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Radiography for Autopsy of Damaged Foams

Bernice E. Mills and LeRoy L. Whinnery
Sandia National Laboratories,
Livermore, CA

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Why use foams?

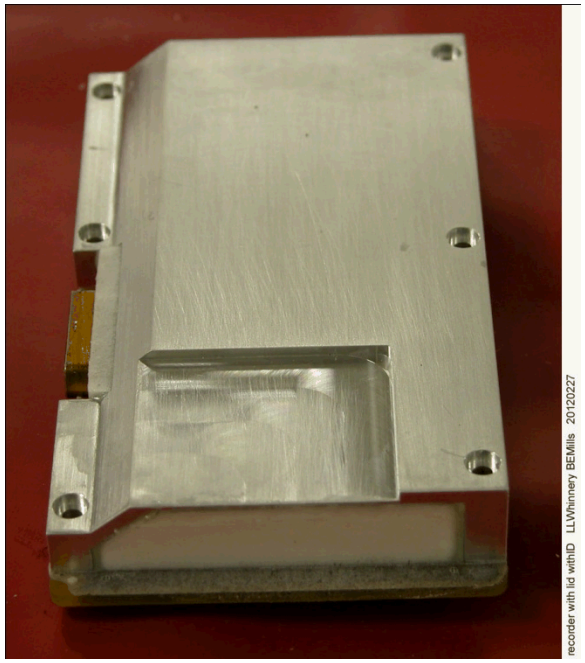
- Encapsulation
- Structural materials

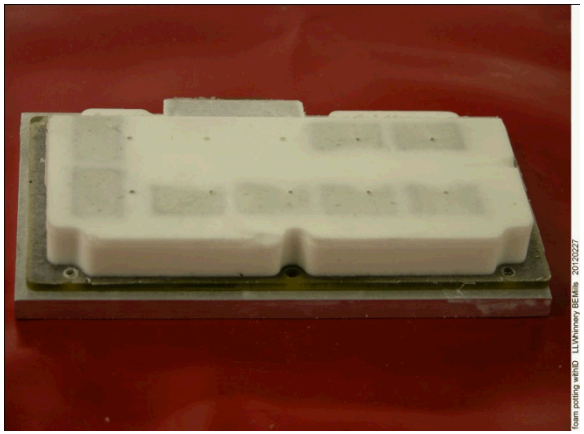
- For shock mitigation
- For electrical isolation
- As an obscurant
- To keep other components in place

How study foams in place?

- Neutron radiography (NR) is sensitive to protons but not easily available.
- X-rays are more sensitive to higher-Z materials. However:
  - They can be employed with foams.
  - Generally considered non-destructive.
  - Can be used as a guide to destructive testing.

Examples of foamed components.





> Some components will be harder to image.

> More high-Z material obscures the foam.

Foams used in this study

- Both are closed cell, rigid, water-blown polyurethane foams.

- PMDI is a complex mixture of the isomers of di-, tri-isocyanates and higher polymeric aromatic species derived from side reactions

- TufFoam has a different, more flexible, isocyanate linker in the middle.

Initial tests used a gas gun.

Hunting for the projectile
and its path is a challenge.

Autopsy can damage evidence.

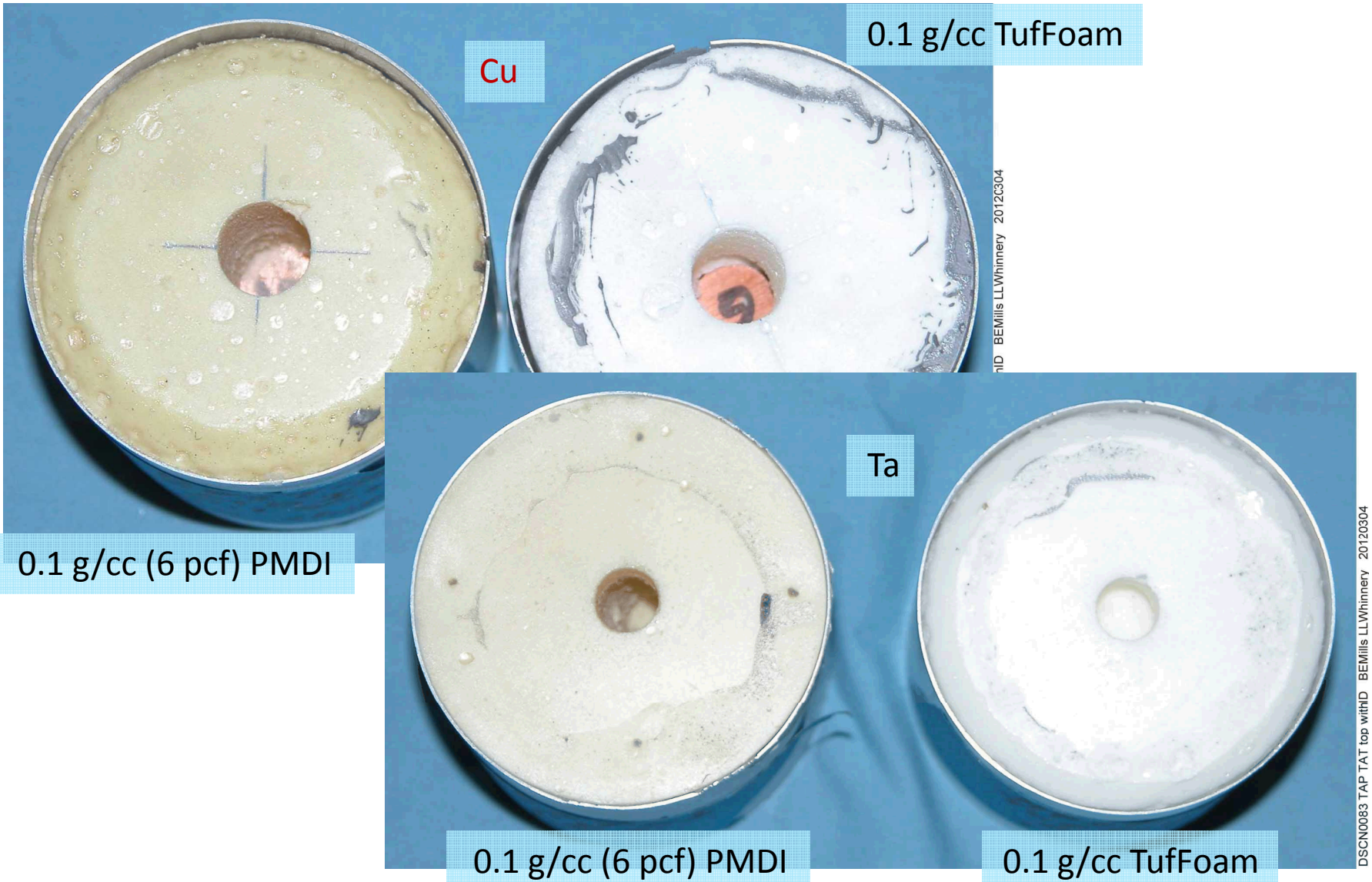
Sectioning reveals trajectory.

Knowing where to section helps.

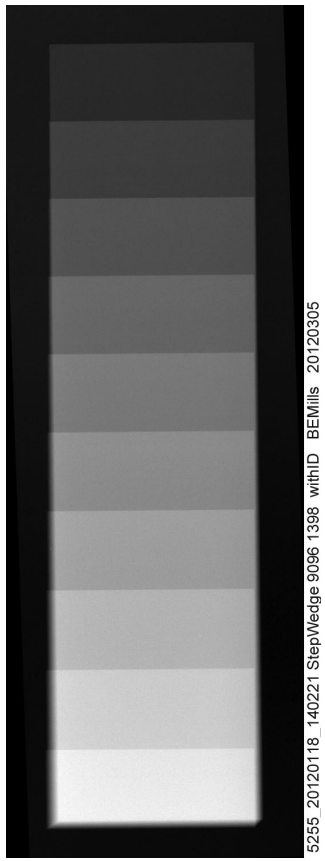
Foam and slug material and density.

ID	HPST	Foam	g/cc	pcf	Slug	g	g/cc	% travel
TAP	1	PMDI	0.1	6	Ta	10	16.6	Full
TAT	1	TufFoam	0.1	6	Ta	10	16.6	Full
Cy5	2	PMDI	0.1	6	Cu	23	9.0	Full
Cy6	2	TufFoam	0.1	6	Cu	23	9.0	61
Cy4	2	PMDI	0.1	6	Al	7	2.7	7.7
Cy2	2	TufFoam	0.1	6	Al	7	2.7	6.1
Cy3	2	PMDI	0.2	12	Al	7	2.7	2.6
Cy1	2	TufFoam	0.2	12	Al	7	Cy5	2.0

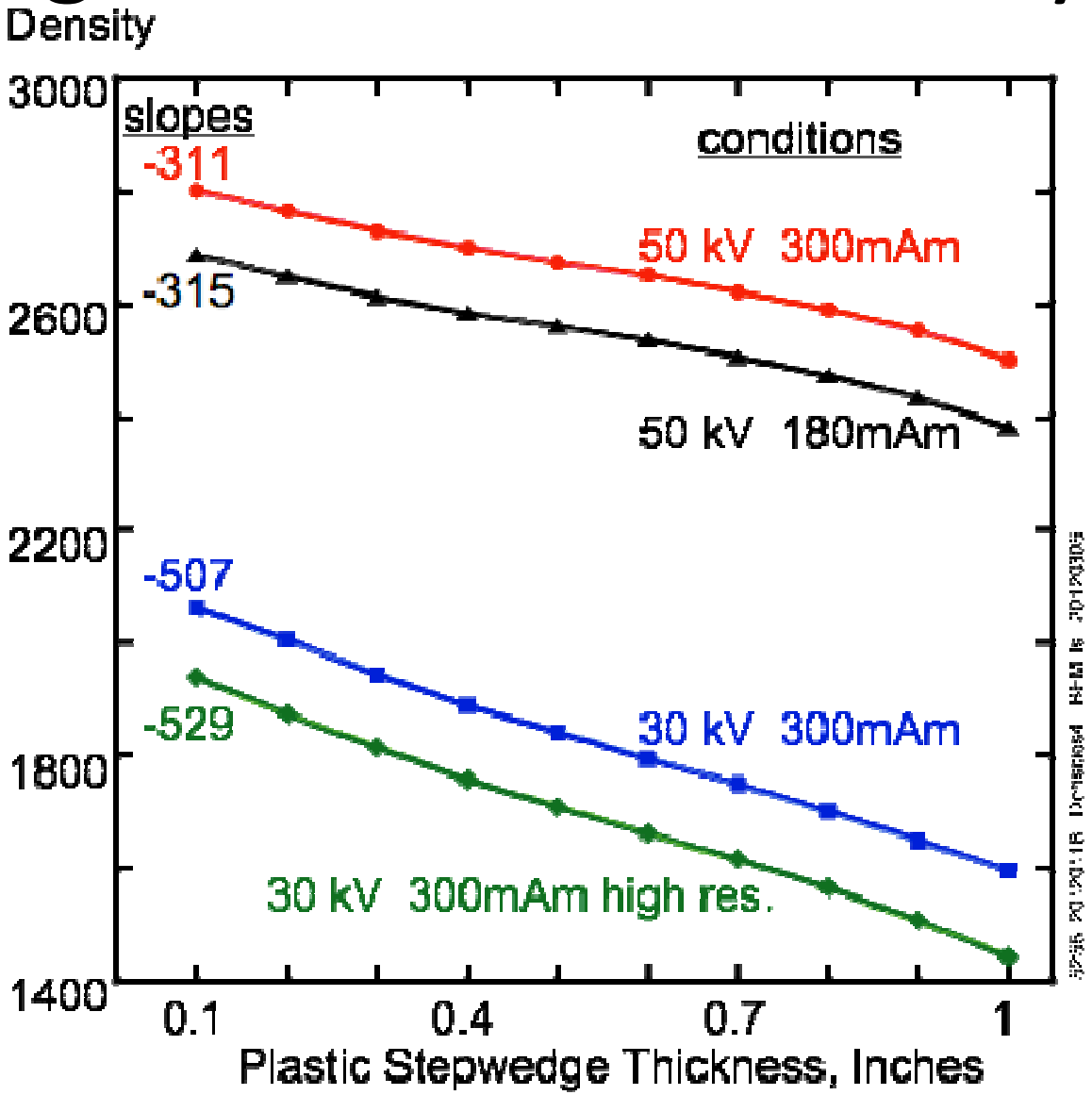
Slugs cannot always be seen.



Step wedge thickness vs. density.



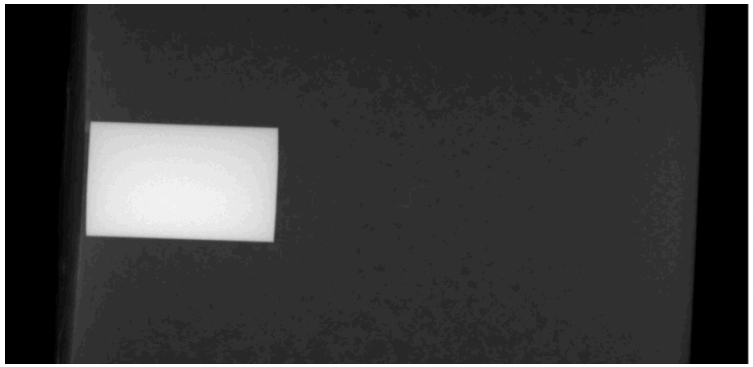
One inch plastic step wedge



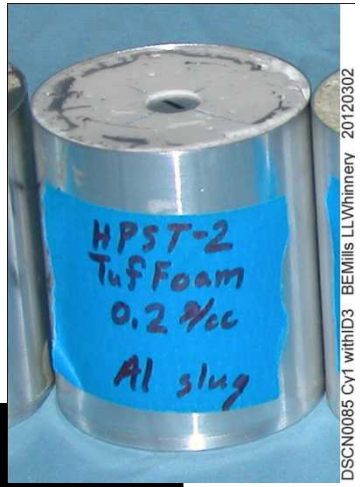
12 pcf TufFoam

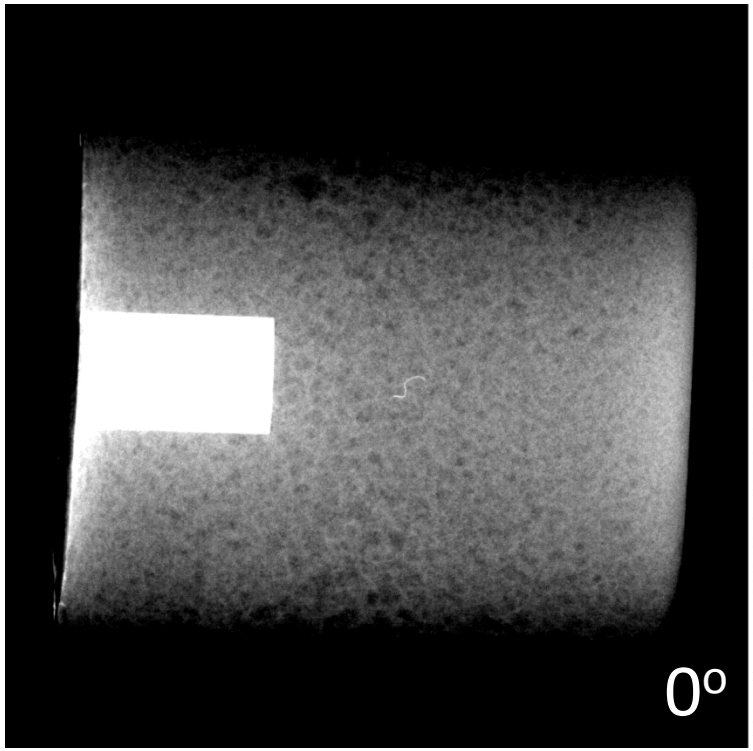
0.2 g/cc TufFoam

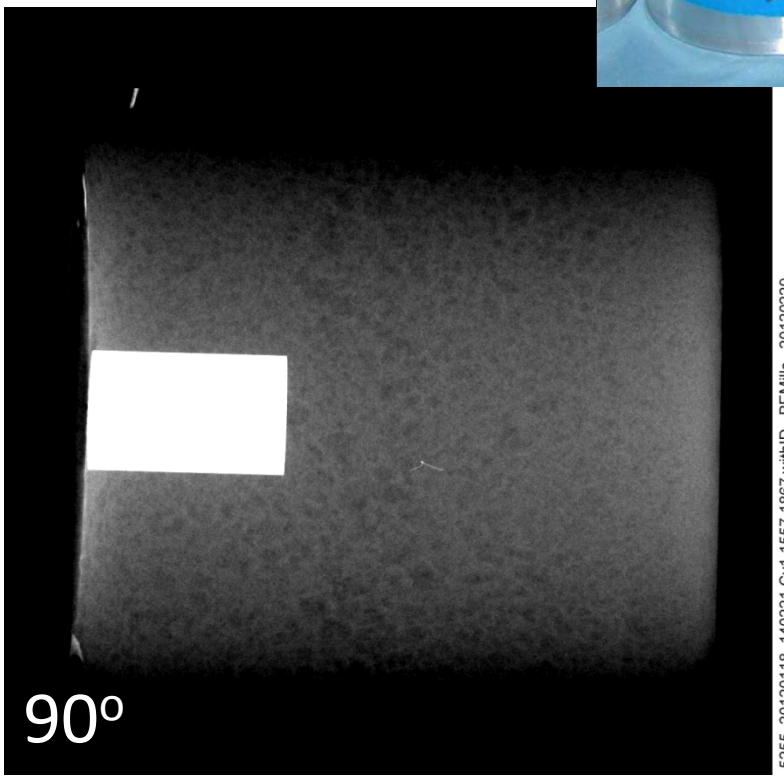
Some slugs moved very little.



0.2 g/cc (12 pcf) TufFoam--2% travel.



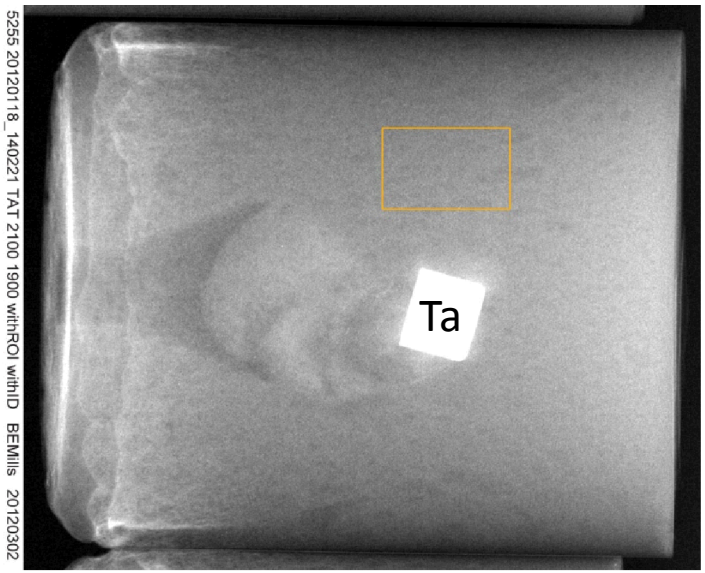


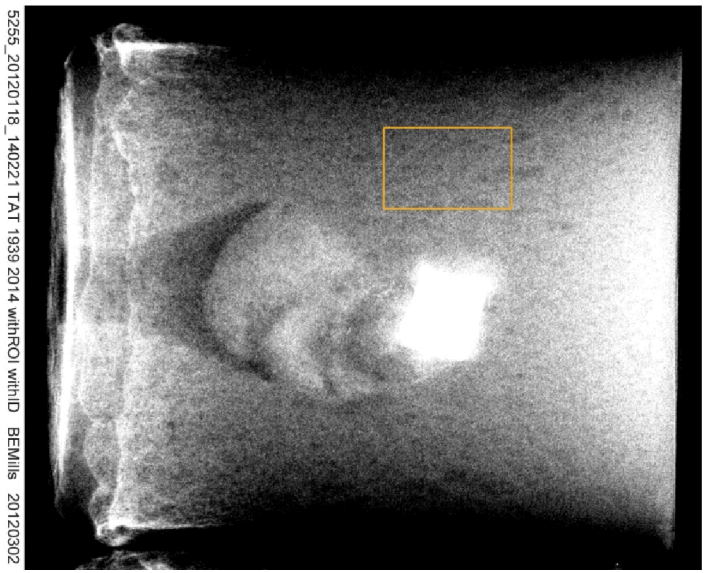


6 pcf TufFoam

0.1 g/cc TufFoam

Scaling highlights differences.



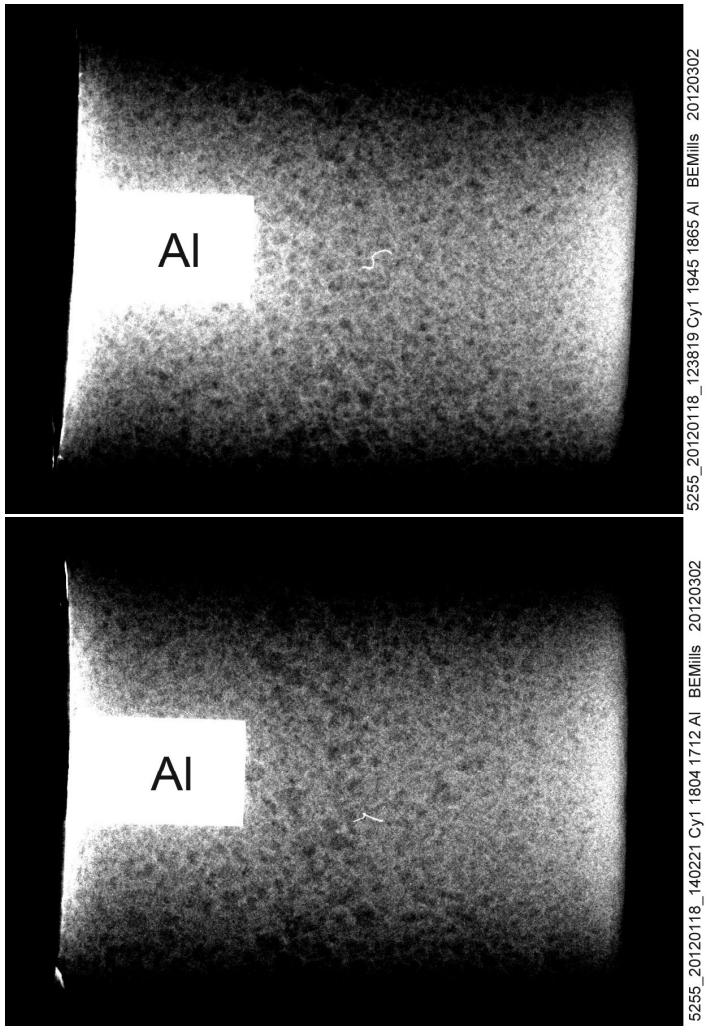


- Choose an area that is “typical”;
- i.e.
  - Not edges
  - Not ends
  - Not displaced
  - Not compressed
- Scale that area as whole dynamic range
- Some of the densest and least dense areas are now out of range.
- Differences in density are now more apparent.

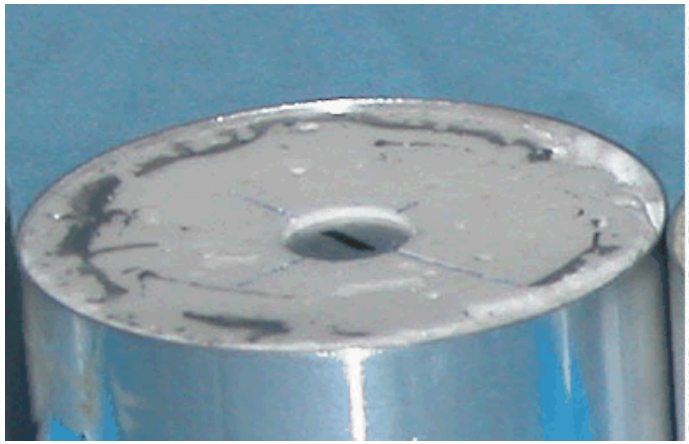
12 pcf TufFoam

0.2 g/cc TufFoam

Little movement = little displacement.



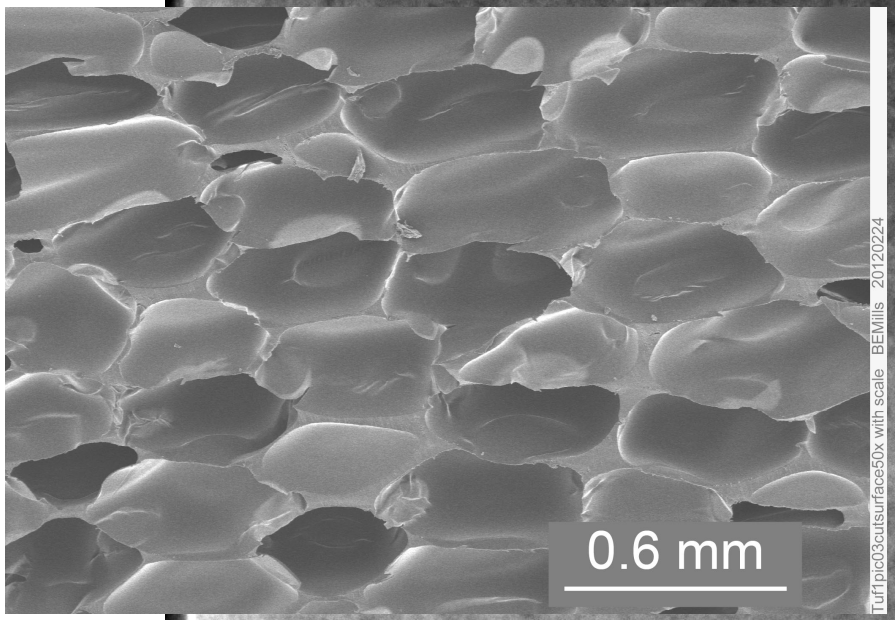
- 2% movement
- Two orthogonal views
- Scaled using an area that is typical
- Density increases:
  - At the free end (right)
  - In front of the slug (slightly)
- Density at left associated with adhesive seen below



12 pcf TufFoam

0.2 g/cc TufFoam

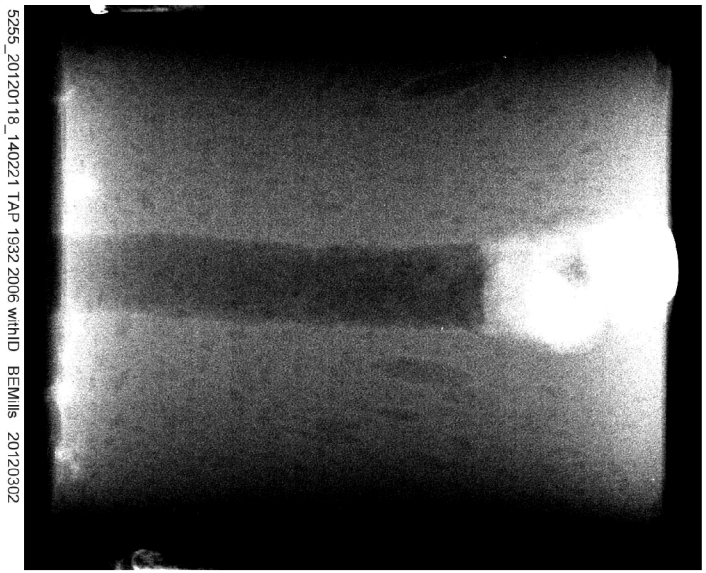
Cell structure is visible.

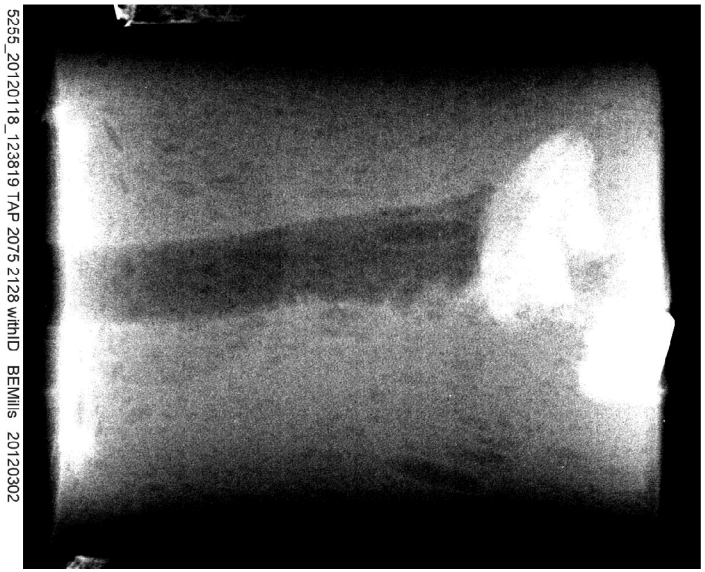


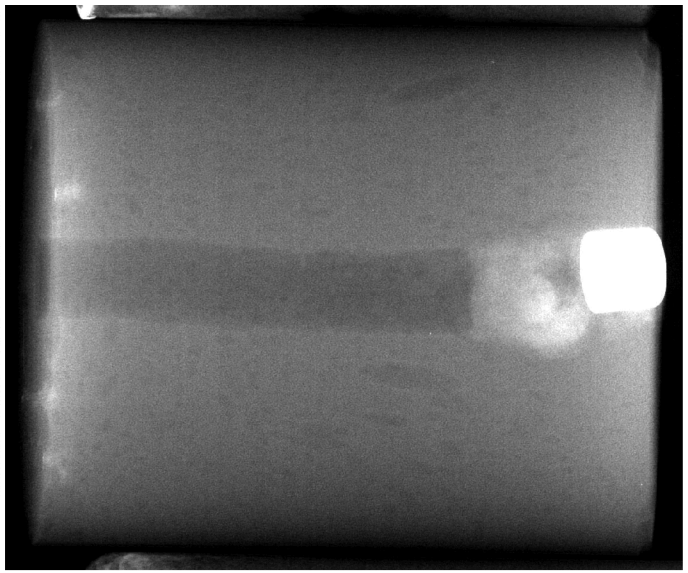
6 pcf PMDI

0.1 g/cc PMDI

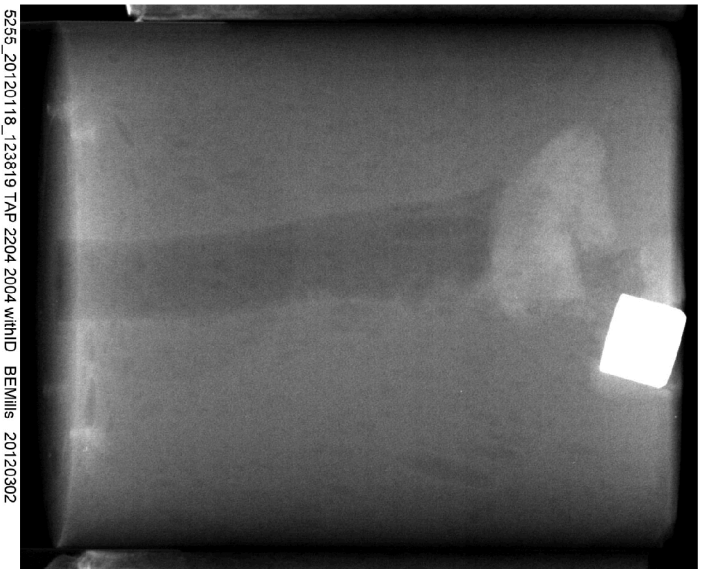
Some slugs “bottom out”.







Ta

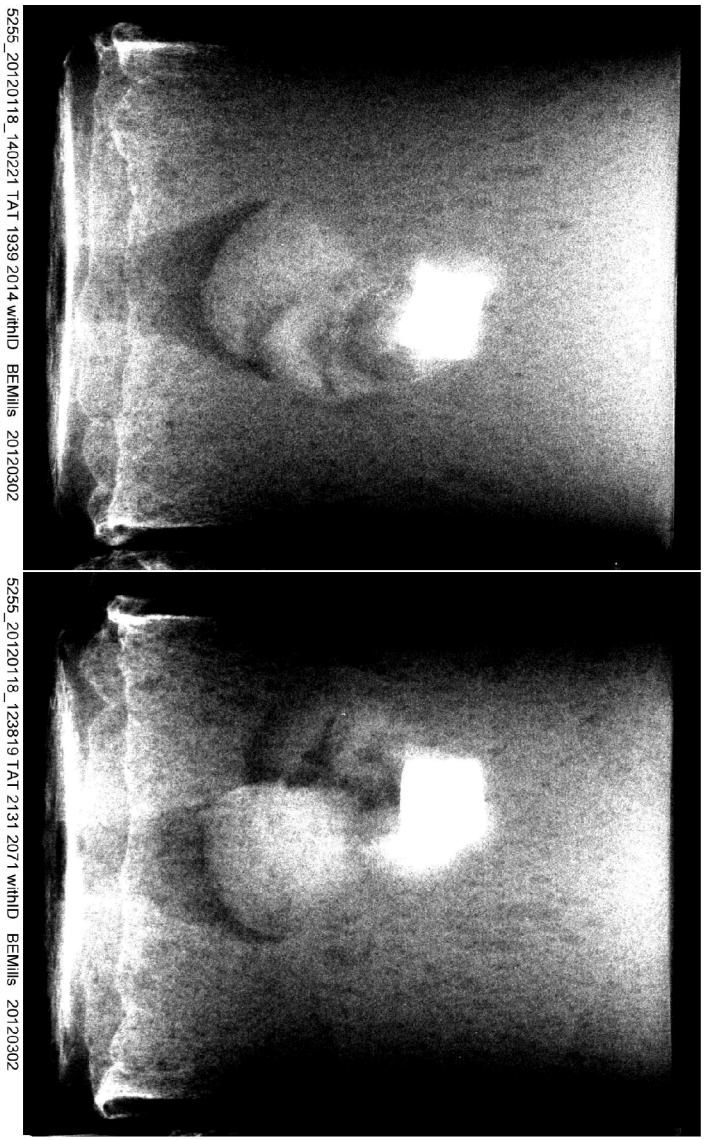


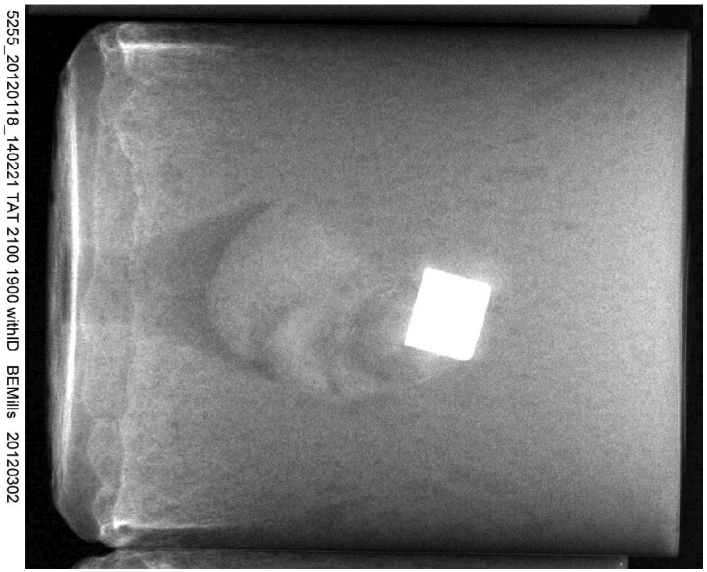
Tunnel then bounce then back?

6 pcf TufFoam

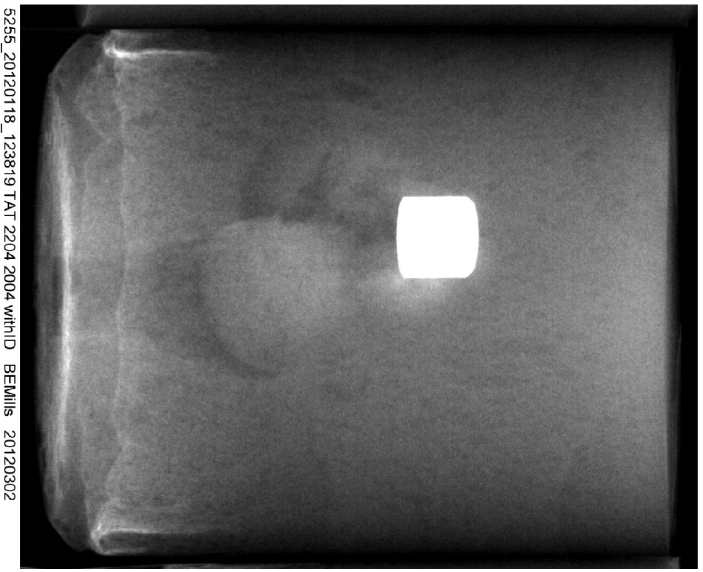
0.1 g/cc TufFoam

Same conditions, half the travel.





Ta

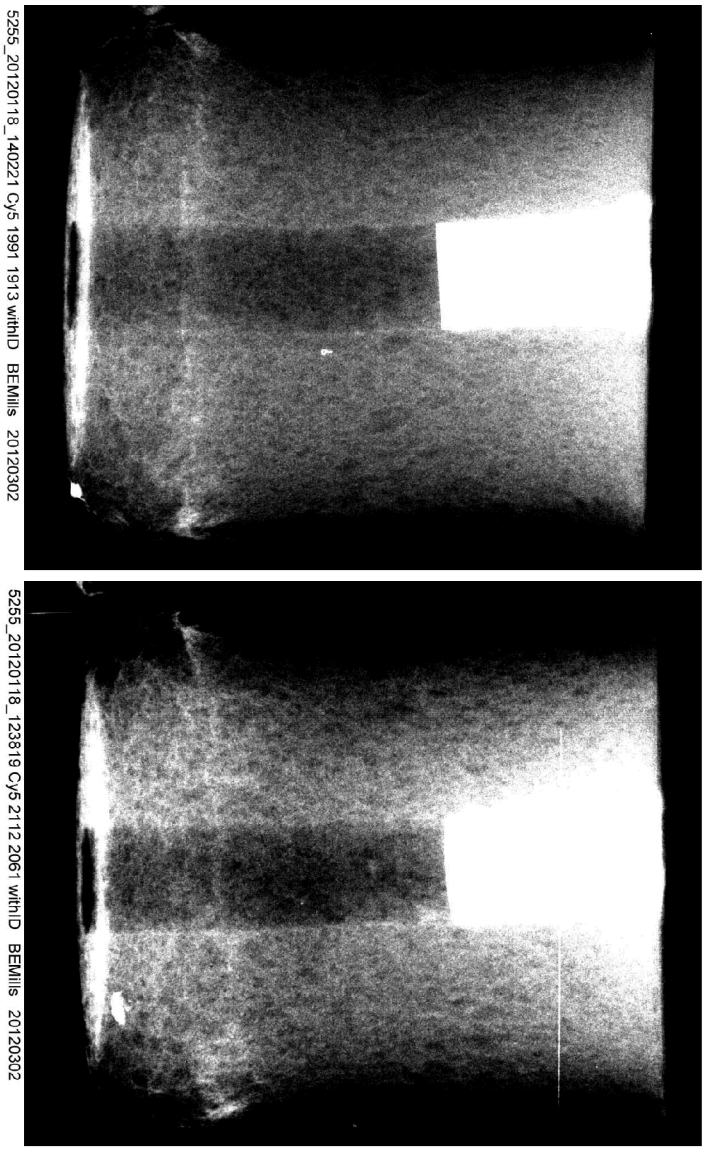


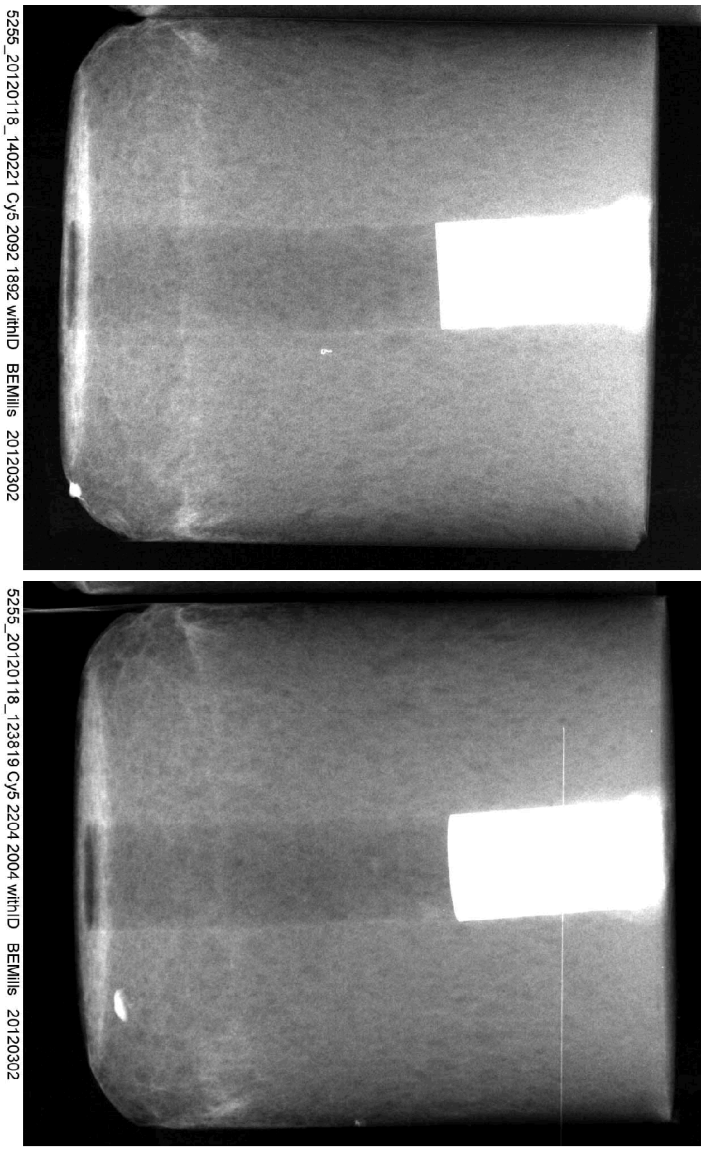
Disruption behind and to side; no compression in front.

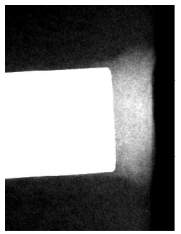
6 pcf PMDI

0.1 g/cc PMDI

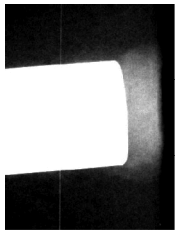
Cu slug with PMDI bottomed out.







Cu

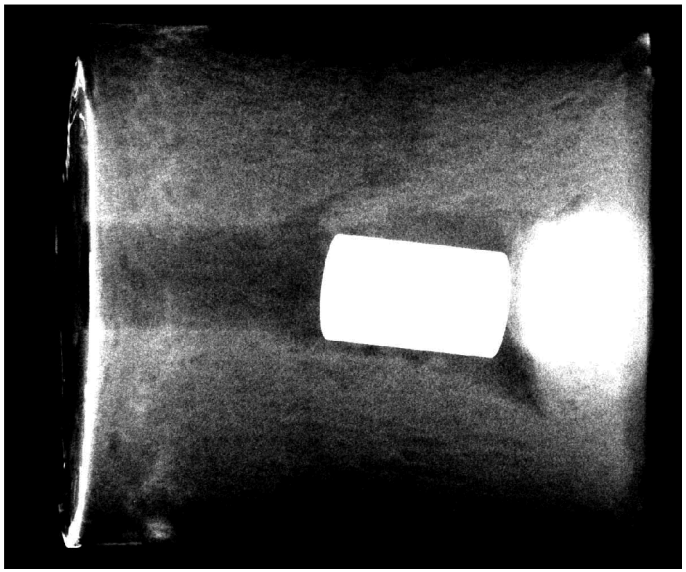


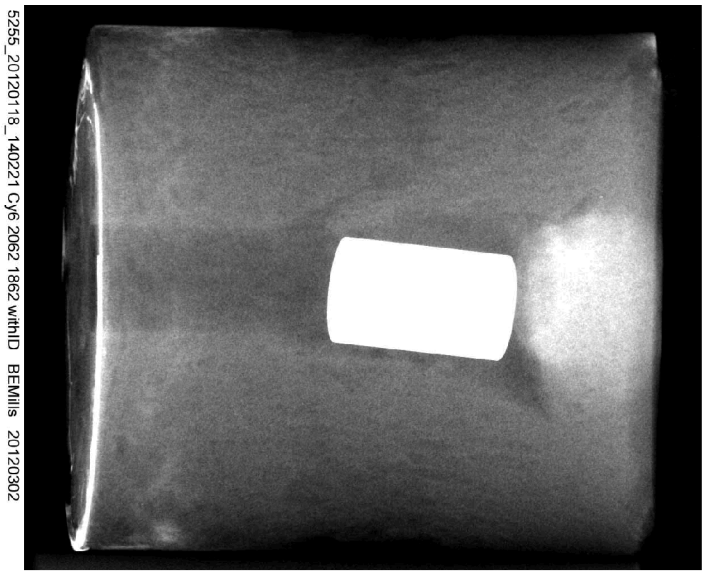
PMDI tunnels neatly through to the backing plate.

6 pcf TufFoam

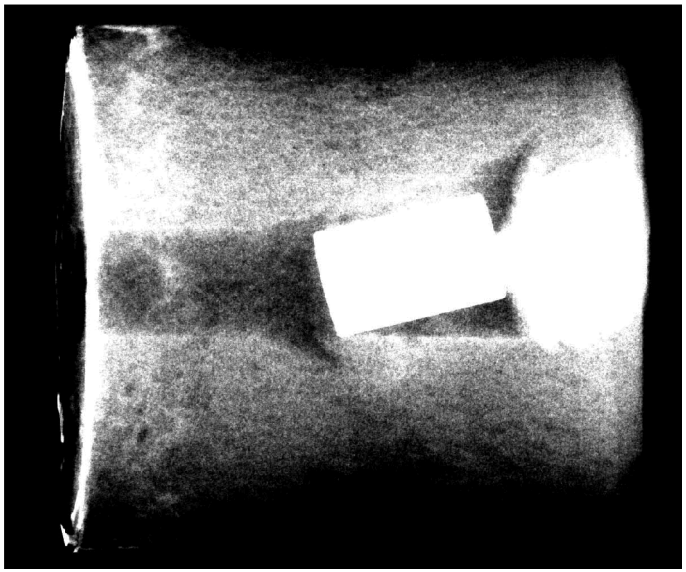
0.1 g/cc TufFoam

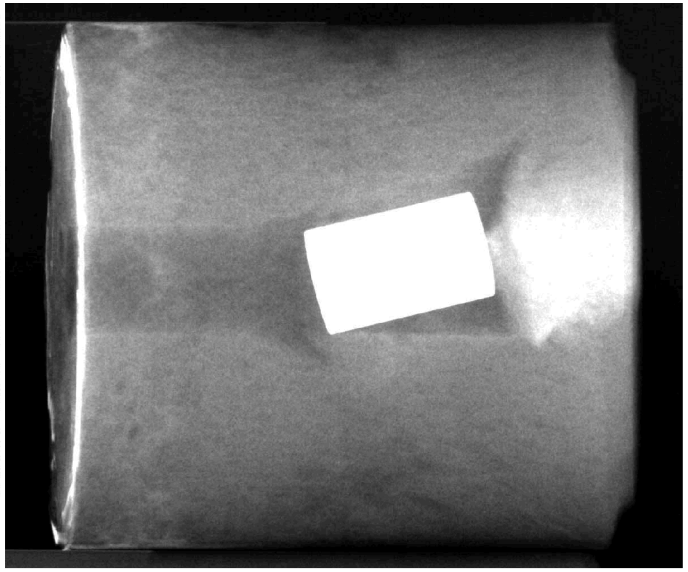
Slug travels less in TufFoam.





Cu



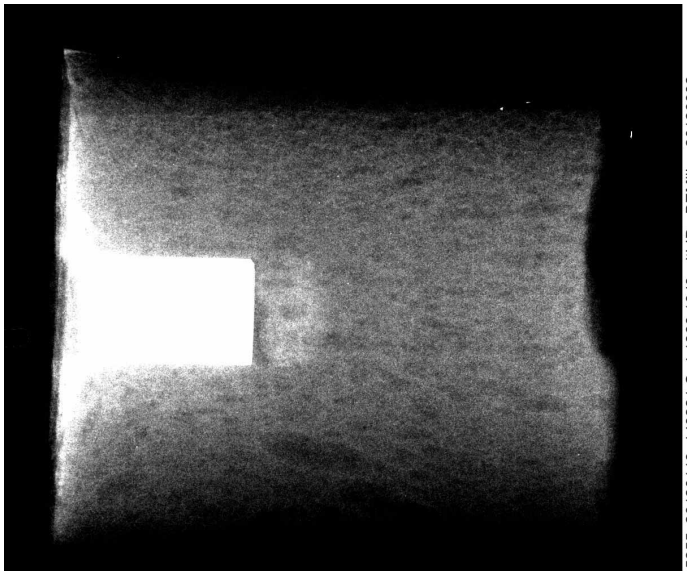


TufFoam tears and compresses a front before the slug.

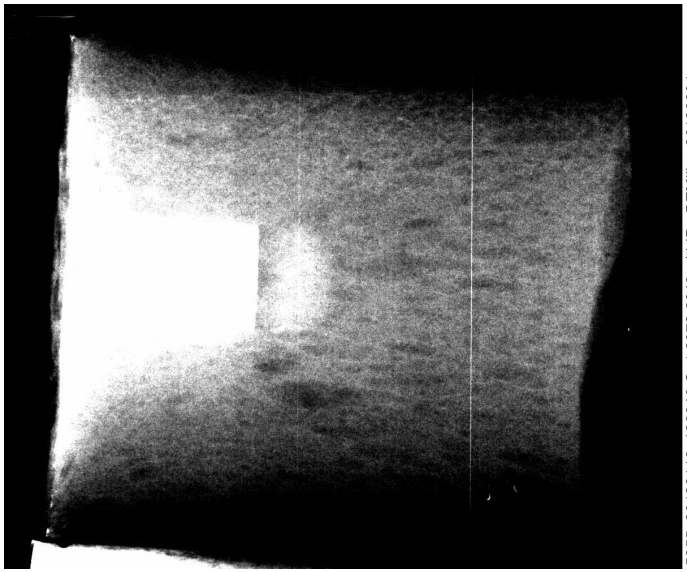
6 pcf PMDI

0.1 g/cc PMDI

Al travels less than Cu or Ta.



Al

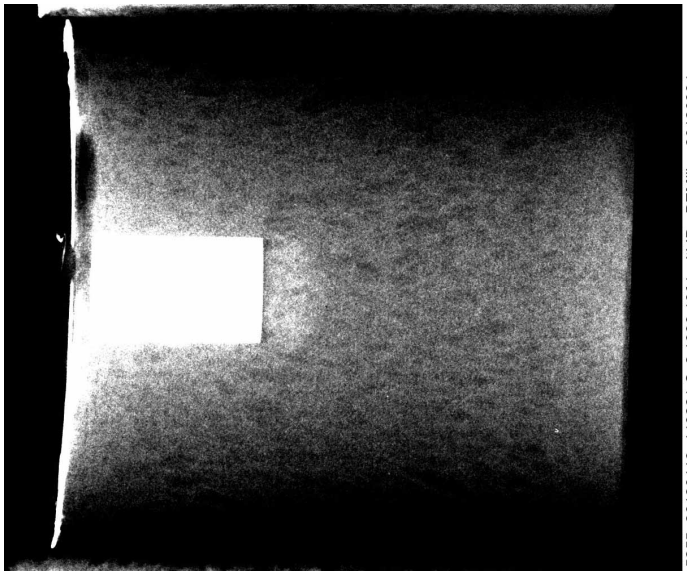


Tunnels and pushes material, creating a densified zone ahead of the slug.

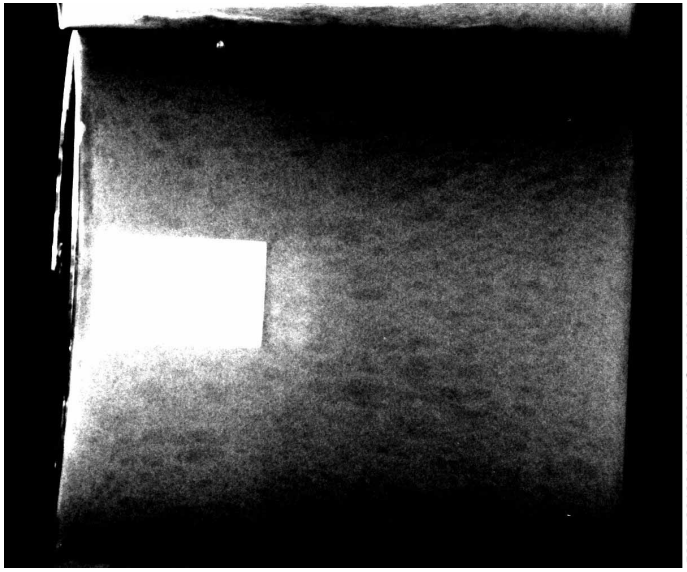
6 pcf TufFoam

0.1 g/cc TufFoam

Al travels less in TufFoam than PMDI.



Al



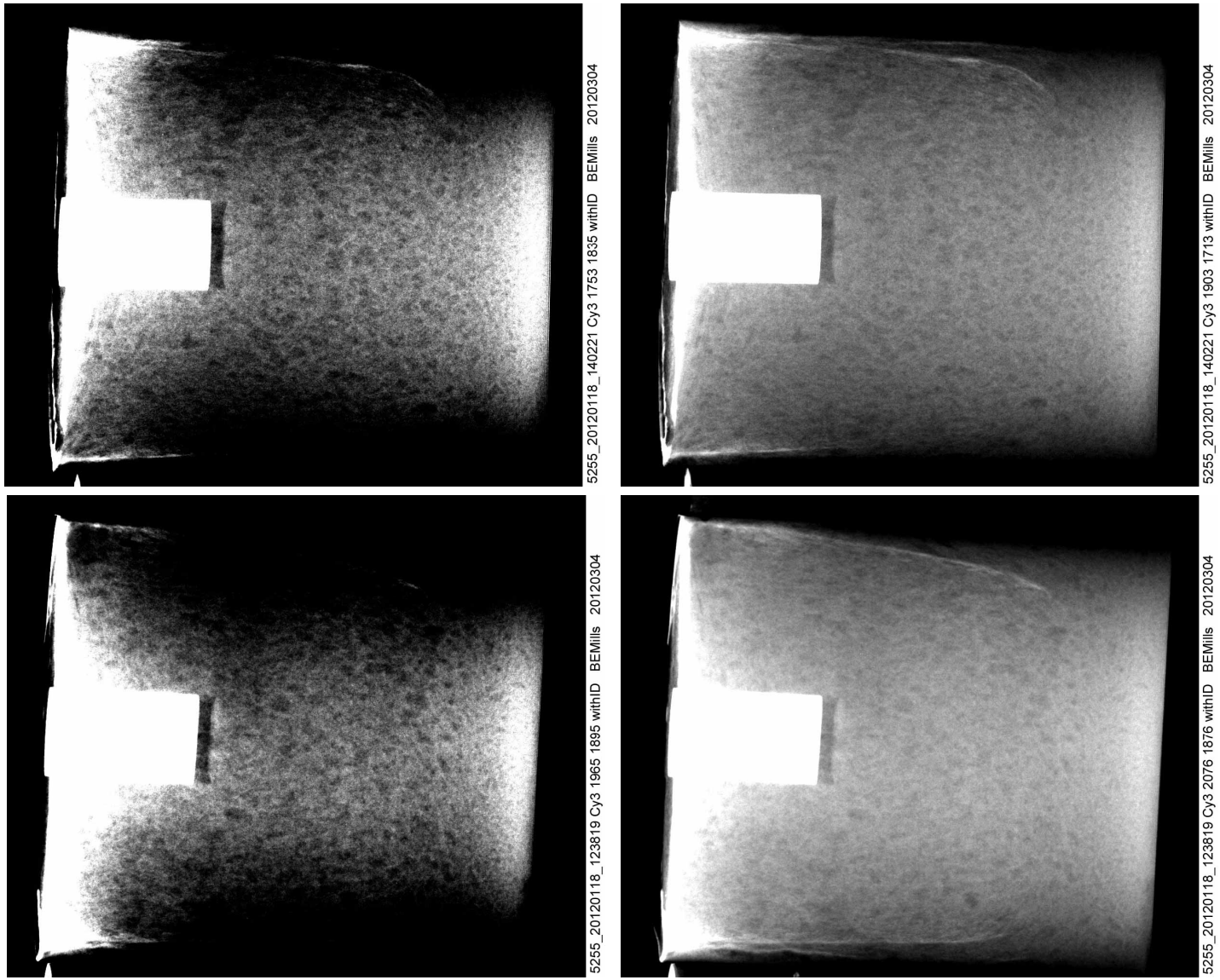
Forms small compression zone.

Perhaps a small bounce.

12 pcf PMDI

0.2 g/cc PMDI

Denser PMDI; less penetration.



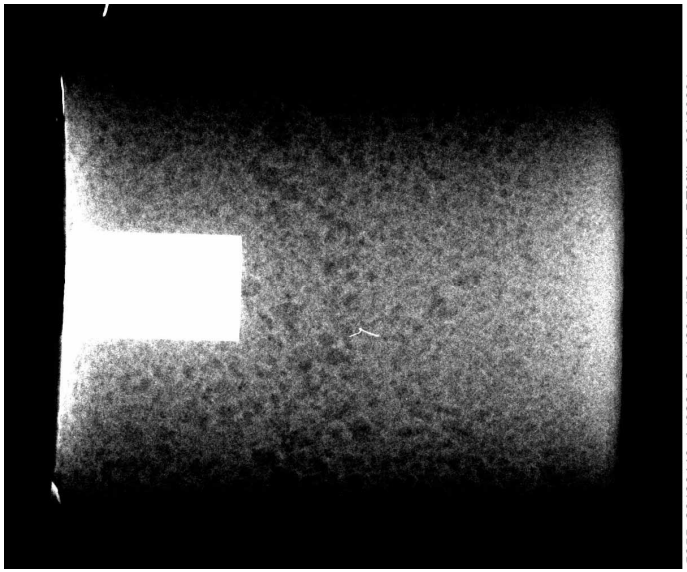
Al

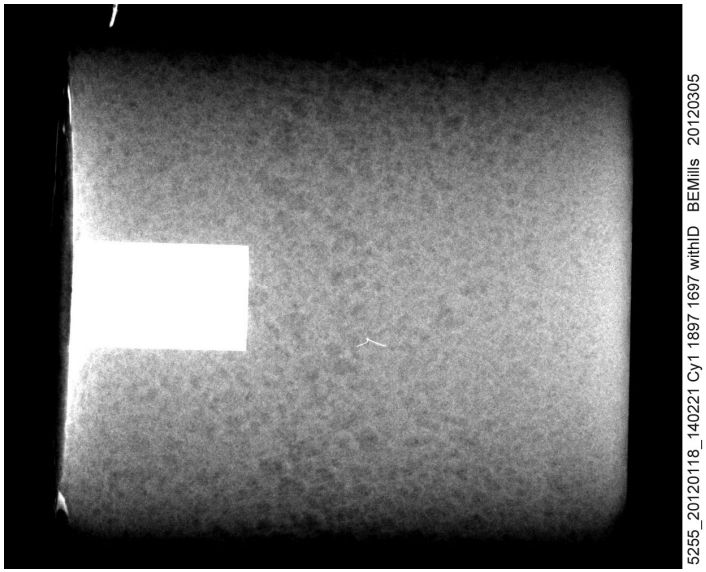
Pronounced bounce or back slippage of slug.

12 pcf TufFoam

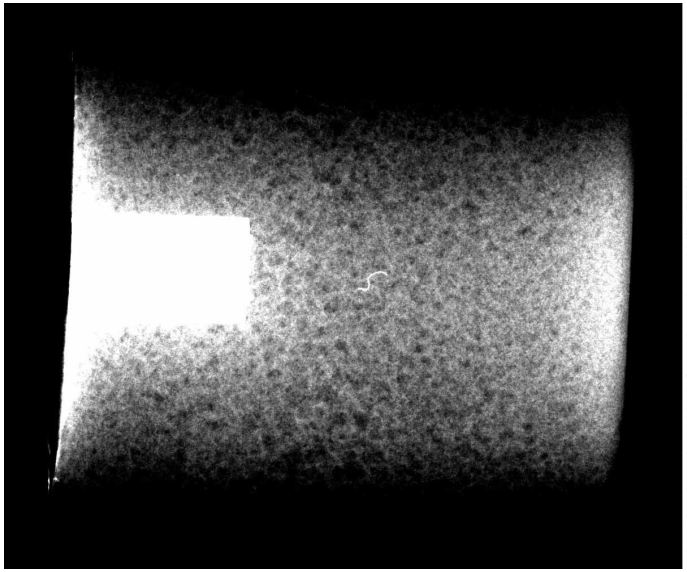
0.2 g/cc TufFoam

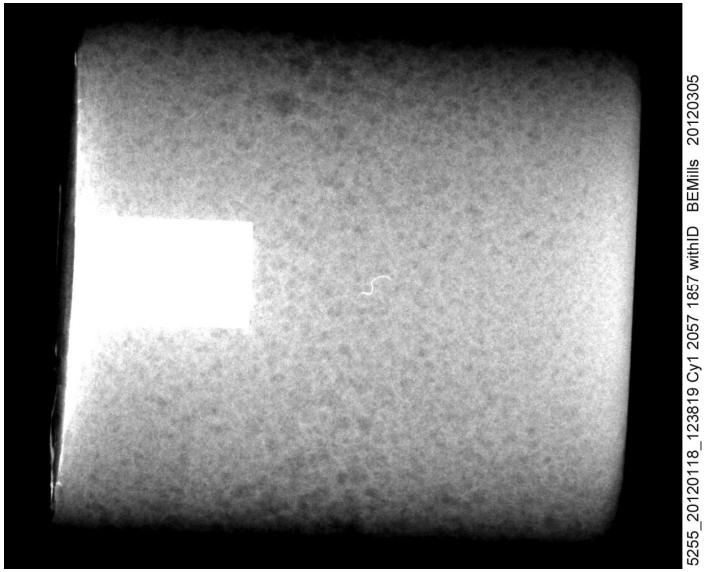
Densest TufFoam; smallest travel.





Al





The winner for least slug travel.

A note to component engineers:

- When considering radiography to determine if a procedure has changed a component, try to obtain “before” radiographs to compare with “after” radiographs.
- Let your radiographer know that that is the purpose of the “before” inspection so that the precise alignment can be documented to be used for the “after” inspection.