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# Ice Penetration by Air Delivered Weapons (U)

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M. M. Hightower, C. W. Young



Prepared by
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under Contract DE-AC04-76DP00789


Classified by L. T. James, Supervisor, Advanced Systems Development Division I, 1611, April 2, 1986

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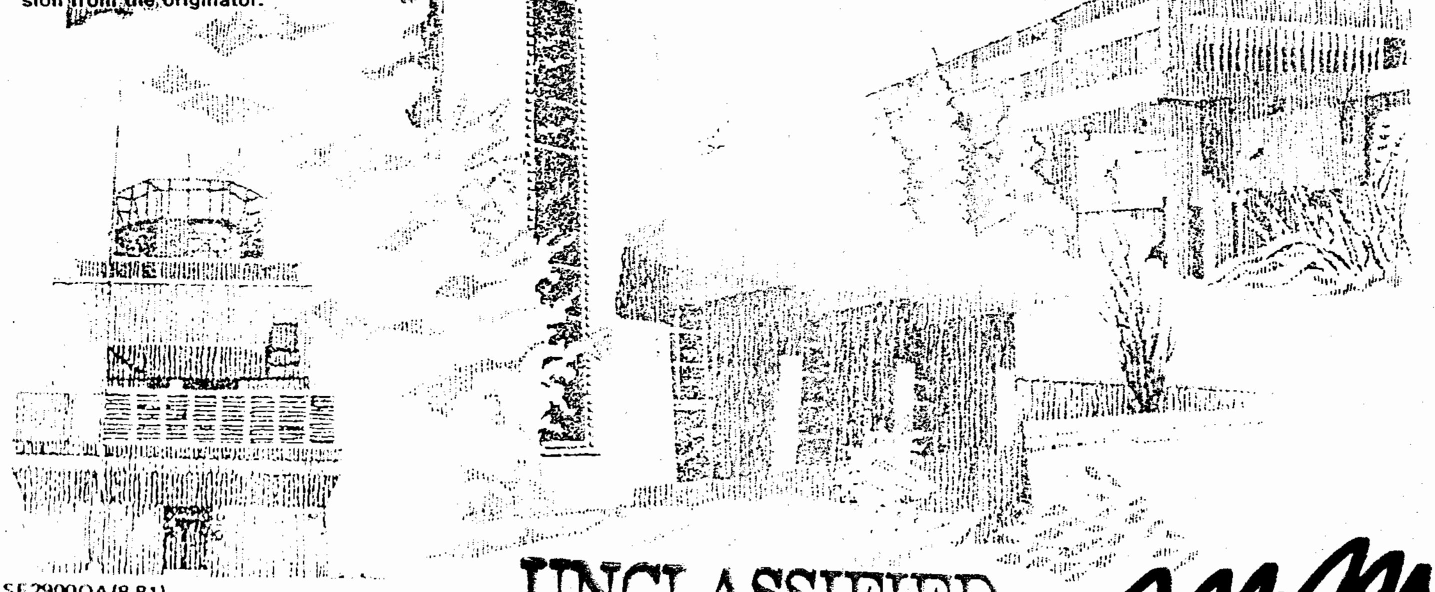

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# ICE PENETRATION BY AIR DELIVERED WEAPONS (U)*

M. M. Hightower & C. W. Young
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May 1986

ABSTRACT

Throughout history, there has been considerable interest in developing weapons to penetrate various targets. In recent years, the emphasis has been directed toward developing weapons which can penetrate hard targets such as rocks, concrete, and thick sea ice, and still function properly. In this report, an overview is presented of the important factors to consider when designing a weapon to penetrate thick sea ice. This discussion is based on both theoretical and experimental results of several programs conducted by Sandia on ice penetration. Additionally, the results of a recent Naval Air Systems Command (NAVAIR)-funded program to determine the ice penetration capability of several conventional air-delivered Naval weapons, including mines, torpedoes, and destructors will be presented.

*This work was supported by NAVAIR.
**A U.S. Department of Energy facility.

# I. WEAPON DESIGN CONSIDERATIONS FOR ICE PENETRATION

Several factors govern the design of an air-delivered, ice penetrating weapon, including: (1) ice type and thickness to be penetrated; (2) impact conditions; (3) release conditions; and (4) system constraints. These factors define the loading on a weapon and determine the mechanical complexity of the system. In this section, information on ice penetration requirements are presented, followed by a discussion on how the factors listed above affect ice penetration and their importance in the design of an optimum ice penetrating weapon within given system constraints.

## Ice Thickness Penetration Requirements

The term "sea ice" refers to several types of ice, each of which varies in age, thickness, and material properties. Sea ice can generally be divided into three categories. Based on age, they are: refrozen leads, annual ice, and multiyear ice. Refrozen leads occur when sections of ice separate, developing narrow channels or open water. These channels normally quickly freeze, giving rise to the name refrozen leads. Since the water is quickly frozen, the ice is relatively thin when compared to other ice types and contains a high concentration of brine, making it soft or weak.

Annual ice is ice which freezes and thaws each year. This ice is frozen slowly throughout the winter and therefore is stronger and contains a lower concentration of brine. Annual ice is typically five to seven feet thick but can be up to 10 feet thick during a severe winter.

Multiyear or pack ice lasts throughout the year, continuing to build up each year and becoming very thick. Pack ice is generally greater than 10 feet thick, and the partial thawing each summer and refreezing each winter tends to leach out the brine and eliminate voids, resulting in a very hard or strong ice.

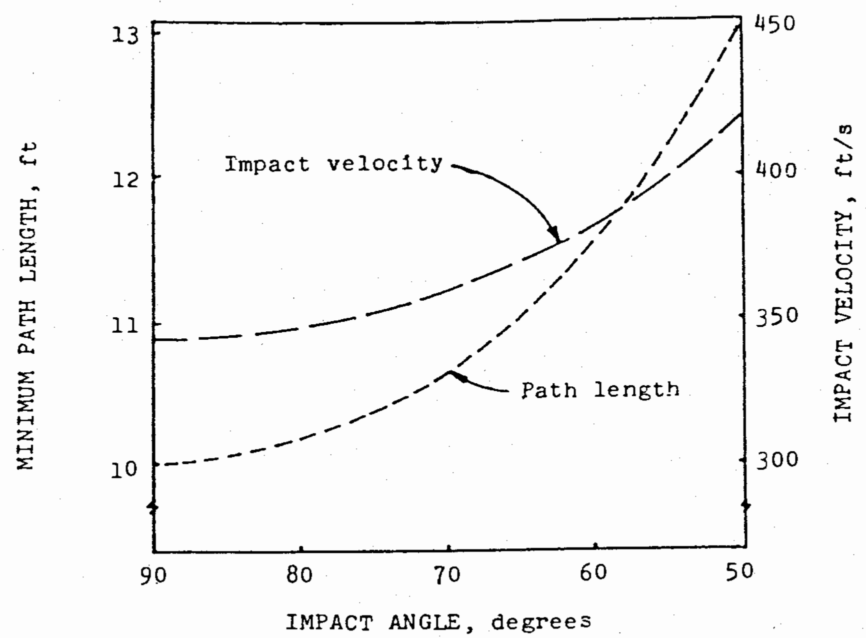


Figure 2. Velocity Required to Penetrate 10 feet of Ice at a Given Impact Angle for a 1500-lb System with a 2.2 CRH Nose

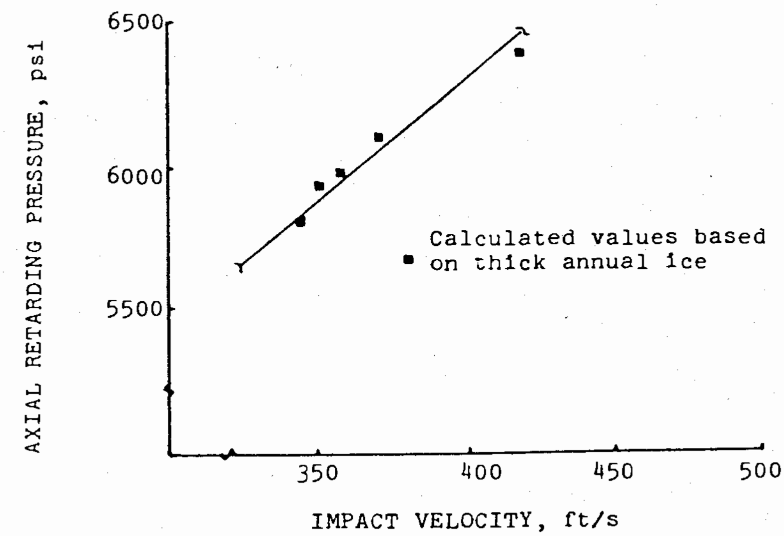


Figure 3. Axial Retarding Pressure on the Nose of a 15-inch Diameter System with a 2.2 CRH Nose at Various Impact Velocities

Weapon System Constraints

On top of all the variables which must be considered when trying to design an ice penetrating weapon, there are several other constraints that must be placed on the weapon system. These constraints vary depending on the type of weapon, whether bottom mine, moored mine, torpedo, etc., the areas of the ocean in which they will be used, and the targets these weapons will engage. Practical constraints are also placed on these systems by the type of aircraft able to deliver them. These additional factors which have to be considered when developing an ice penetrating weapon system, including weapon type and use and aircraft constraints, are presented below.

Weapon Use Constraints

In the previous section, it was illustrated how important it is to maintain selected impact velocities, impact angles, and angles of attack. Trying to maintain the most beneficial impact conditions may greatly increase the complexity of an ice penetrating weapon system because of the effectiveness constraints of a particular weapon. Ice penetrating weapon systems may be divided into two categories: target weapons and area weapons.

An area weapon, such as bottom or moored mines, would be used in a general area with many placed randomly throughout the area. Therefore, the CEP of a single weapon would not be important, and some scatter of the weapons could be tolerated. Figure 6 shows the release conditions required to enable a nonretarded 2.2 CRH, 1500-lb weapon system to impact at a minimum $55^{o}$ impact angle at the velocities required to penetrate 10 feet of ice. As can be seen from this figure, release altitudes in excess of 2500 feet are required to attain the required impact velocity and impact angle. Some scatter would be expected if dropped from this height, but for general area weapons where the CEP is not important, a simple, aerodynamically-stable, free fall weapon system could attain an adequate impact velocity and impact angle.

A target weapon, such as destructors and torpedoes, is used against a specific target and therefore needs to be delivered with a generally small CEP. This would probably require either a low-level delivery to prevent scatter or a guided weapon system. A guided weapon system can be very complicated, while low-level deliveries do not generally provide acceptable impact velocities and impact angles for ice penetration in either free-fall or retarded configurations. Low-level deliveries would probably require that a weapon system be retarded to attain the required impact angles and then be boosted to attain the required impact velocities. Therefore, either a guided or low-level delivery of a target weapon could substantially increase the complexity of an ice penetrating system in order to meet survivable impact conditions.

## Aircraft Constraints

The two systems suggested for delivery of ice penetrating weapons are the P3 and B52 aircraft which have practical system constraints as listed in Table 2. [7,8].

Table II. Practical Delivery System Constraints for Ice Penetrating Weapons

| SYSTEM | PRACTICAL SYSTEM CONSTRAINTS | | | |
|---|---|---|---|---|
| | Number of Weapons | Weight (lbs) | Diameter (inches) | Length (inches) |
| B52 (Bomb Bay) (2 Clip System) | 8-12 | 2500 | 24 | 150 |
| B52 (Wing Pylon) (Each Wing) | 5 | 2500 | 24 | 150 |
| P3 (Bomb Bay) | 3 | 1600 | 21 | 133 |
| P3 (Bomb Bay) | 1 | 2450 | 23-5/8 | 133 |
| P3 (Wing Stations) | 6 | 2450 | -- | -- |

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# IV. CONCLUSIONS

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14. Longcope, D. B., and Foresstal, M. J., "Penetration of Targets Described by a Mohr-Coulomb Failure Criterion with a Tension Cutoff, "Journal of Applied Mechanics, Vol. 50, June 1983, pp. 327-333.

15. Young, C. W., and Young, E. R., "Simplified Analytical Model of Penetration with Lateral Loading, SAND 84-1635, Sandia National Laboratories, Albuquerque, NM, May 1985.

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Subject: Load/Time Histories for Mk-82, -83, and -84 Bomb Shapes Penetrating 10 Feet of Ice (U)

Gentlemen:

Under Sandia National Laboratories' contract with the Naval Air Systems Command to determine the ice penetration capability of several of the Navy's conventional mines, torpedoes, and destructors, we have calculated the axial and lateral loading environments for those weapons which will structurally survive 10 feet of ice penetration. Under this agreement, we are to provide this data to the appropriate Naval laboratories so that they can analyze





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Table 1.

NAVAIR P3 Aircraft Compatibility System Constraints

| SYSTEM TYPE | SYSTEM CONSTRAINTS Weight (lbs) | Diameter (inches) | Length (inches) |
|---|---|---|---|
| 1 | 1200 | 14 | 134 |
| 2 | 1600 | 21 | 133 |
| 3 | 2450 | 23-5/8 | 133 |
| 4 | 2450 | -- | --- |

to try and make these modifications fall within the constraints of either Systems 1 or 2. In this report, the modifications required for ice penetration and the expected loading environments for the following weapons will be addressed: Mk-65 Quickstrike, Mk-60 Captor, Mk-56 moored mine, and Mk-55 and Mk-52 bottom mines. The modifications required for ice penetration and the loading environments expected were presented in [2] for the Mk-82, -83, and -84 bomb shapes and in [3] for the Mk-46 and ALWT torpedoes.

The loading information calculated for each of the weapons which could be modified within the constraints listed in Table 1 include:

Axial acceleration/time
Lateral acceleration/time
Lateral forces/time

[redacted]

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[redacted]

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References:

[1] CNSI Letter dtd 9-26-83, M. M. Hightower, SNLA, to CMDR H. W. Hickman, NAVAIR, subj: "Progress Report for September on SNL's Ice Penetration Study" (U)

[2] CNSI Letter dtd 10-5-83, M. M. Hightower, SNLA, to M. M. Kleinerman, NSWC, and F. Smith, NWC, subj: "Load/Time Histories for Mk-82, -83, and -84 Bomb Shapes Penetrating 10 Feet of Ice" (U)

[3] CNSI Letter dtd 10-14-83, M. M. Hightower, SNLA, to CMDR H. W. Hickman, NAVAIR, subj: "Ice Penetration Study" (U)

[4] Forrestal, M. J., "Forces on Conical-Nosed Penetrators Into Targets With Constant Shear Strength," (U), Mechanics of Materials 2, pp. 173-177, 1983.

[5] Hightower, M. M.; Norwood, F. R.; and Young, C. W., "Development of an Ice Penetration Model," (U) Report SAND82-0599, Sandia National Laboratories, Albuquerque, NM, December 1982.

[6] Letter dtd 3-7-77, C. W. Young, SNLA, to M. M. Kleinerman, NSWC, subj: "Mk-82 and Mk-65 Quickstrike Penetration Tests at White Sands Missile Range" (U)

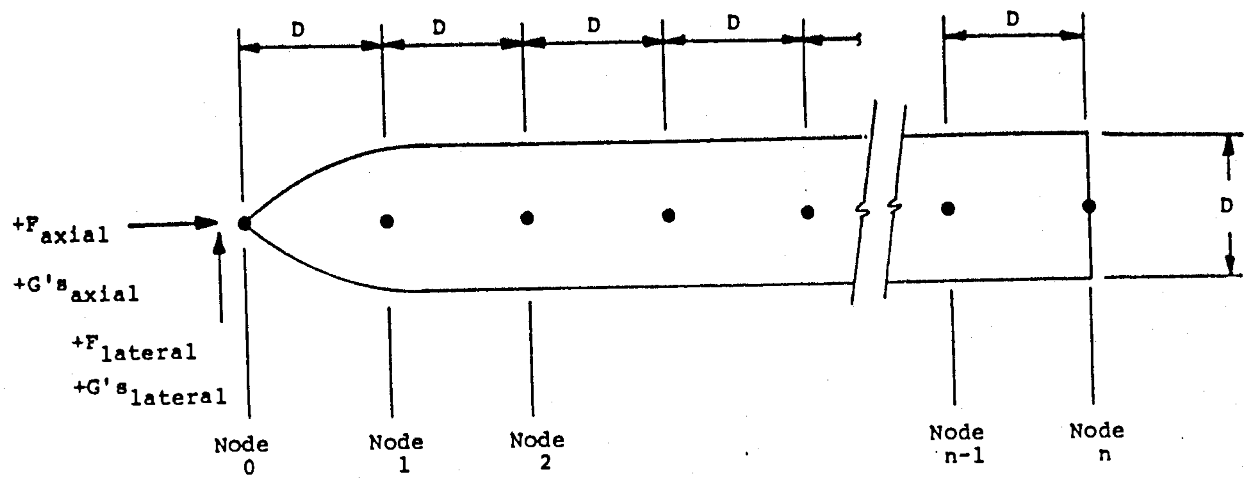


Figure 1. Location of nodes for the lateral loading plots.

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APPENDIX D

Table 1.

NAVAIR P3 Aircraft Compatibility System Constraints

| SYSTEM TYPE | SYSTEM CONSTRAINTS Weight (lbs) | Diameter (inches) | Length (inches) |
|---|---|---|---|
| 1 | 1200 | 14 | 134 |
| 2 | 1600 | 21 | 133 |
| 3 | 2450 | 23-5/8 | 133 |
| 4 | 2450 | -- | --- |

This preliminary report considers only possible modifications to the Mk-46 and ALWT torpedoes.

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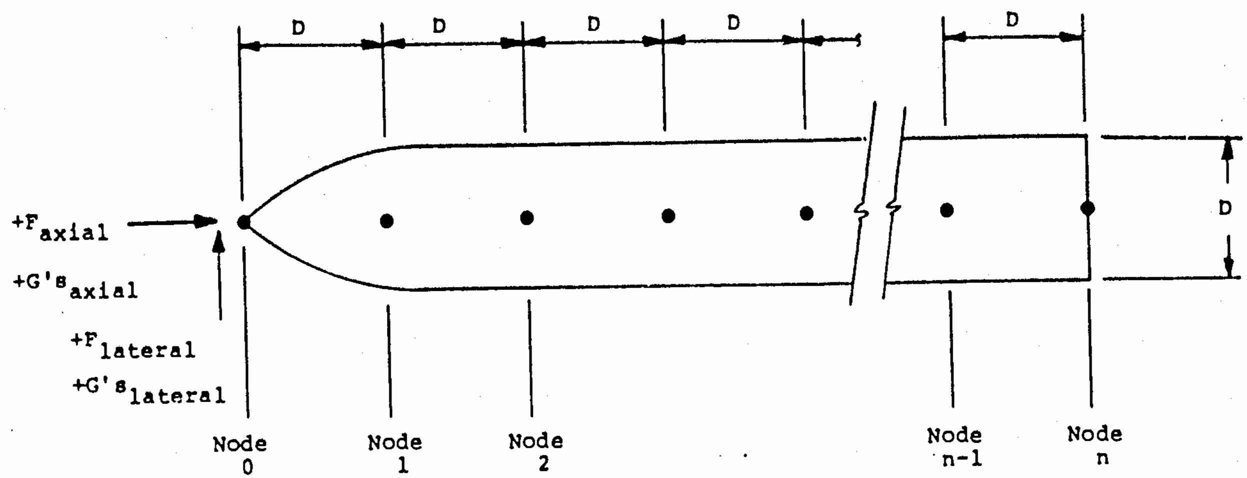


Figure 1. Location of nodes for the lateral loading plots.



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