Perforator with Energetic Liner

David Davison
Shock Transients, Inc., PO Box 5357, Hopkins, MN 55343 USA
(952) 944-3539, X2 voice/(952) 944-8170 fax — dkd1@shocktrans.com

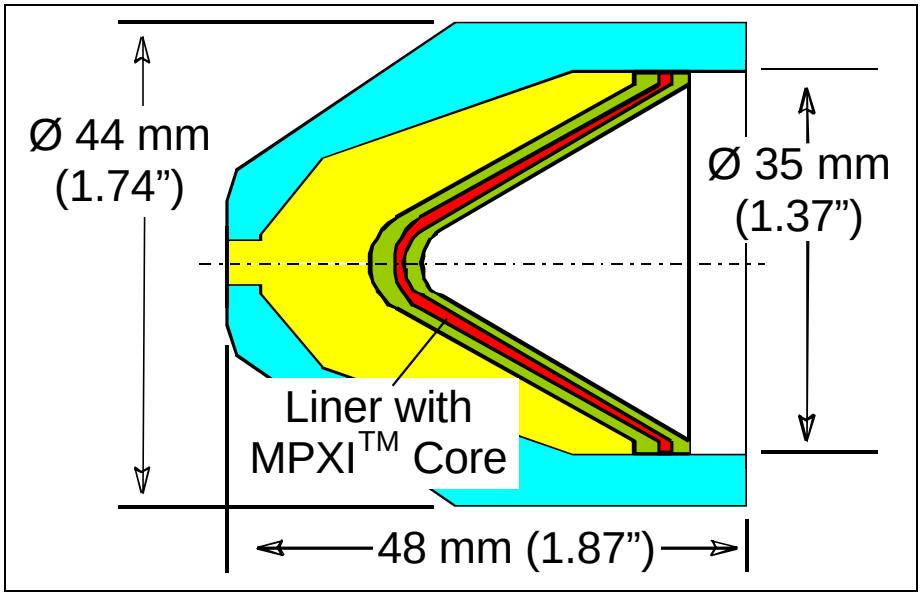
Dan Pratt
Owen Oil Tools, PO Box 568, Godley, TX 76044 USA
(817) 551-0540, X1074 voice/(817) 551-1674 fax — Dan.Pratt@CoreLab.com

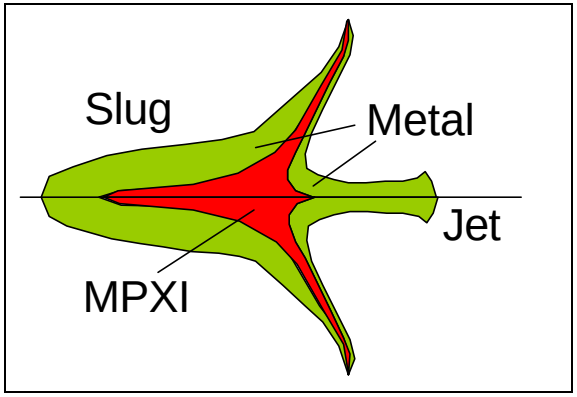
— International Ballistics Symposium, September 2011 —

Summary

- Jet formation process
- MPXI™ insensitivity
- Expansion of copper bands around concrete targets
- Test arrangements
- Holes in steel targets
- Framing camera images of band expansion
- Dual chamber test fixture
- Conclusions

Perforator and Liner Collapse Process



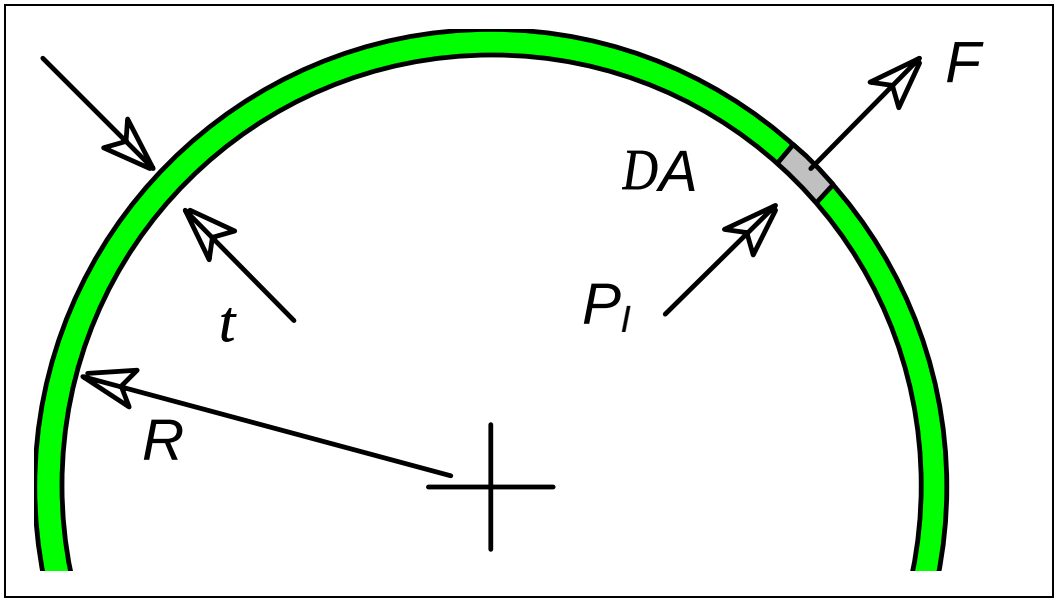


The the MPXI™ material experiences not only the compression from the detonation front and the squeezing during liner collapse but also the distortion that occurs in the jetting process .

Insensitivity of MPXI™ Material

A test of an MPXI™ puck perforated by a shaped charge jet shows insensitivity to extreme impact. The material was also insensitive when “cooked” over a fire for 30 minutes.

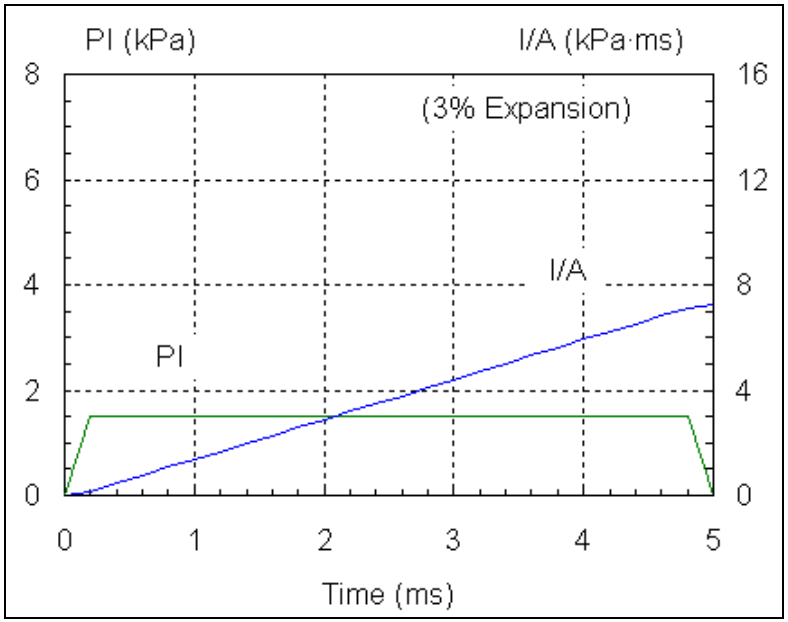
Copper Bands around Concrete Targets

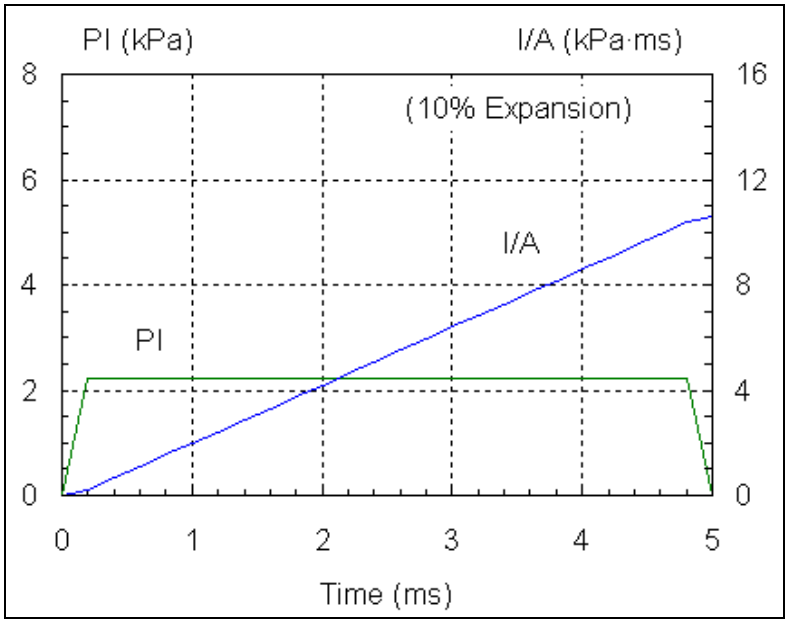


Impulse analysis (Y = 1.0 kbar, r = 8.9 gm/cm³, & $r(t) = R(t)/t(t)$):

Force	$F = (P_I - Y/r)\cdot DA = a\cdot Dm = a\cdot r\cdot t\cdot DA$, where
Acceleration	$a(t) = [P_I(t) - Y/r(t)]/r\cdot t(t)$, and
Impulse/Area	$I/A = \int P_I\cdot dt$.

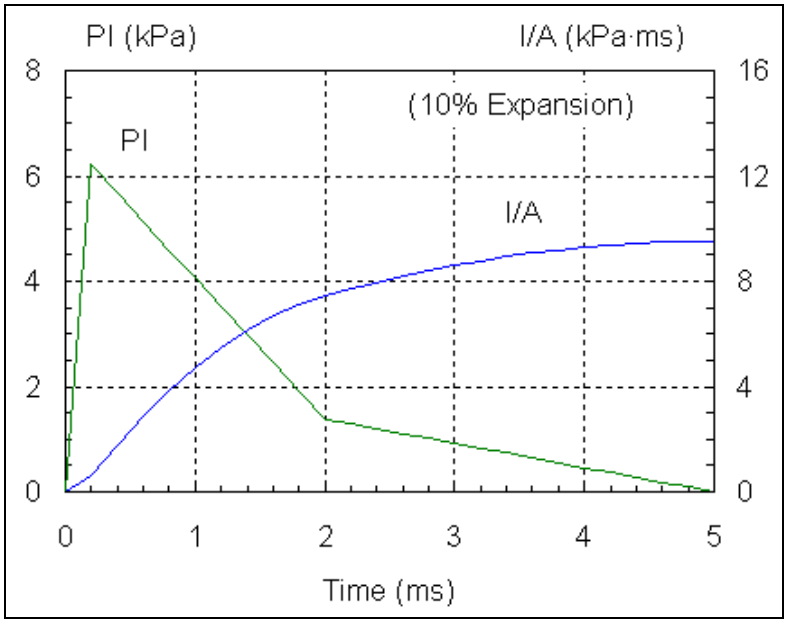
Impulse/Area for Constant Pressure

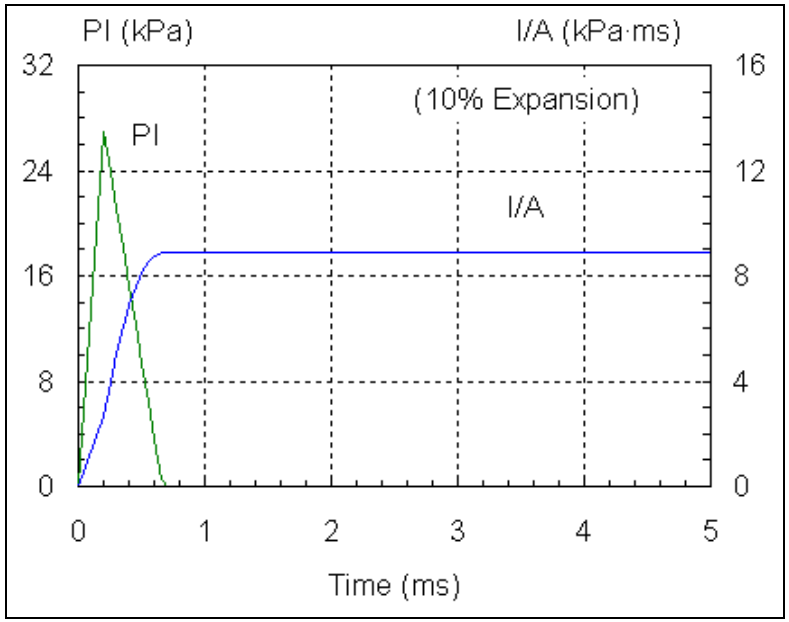




Band expansions were ≈3% for ordinary liners and ≈10% for sandwiched MPXI™ liners of equal mass. Computed impulses per unit area were 7.38 and 10.59 kPa·ms, respectively, indicating a 45% increase in impulse/area for the greater expansion and suggesting a 45% increase in blast effect for sandwiched MPXI™ liners in place of ordinary ones.

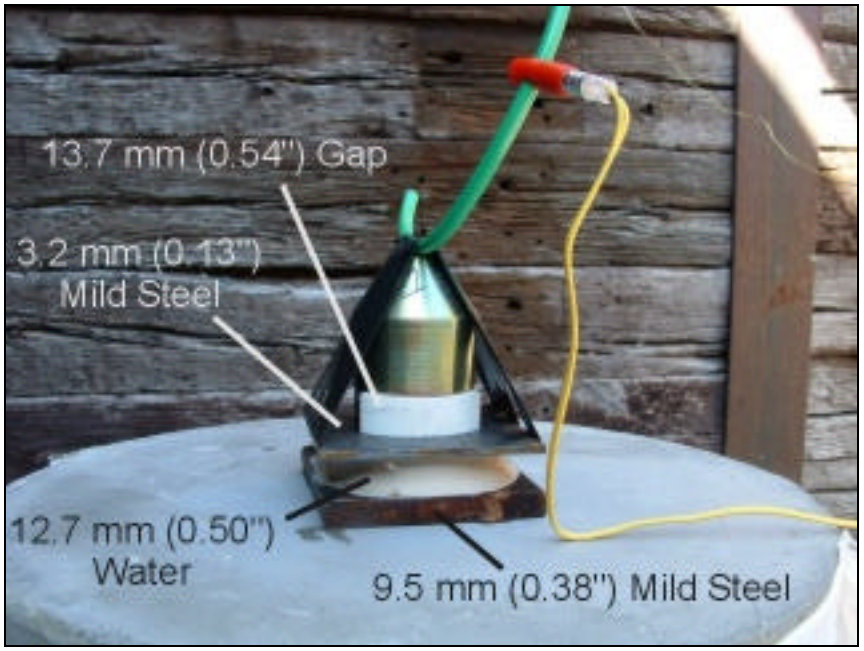
Impulse/Area for Constant Expansion

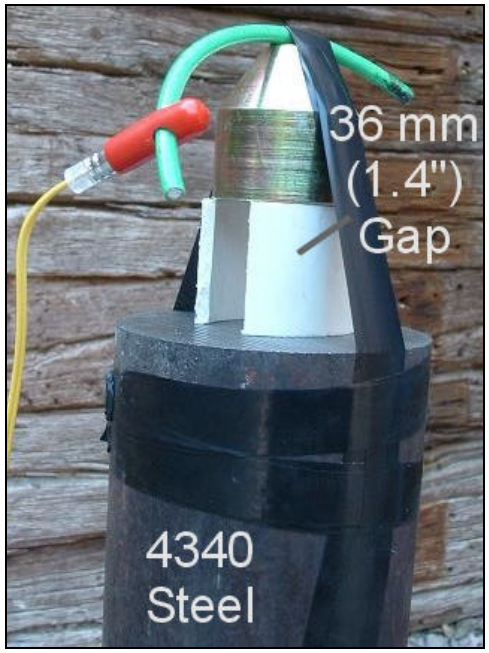




For a 10% expansion, computed impulses per unit area were 10.59 kPa·ms (prior chart) for constant pressure, and 9.52 and 8.89 kPa·ms (above) for progressively sharper pressure spikes, i.e., the shape of the pressure pulse affected the computed impulse/area, so dynamic measurements of expansion are needed to refine the evaluation of MPXI™ benefit.

Test Arrangements



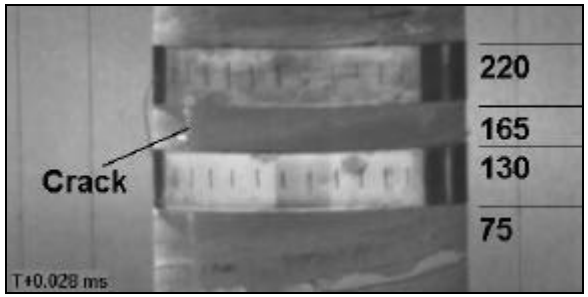


The top arrays for the Ø 305 mm x 610 mm (Ø 12” x 24”) concrete targets were oilfield quality control arrays. The concrete targets were cured for 7 days or more. Short lengths of detonator cord initiated the perforators. The steel targets were Ø 95 mm x 305 mm (Ø 3.75” x 12”), 4340 alloy, hardness 40 on the Rockwell C scale.

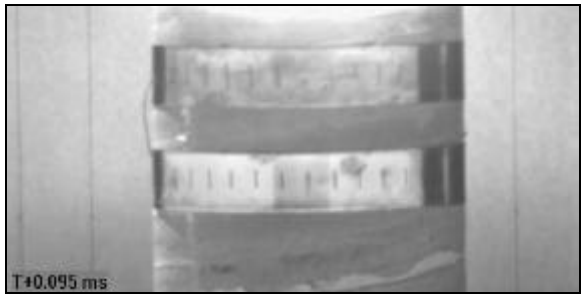
Holes in Steel Targets

Holes in 4340 steel targets penetrations for baseline perforators (LS-28) were equivalent to those for MPXI™-boosted perforators (LS-29).

Framing Camera Images of Band Expansion



Frame 1 0.000 ms

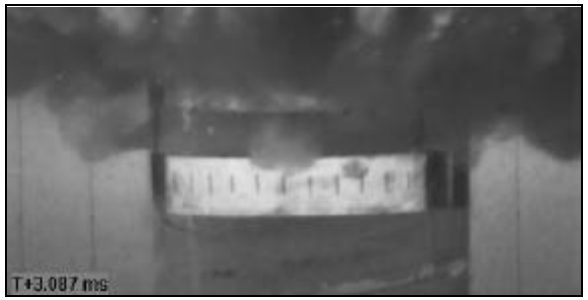


Frame 2 0.067 ms

Frame 9 0.532 ms

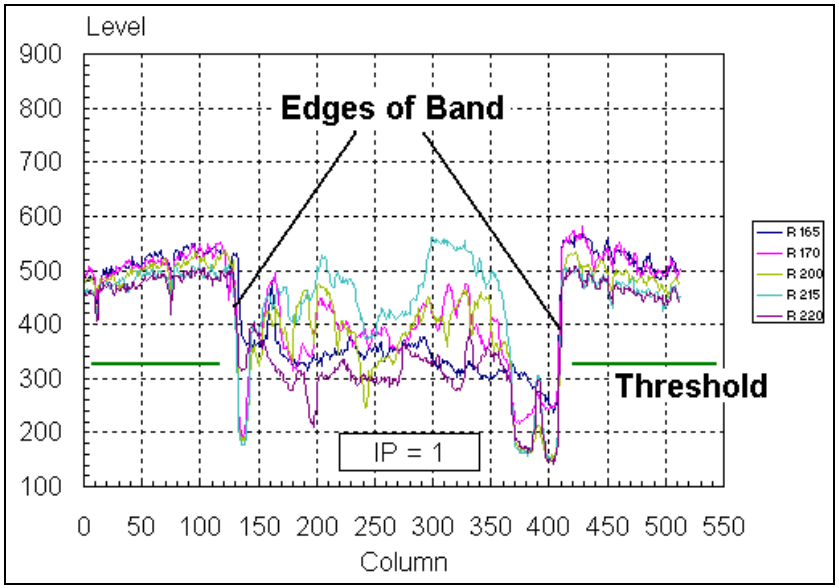
Frame 16 0.998 ms

Frame 31 1.995 ms

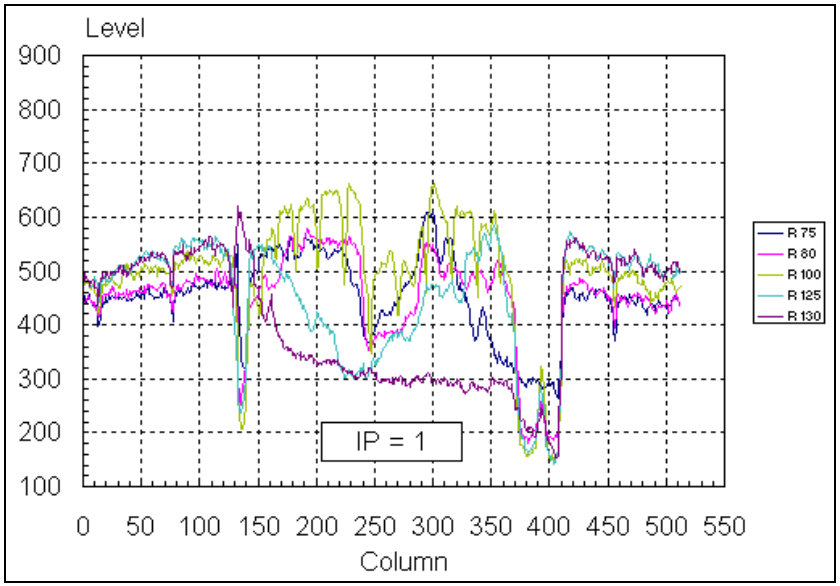


Frame 46 2.993 ms

Scans across Image 1



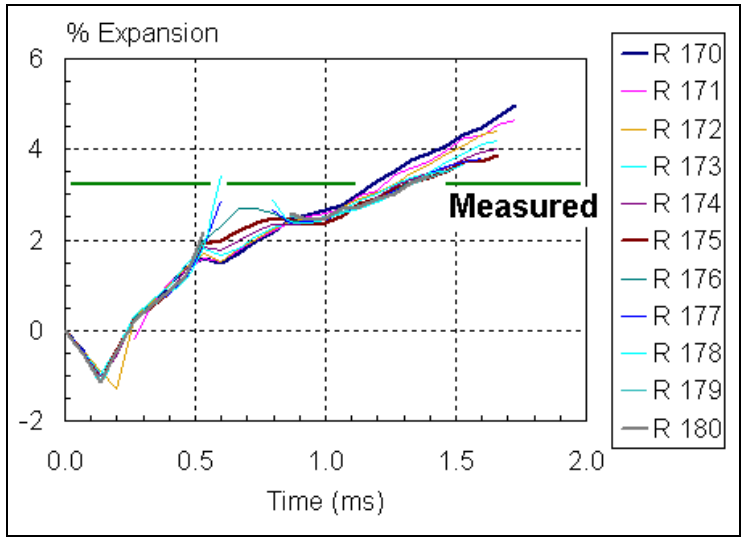
Upper Band



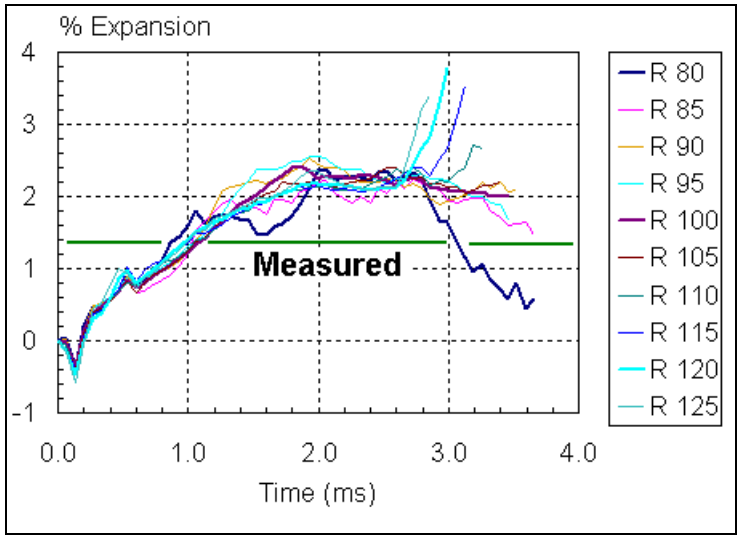
Lower Band

We extracted gray levels for the upper band between pixel rows 170 and 215 and the lower band between pixel rows 80 and 125. The threshold was a third of the way between the minimum and maximum gray levels for the rows of interest.

Band Expansions



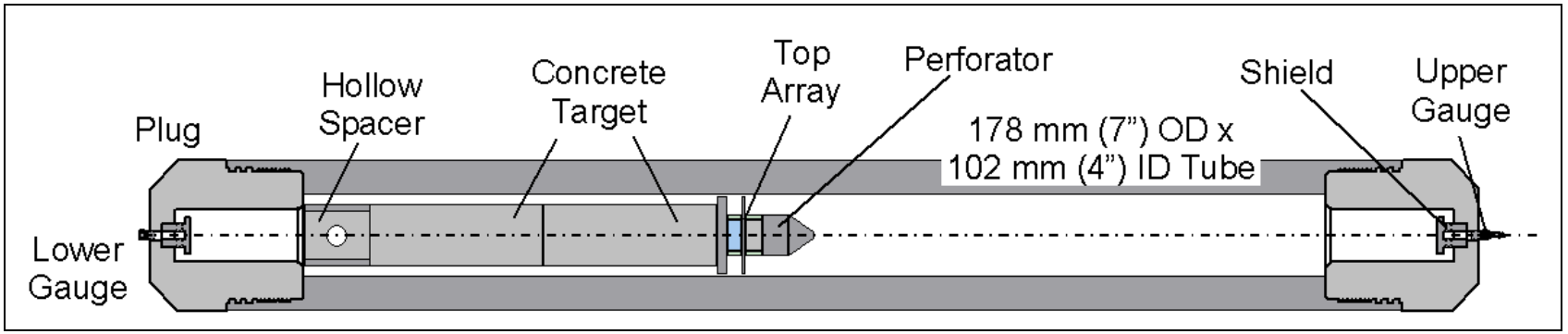
Upper Band

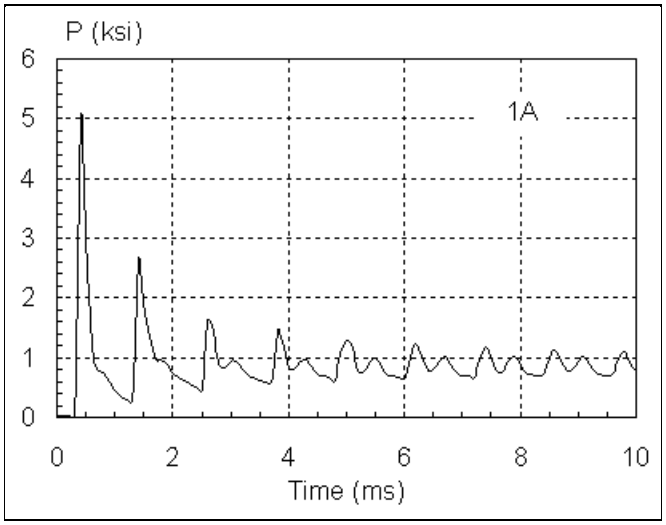


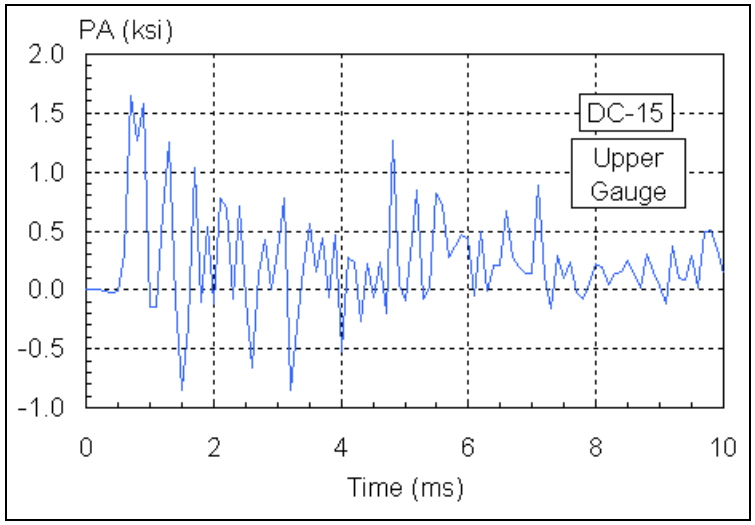
Lower Band

Measured expansions were 3.3% for the upper band and 1.7% for the lower band. Plotted percentages are relative to the band width in frame 1. Rebound to the initial shock loading caused the dips at early time. Smoke covering the upper bands gave breaks in the curves. Elastic response of the copper band caused the late-time rebound.

Dual Chamber Test Fixture







Analysis (1A) gave an initial 5 ksi peak followed by lower peaks and a steady pressure. *Tests* gave erratic data (DC-15 typical) with piezo gauges.

Conclusions

- MPXI™ is safe until activated by extreme impact.
- Steel penetrations for baseline perforators were equivalent to those for MPXI™-boosted perforators.
- Band expansions for baseline perforators were ≈3%; for MPXI™-boosted perforators expansion were ≈10%.
- Piezo gauges may be unsuitable for dual chamber pressure measurements.