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SAND89-8208
Nuclear Weapon Data • Sigma
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Printed July 1989

The Influence of Surface Coatings on the Performance of Strategic Earth Penetrators (U)

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Abstract (U)

The effect of surface coatings on the performance of 1/10-scale model earth penetrators has been investigated. Test units were accelerated using a 4 inch diameter light gas gun and, after a short free flight, impacted a simulated rock target.

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Acknowledgements

The authors wish to express their gratitude to D. B. Sparger and J. E. Collins who assisted in all aspects of this study. The authors also acknowledge contributions from the following: M. L. Chiesa (numerical earth penetration simulations), M. L. Tootle and J. S. Korellis (gas gun facility), B. R. Pelletier and D. M. Abrahams (high speed photography), and C. J. DeCarli (statistical analyses).

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2 Experimental Procedure

A 4 inch diameter light gas gun, operated and maintained by Division 8243, was used in this study. The test facility, depicted schematically in Figure 1, consists of a gas gun, a sabot stripper mounted at the end of the gun barrel, and a target chamber. Prior to launching, a 1/10-scale model penetrator is assembled into an aluminum/polyurethane foam sabot with a preset 0° angle of attack (Figure 2). Since the weight of the sabot is approximately the same as the test unit, it was necessary to strip the sabot prior to target impact. The stripper was designed to separate the model from the sabot and capture most of the debris associated with the stripping process at the muzzle of the gun. A schematic of the stripper is shown in Figure 3. Projectile velocity and attitude in free flight were recorded with two image motion or streaking cameras (focused at 3 and 20 inches from the gun barrel). By using mirrors, both side and bottom views were captured with a single camera (Figure 4). These two views are needed to determine the pitch and yaw angles of attack prior to impact.[1] After travelling a total of 30 inches in free flight, the penetrator impacted the target. The impact angle was 90° (normal impact) for all tests.

The target consisted of foundry stone, a man-made rock resembling cemented sandstone. This material is primarily silica sand with chemical binders and a catalyst (see Appendix A). Targets were fabricated at the Sandia Foundry, Division 7473, using the same process as that used to make molds for metal castings. Physical and mechanical properties measured periodically during this program [2,3] indicated that foundry stone was slightly weaker than Antelope Tuff, a low strength rock at TTR used for large-scale earth penetration tests.[2] The strength of foundry stone can be varied by adjusting the binder content. Targets containing 7% binder (by weight) were chosen after investigating 1% and 3% targets.[3]

Early development tests revealed severe cracking and fragmentation of the target. This damage was influenced by (1) a low tensile strength target, and (2) edge effects due to a finite radius target. Analyses [4] showed that the addition of a 1/2 inch thick mild steel sleeve around a target approximately 3 feet in diameter would considerably reduce the hoop tensile stresses and thus minimize target cracking during penetration. In addition, these analyses indicated that using a constrained target of this size would result in 1/10-scale model penetration depths similar to that expected for a semi-infinite medium. Satisfactory results were achieved when a hexagonal target was used with a matching sleeve. This sleeve, which was fabricated in two parts, was

[1]The measured angle of attack in both pitch and yaw planes was nominally less than 1/4°.

[2]Laboratory tests of Antelope Tuff indicate that it has an average density of 112 lb/ft^3 and a nominal unconfined compressive strength of 2500 psi.

[3]The penetration depth for uncoated penetrators tested at identical impact velocities was approximately 33% less for 7% binder targets compared to 1% targets.

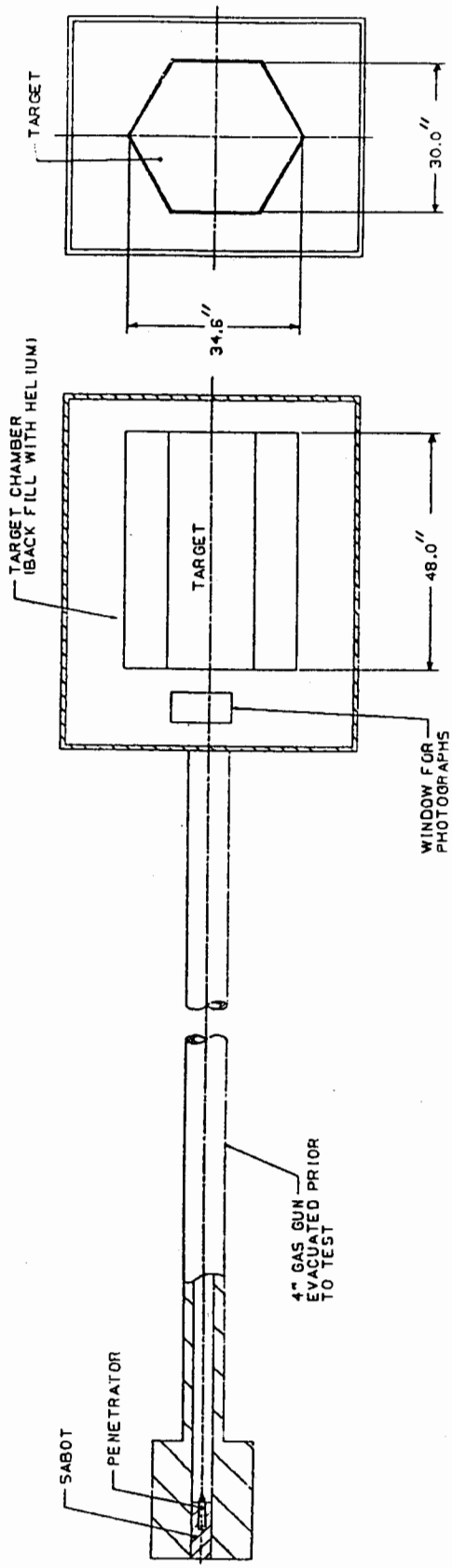

Figure 1. Gas gun facility

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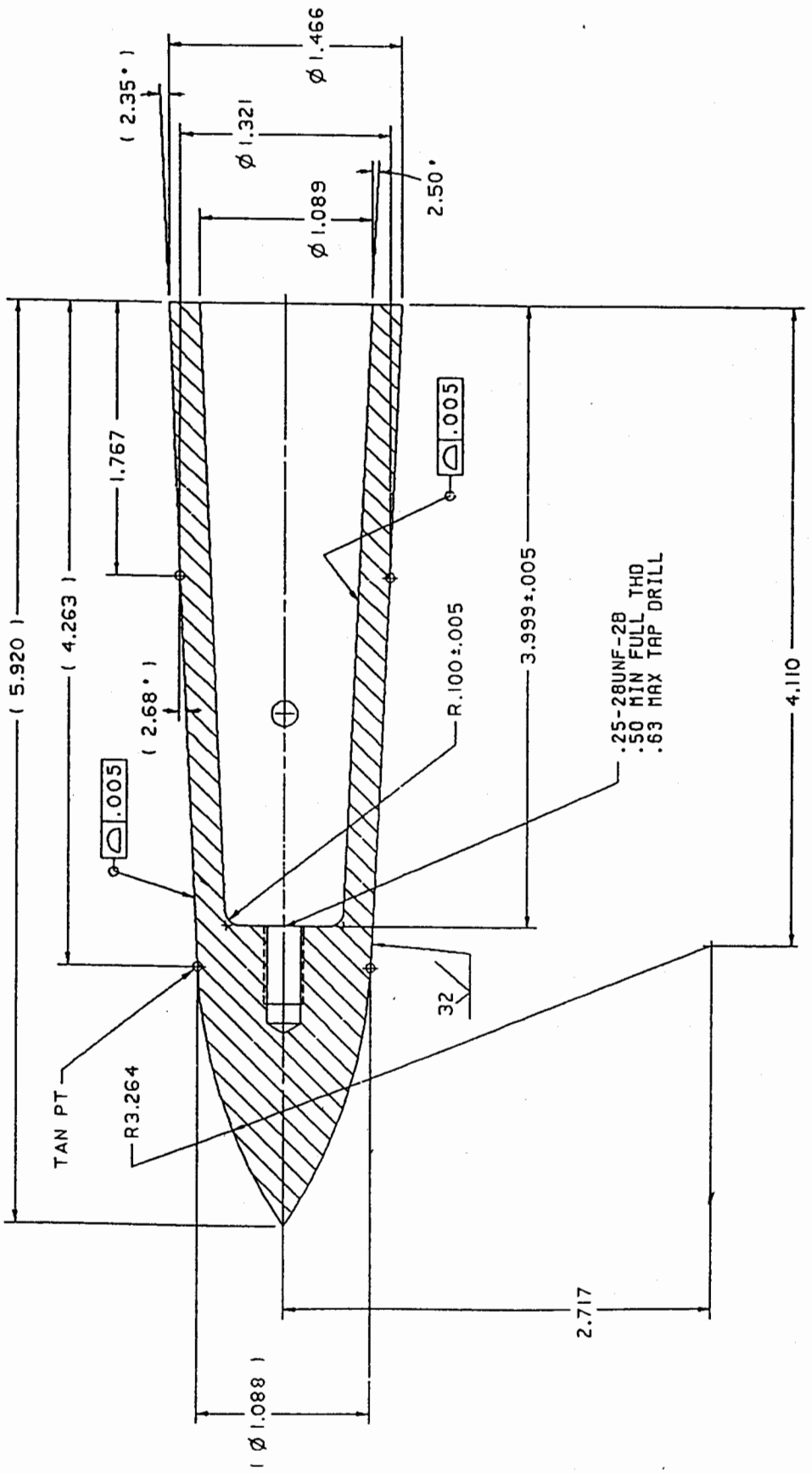

Figure 5: Drawing of 1/10-scale model earth penetrator. All dimensions are in inches.

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Table 2: Penetration depth test results

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3.2 Post-test Macroscopic Observations

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4 Discussion

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5 Conclusion

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6 References

[1] M. L. Chiesa, Sandia National Laboratories, Livermore, CA., unpublished analyses.

[2] S. C. Blair, "Material Properties of 7% Foundry Stone," Lawrence Livermore National Laboratory, Livermore, CA., memorandum to Artie Ortega, October 3, 1986.

[3] S. C. Blair, "Testing of 7% Foundry Stone," Lawrence Livermore National Laboratory, Livermore, CA., memorandum to Artie Ortega, March 23, 1987.

[4] M. L. Chiesa, "Target Size for Small Scale Testing," Sandia National Laboratories, Livermore, CA., memorandum to A. R. Ortega, June 13, 1984.

[5] C. W. Young, "Equations for Predicting Earth Penetration by Projectiles: An Update," Sandia National Laboratories, Albuquerque, N. M., SAND88–0013, July 1988.

[6] C. J. DeCarli, "Statistical Analysis of Penetrator Data," Sandia National Laboratories, Livermore, CA., memorandum to A. Ortega, January 13, 1988.

[7] R. S. Montgomery, "Surface Melting of Rotating Bands," *Wear*, Vol. 38, 1976, p. 235.

[8] R. S. Montgomery, "Friction and Wear at High Sliding Speeds," *Wear*, Vol. 36, 1976, p. 275.

[9] N. A. Lapetina, Sandia National Laboratories, Livermore, CA., private communication.

[10] J. Lipkin, "DSP-212 and DSP-216 Davis Gun SEPW Field Tests," Sandia National Laboratories, Livermore, CA., SAND89–XXXX, in press.

7 Appendix A

Table 4: Constituents of 7% binder foundry stone

Weight (lbs.)	Component
100	silica sand (grain size 50)
3.5	Pep Set* 53-914
3.5	Pep Set 2610
0.14	Pep Set 3500

* Pep Set is a trade name of Ashland Chemical Co.

8 Appendix B

Summary of Cauchy Scaling Laws

Definitions:

l = length	m = mass
v = velocity	a = acceleration
ρ = density	σ = stress
t = time	$\dot{\varepsilon}$ = strain rate

λ = geometric scale factor; e.g. for $\frac{1}{10}$ - scale, $\lambda = \frac{1}{10}$

superscript * = sub-scale quantity

The following set of independent relationships forms a basis from which other quantities can be generated:

$$l^* = \lambda l \qquad \sigma^* = \sigma \qquad \rho^* = \rho$$

For example, one can derive the expressions shown below:

$$t^* = \lambda t \qquad m^* = \lambda^3 m \qquad a^* = \frac{1}{\lambda} a$$

$$v^* = v \qquad \dot{\varepsilon}^* = \frac{1}{\lambda} \dot{\varepsilon}$$

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