Summary of Test Results - Nukote Blast Resistant Coatings

Blast exposure testing was performed by Southwest Research Incorporated at their Ballistics and Explosive Range at their San Antonio, Texas facility. All tests and reports were supervised by Donald Grosch, SwRI testing engineer, and the SwRI range master.

Test Arrangement and Fixturing

The flat, cylindrical (h / d = 0.3) 2 pound (0.91 kilogram) C4 charge was place on the surface of an engineered soil pot having a fill density of 120 pounds per cubic foot. A 10,000-pound test fixture was located above the charge. All test specimens were attached to the underside of the test fixture using 16, one-inch diameter bolts. All coated surfaces were positioned facing the charge (facing downward).

Test frame, specimen, and explosive pot


Explosive on engineered soil pot

Test Specimens

All test specimens were prepared using nominal 3/8-inch-thick (9 mm) by 4-foot (1220 mm) square armor plate delivered in new condition and certified by the manufacturer to meet military specification 46100-E. All edges and mounting holes were abrasive liquid jet cut. Surfaces were abrasive blast cleaned and primed. Nukote products were applied to form a composite in a series of self-adhering 3 mm thick layers until the desired total thickness was achieved.


Pre-detonation view of specimen

High speed photo of blast initiation

Five tests were conducted: The first baseline exposure was set at 18 inches (454 mm) from the explosive. To increase the severity, the explosive charge was move closer to the target surface of the specimen and a second base exposure was detonated. The results of this one baseline exposure (composite thickness equals zero) and three product exposures are summarized as follows:

Nominal Composite Thickness (mm)	C4 Standoff to Coating (mm)	Maximum Permanent Deflection (mm)	Est Residual Strain Quartic Curve Fit
0	305	27.96	0.13%
3	292	25.85	0.12%
7	279	22.51	0.11%
11	286	22.26	0.10%


Post-blast exposed face heat/chem resistant layers


Ablative, energy absorbing layers, no breach

Post-blast permanent deflection, no breach

Discussion

A precise model for the total explosive energy that is transmitted to a target is complex to generate and generally relegated to the domain of custom programming and very high speed computing systems. Very good estimates can be developed using dedicated commercial 3D models. A common simplification that yields good agreement with test results is to separate dynamic responses from observable static responses.

Dynamic responses are theorized to take the form of a surface vibration that propagates and then dampens. The degree and speed by which the wave forms and extinguishes relates to the dampening effect of the base metal in combination with the coating. Faster dampening and lower amplitudes indicate a more efficient coating system. Sophisticated equipment is required to capture the dynamic response profile. However, coating efficiency can be inferred from the inelastic response profile if the base material properties are well defined as being isotropic in the elastic region. Metals generally fit this description.

Static portions of total energy are more straight forward to estimate because residual deflection is measured directly from the specimen after it has been exposed to the blast as shown in the enclosed table. The energy stored by the inelastic response of the base material can be estimated by employing one of several strain energy models. This is true so long as the base metal exhibits a stress-strain relationship that is initially linear up to the yield point and, after a transition phase, becomes less dependent upon stress and driven more by deformation/dislocation of the metal matrix (total strain) until rupture. Removal of the applied load should result in the return of most of the plastic portion of the deformation (via vibration) when adjusted for any changes in material properties due to strain hardening.

Key Conclusion

The Nukote composite was designed to provide protection via several energy dissipating mechanisms. The surface of the composite reflects a portion of the shockwave and associated heat. It also resists surface erosion caused by the supersonic gas flow and debris. Other components of the composite absorb energy by sacrificial ablation and by dampening the elastic response of the armor plate.

The reduction of inelastic strain energy provided by the 11-mm Nukote coating is estimated to be 24% relative to the baseline plate. The elastic dampening effect can be significant when multiple impacts are involved, but for a blast exposure it represents something less than 15% of the total energy dissipated and is similar but not identical for both the baseline and specimen. Therefore, the dampening effect of the coating is inferred as a function of volume difference between the unaffected regions of baseline plate in comparison to the specimen. This difference is estimate to be about a 12% reduction. Therefore, the total reduction in transmitted energy attributable to the 11-mm Nukote composite is estimated to be 34%.