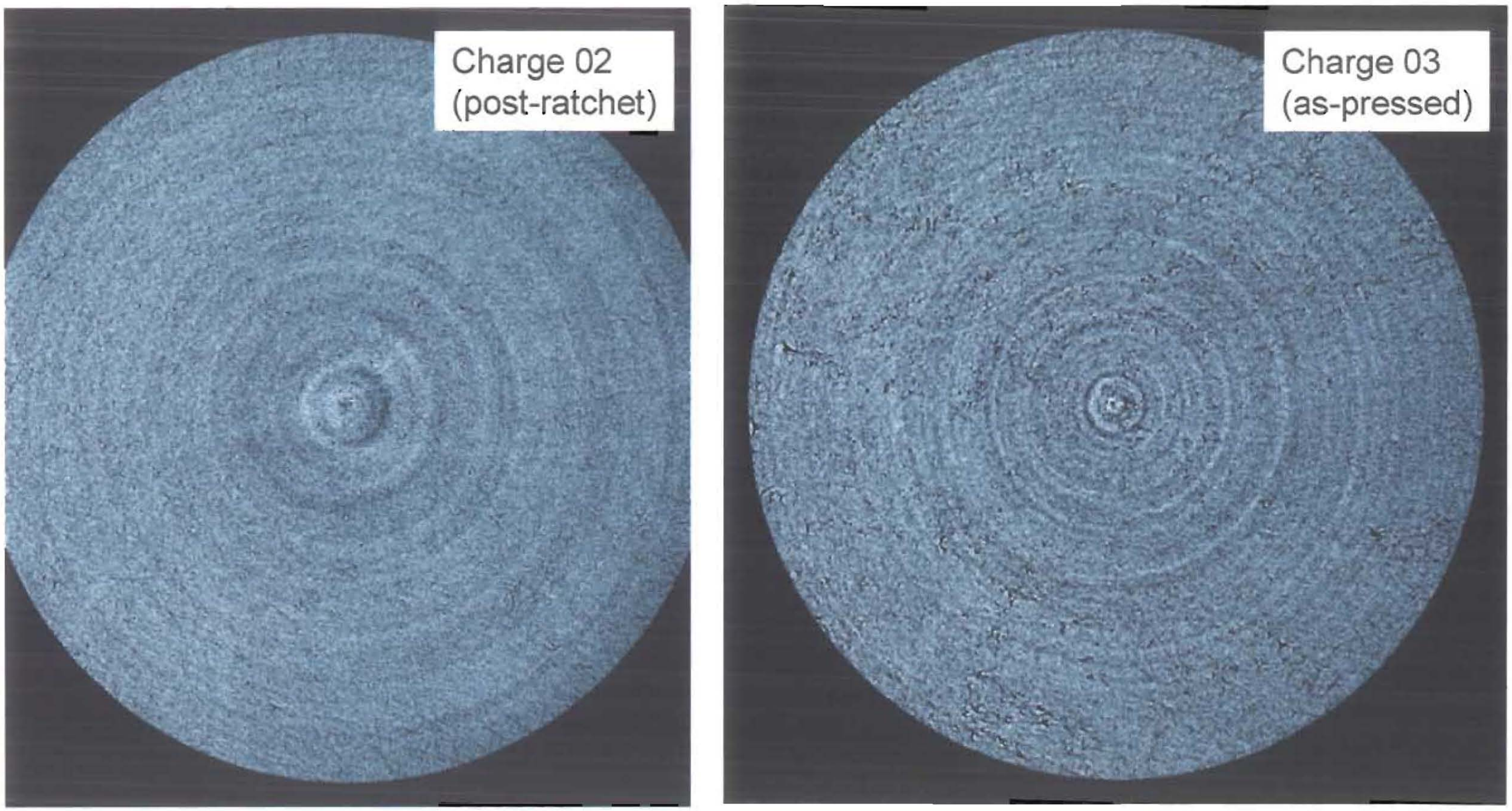
50°C, 0.0001 s^{-1}





From 50°C compression data, ratchet grown specimens have a similar strength, but a lower modulus and higher strain than would be predicted based on their density alone.

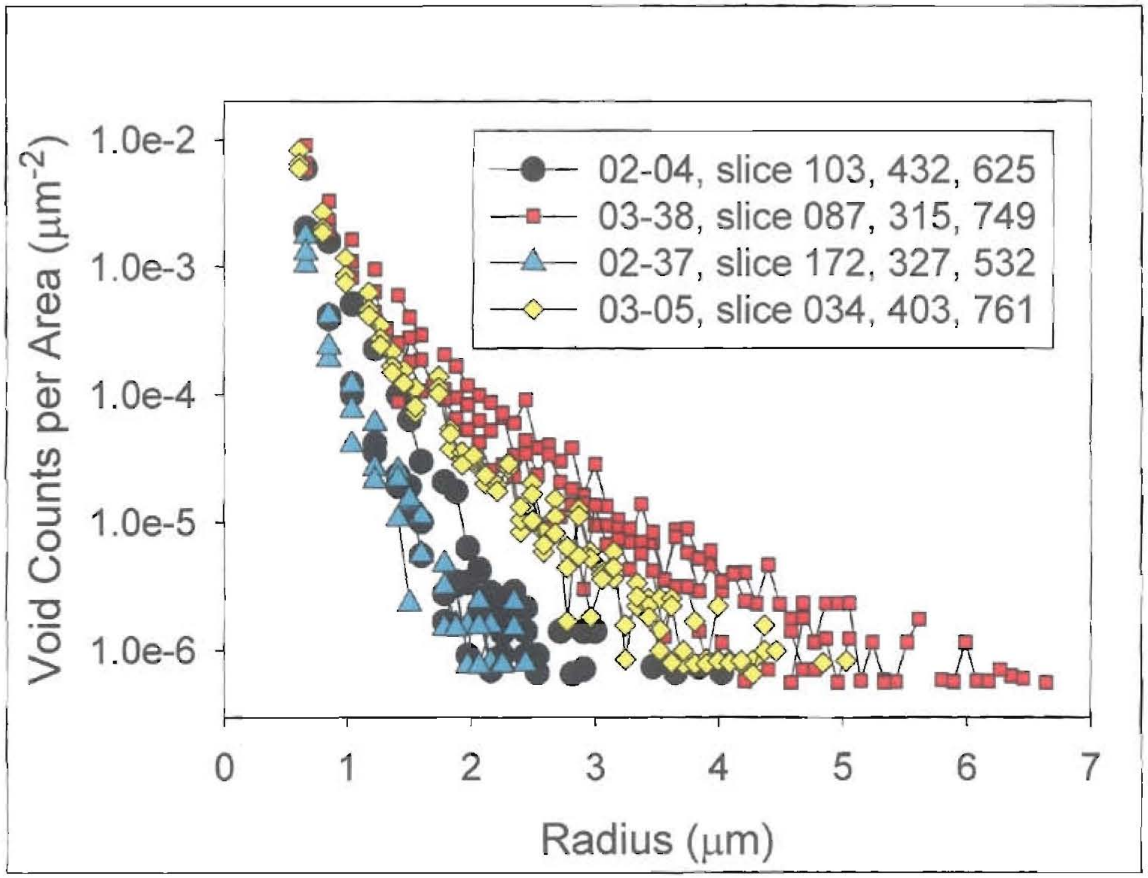
Micro X-Ray Computed Tomography – Brian Patterson, MST-7



0.25 mm

Measurements performed at LANL on an Xradia (Concord, CA) micro CT Instrument with an acceleration voltage of 80 kV produce 3D tomography images with ~2μm resolution.

Micro X-Ray CT Image analysis: Clemex Vision



Three different grayscale threshold values were used to determine pore size distribution; these results were averaged for three different slices through four different specimens.

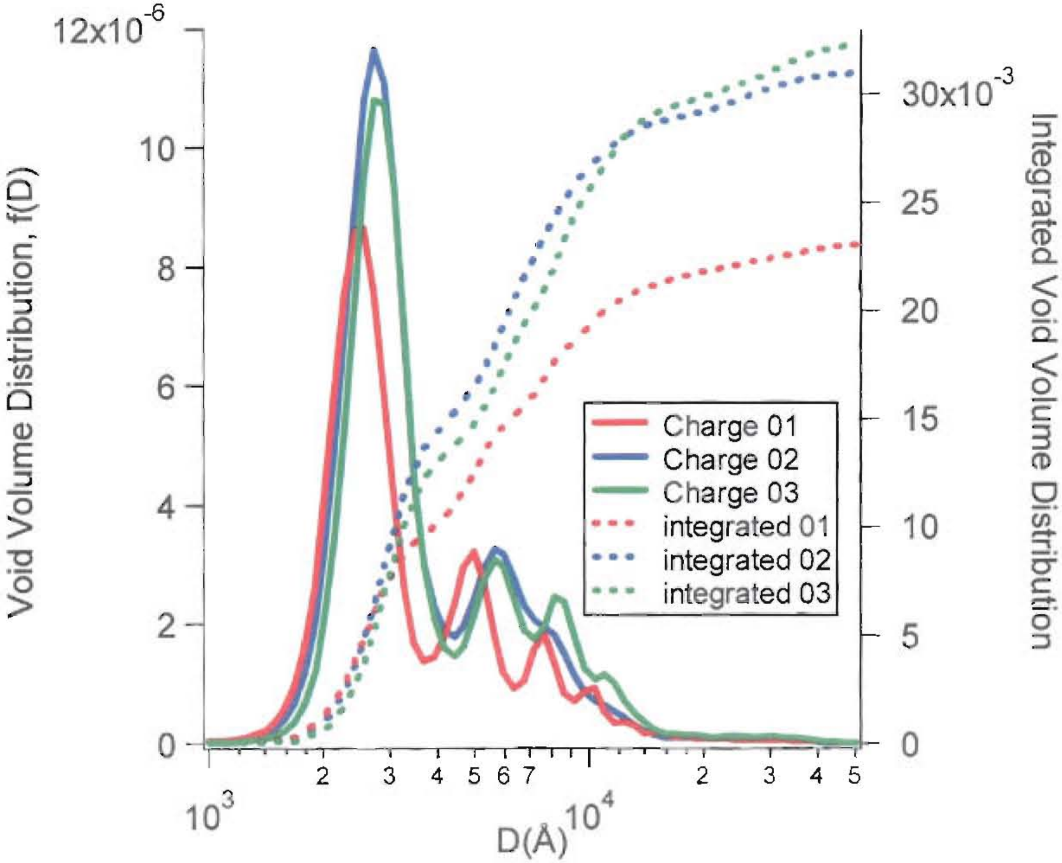
The average pore size distributions are easily distinguished for equivalent-density Charge 02 and 03 specimens.

Efforts to demonstrate aspect ratio differences of pores between Charge 02 and 03 were not successful. Charge 04 imaging is underway, where differences in pore size, aspect ratio and orientation should evident.

Ultra-Small Angle Neutron Scattering (USANS) – Joe Mang, DE-1

Measurements performed at the National Institute of Standards and Technology Center for Neutron Research (NCNR), provides pore-size distribution information in the size range of 0.05 to 10 μm;

$$I(Q) = \phi \overline{\Delta\rho}^{2} \int_{0}^{\infty} f(R) V(R) \left\langle \left| F(Q,R) \right|^{2} \right\rangle dR$$



$I(Q) =$ differential cross section

$\Delta\rho =$ contrast

$\left\langle \left| F(Q,R) \right|^{2} \right\rangle =$ assumed shape function

$\phi =$ void volume fraction

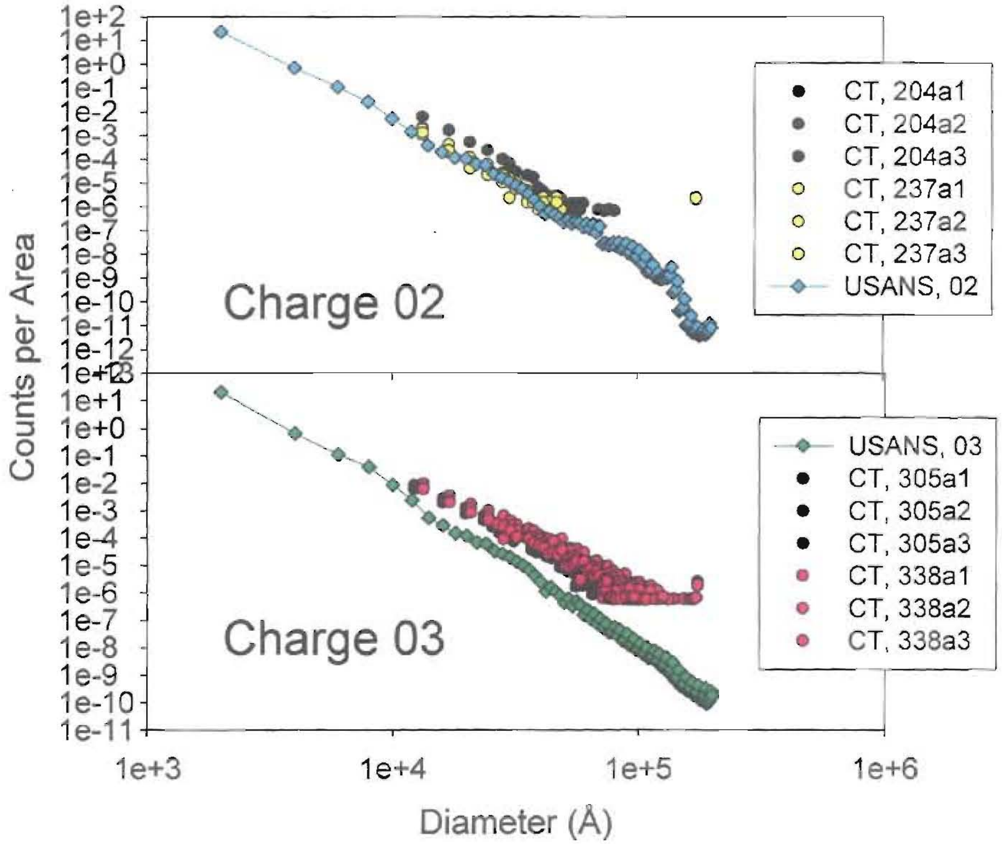
$V(R) =$ void volume

$f(R) =$ probability of void at R

Integrated peak areas correlate well with total pore content:

Charge 01: 2.3% (2.6%)
Charge 02: 3.1% (3.6%)
Charge 03: 3.2% (3.7%)

Overlay of pore size information from USANS and Micro X-Ray CT



Size range of two techniques is complementary, showing similar results, with no pore diameters exceeding ~10 μm.

Summary and Conclusions:

Low-load (100 psi) uniaxial confinement stops growth in one dimension but enhances growth laterally; has a small effect on lowering overall density change.

Above the binder T_g (28°C), both tension and compression parameters (tested at 50°C) show that, for specimens of similar density, ratchet grown specimens have lower modulus values and higher strains at failure. The compressive strength appears to correlate linearly with specimen density, regardless of how that density is obtained, while the tensile strength is significantly lower for ratchet grown parts when compared with as-pressed parts of the same density.

Below binder Tg, brittle failure does not correlate with how lower density is obtained.

Micro-structural characterization by USANS and Micro X-Ray CT are shown to provide complimentary information for these materials; for specimens of the same density, ratchet grown specimens are identified as having a significantly smaller average pore size.

Ongoing Work:

Ratchet growth and low-density pressed specimens from this project have been provided for embedded-gauge plate impact testing (sensitivity), detonation failure cones (performance) and may be used for cylinder tests (equation of state).