AD-A020 188

TORPEDO LAUNCH FROM HIGH-SPEED SURFACE SHIPS

R. H. Waser

Naval Surface Weapons Center
Silver Spring, Maryland

25 November 1975

NSWC/WOL/TR 75-187

NSWC TECHNICAL REPORT

WHITE OAK LABORATORY

TORPEDO LAUNCH FROM HIGH-SPEED SURFACE SHIPS

BY
R.H. Waser

15 25 NOVEMBER 1975

NAVAL SURFACE WEAPONS CENTER
WHITE OAK LABORATORY
SILVER SPRING, MARYLAND 20910

Approved for public release; distribution unlimited

NAVAL SURFACE WEAPONS CENTER
WHITE OAK, SILVER SPRING, MARYLAND 20910

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NSWC/WOL/TR 75-187	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TORPEDO LAUNCH FROM HIGH-SPEED SURFACE SHIPS		5. TYPE OF REPORT & PERIOD COVERED Final 7-73 to 11-75
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. H. Waser		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Surface Weapons Center White Oak Laboratory White Oak, Silver Spring, Maryland 20910		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS SR 1230103/SEA1848210632
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 25 November 1975
		13. NUMBER OF PAGES ~~28~~ 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

torpedo launch, water entry, hydrofoil ships, surface effects ships

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Laboratory tests were made to study the launch of the Mk 46 torpedo from the deck of high-speed surface ships. Bow, stern, and amidship launch tube azimuth angles with different amounts of depression were tested. The torpedo used was a 1/2.125 scale model internally instrumented with accelerometers to provide water-entry impact loads. High-speed photographic coverage provided trajectory data. Test results indicated that under most launch conditions acceptable water entry occurred.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

NSWC/WOL/TR 75-187 25 November 1975

TORPEDO LAUNCH FROM HIGH-SPEED SURFACE SHIPS

This report is a result of the continuing effort at the Naval Surface Weapons Center, White Oak Laboratory, to develop water-entry technology. The work reported herein was supported entirely by NAVSEA Code 03512 (Dr. T. Peirce) under task SR 1230103/SEA1848210632. The author would like to acknowledge the assistance of Messrs. W. Hinckley, D. Newell, C. Smith and H. Steves in the execution of this program.

K. R. ENKENHUS
By direction

TABLE OF CONTENTS

	Page
INTRODUCTION	4
Simulation of Launch with a Stationary Catapult-Type Launcher	4
MODEL SCALING	9
LABORATORY SETUP AND EXPERIMENTAL MODEL	10
TEST PLAN	11
Test Results: Trajectory	11
Test Results: Acceleration Loads	12
SUMMARY OF TEST RESULTS	12
CONCLUSIONS	13

ILLUSTRATIONS

Figure	Title	Page
1	Torpedo Launch Simulation	15
2	Ship Launch Coordinate System	16
3	Laboratory Launch Coordinate System	17
4	Mk 46 Torpedo Test Model	18
5	Torpedo Launch With 30° Tube Azimuth Trajectory Plan View	19
6	Torpedo Launches with 90° Tube Azimuth Trajectory Plan View	20
7	Model Acceleration Traces	21

TABLE

Table	Title	Page
1	Test Matrix and Water-Entry Acceleration Levels	14

LIST OF SYMBOLS

a	acceleration
A	vector magnitude in i direction
A'	$A + V_s$
B	vector magnitude in j direction
B'	B corrected for gravity acceleration
C	vector magnitude in k direction
d	diameter
F	Froude number
$\underline{g}$	gravity
$\bar{H}$	horizontal reference vector
$\hat{i}$	unit vector
I	moment of inertia
$\hat{j}$	unit vector
$\bar{J}$	horizontal reference vector
$\hat{k}$	unit vector
m	mass
t	time
$\bar{T}$	reference vector
V	velocity
y_1	height of launcher
y_2	instantaneous height of torpedo above water
θ	shipboard launcher depression angle
θ'	pitch angle
θ''	Laboratory launcher depression angle
λ	scale factor
ϕ	Laboratory launcher roll angle
ϕ'	Laboratory model roll angle
ψ	shipboard launcher azimuth angle

Subscripts

m	model
p	prototype
s	ship
t	torpedo

INTRODUCTION

With the development of hydrofoil and surface effects ships, the Navy now has available ships capable of operating at much higher speeds than those in the past. The speed of these ships makes them good ordnance launch platforms in tactical situations. Anticipated weaponry includes torpedoes fired from deck-mounted launch tubes. This study was directed toward investigating possible launch problems resulting mainly from the high cross velocity of the torpedo at water entry when launched at off-beam azimuth angles. The problems are those of (1) unacceptable trajectory perturbation, (2) damage at water impact, and (3) broaching. Limited full-scale tests with the Mk 46 torpedo, reference (1), indicated that such launches could be made successfully, although the gyroscopes were noted to have deflected at water entry. The tests reported here were designed to extend the ship velocity range and provide actual impact acceleration values.

In this study, a 1/2.125 scale model of the Mk 46 torpedo was launched into the NAVSURFWPNCEN, White Oak Laboratory's, Hydroballistics Tank. Crossflow conditions were exactly simulated by launch of the model with pitch, yaw, and roll from a stationary catapult-type launcher. Data from accelerometers inside the model were recorded through an electrical cable trailing from the model. High-speed cameras were used to confirm the model trajectory.

Simulation of Launch with a Stationary Catapult-type Launcher

Figure 1 illustrates the method of simulating the launch of a vehicle from the stern of a moving craft (180-degree azimuth) by use of a stationary catapult-type launcher. The ship, while moving at velocity $\overline{V}_s$, launches a torpedo with a velocity relative to the ship of $\overline{V}_{t/s}$. The resultant velocity vector of the torpedo is $\overline{V}_t$ with a torpedo pitch angle of θ. To simulate the launch with a stationary launcher, the launcher is depressed to the angle of $\overline{V}_t$, the torpedo is mounted with the θ pitch angle, and the launch is made at the properly scaled $\overline{V}_t$ speed.

---

[1]Attri, Paul S., "Plainview (AGEH-1) Torpedo Trials of 23 Feb 1972", NAVTORSTA Rept 1160, Jun 1972

For the case of an amidship launch simulation, the technique is similar to that above except that rather than being a two-dimensional problem, it is a three-dimensional problem which involves roll and yaw positioning in the stationary launcher. Derivation of the relationships between the actual and simulated launch conditions is essentially one of a coordinate system transformation. This was done making use of vector relationships and as a check was done using matrix operations. The following is the derivation of the relationships using the vector operation technique. This derivation is considerably shorter than the matrix technique and provides visualization of the process. First, the vector equations representing the prototype torpedo launched from the ship are written. Figure 2 shows the ship coordinate system.

Using unit vector notation, the relationships are:

$\bar{V}_s = V_s \hat{i}$ ship velocity (1)

$\bar{V}_{t/s} = A\hat{i} + B\hat{j} + C\hat{k}$ torpedo velocity relative to ship at the instant of launch (2)

where

$$A = V_{t/s} \cos \Psi \cos \theta \quad (3)$$

$$B = V_{t/s} \sin \theta$$

$$C = V_{t/s} \sin \Psi \cos \theta$$

$\bar{V}_t = \bar{V}_s + \bar{V}_{t/s}$ resultant velocity (4)

or substituting (1) and (2) into (4)

$$\bar{V}_t = (A + V_s)\hat{i} + B\hat{j} + C\hat{k} \quad (5)$$

defining

$$A' = A + V_s \quad (6)$$

$$\bar{V}_t = A'\hat{i} + B\hat{j} + C\hat{k} \quad (7)$$

While the torpedo is in air flight after launch, it is accelerated by gravity. Defining

y_1 = height of shipboard launch tube above water

y_2 = height of torpedo above water at time of interest.

Then

$$B' = \sqrt{B^2 + 2g(y_1 - y_2)} \tag{8}$$

Equation (7) thus becomes

$$\bar{V}_t' = A'\hat{i} + B'\hat{j} + C\hat{k} \tag{9}$$

The magnitude of the torpedo velocity at any time is

$$V_t' = \sqrt{(A')^2 + (B')^2 + C^2} \tag{10}$$

Having the above relationships, it is now necessary to satisfy them using a stationary launcher. Figure 3 defines the angular and vector relationshps of the test model and stationary launcher. The angles defined in Figure 3 were chosen because they are the easiest to measure during the launcher setup and loading.

Velocity, V_t': The velocity magnitude is defined by equation (10). (Note that the height of the stationary launcher above the water surface may be made different from that of the ship launcher by using appropriate values of y_1 and y_2 in the equation for B'.)

Launcher Angle, θ'': The depression angle of the stationary launcher, θ'', is the angle between the resultant velocity vector, $\bar{V}_t'$, and the water surface, or

$$\theta'' = \arcsin\left(\frac{B'}{V_t'}\right) \tag{11}$$

Model Pitch Angle, θ': The pitch angle is the angle between the model axis and the launcher axis. The model axis must be parallel to the prototype axis which is the vector direction given by equation (2).

$$\bar{V}_{t/s} = A\hat{i} + B\hat{j} + C\hat{k} \tag{2}$$

The launcher axis is coincident with the resultant velocity vector which is given by equation (9)

$$\bar{V}_t' = A'\hat{i} + B'\hat{j} + C\hat{k} \tag{9}$$

The pitch angle, θ', between these two vectors may be calculated using the vector dot product

$$\bar{V}_{t/s} \cdot \bar{V}_t' = |\bar{V}_{t/s}||\bar{V}_t'|\cos\theta'$$

or

$$\theta' = \text{arc cos}\ \frac{\bar{V}_{t/s} \cdot \bar{V}_t'}{|\bar{V}_{t/s}||\bar{V}_t'|}$$

Substituting from equations (2) and (9)

$$\theta' = \text{arc cos}\ \frac{(A\hat{i} + B\hat{j} + C\hat{k}) \cdot (A'\hat{i} + B'\hat{j} + C\hat{k})}{\sqrt{A^2 + B^2 + C^2}\sqrt{A'^2 + B'^2 + C^2}}$$

or

$$\theta' = \text{arc cos}\ \frac{AA' + BB' + C^2}{\sqrt{A^2 + B^2 + C^2}\sqrt{A'^2 + B'^2 + C^2}} \qquad (12)$$

<u>Roll of Launcher Post, ϕ</u>: The angle ϕ is measured from the horizontal. A horizontal vector normal to the launcher axis can be obtained by taking the vector cross product of the launch vector, $\bar{V}'_t$, and a vertical unit vector, $\hat{j}$. Defining this horizontal vector to be $\bar{H}$,

$$\bar{H} = \bar{V}'_t \times \hat{j}$$

substituting $\bar{V}'_t$ from equation (9)

$$\bar{H} = (A'\hat{i} + B'\hat{j} + C\hat{k}) \times \hat{j}$$

$$\bar{H} = -C\hat{i} + A'\hat{k} \qquad (13)$$

A vector, call it $\bar{T}$, perpendicular to the plane of the launcher axis/model axis can be obtained by taking the vector cross product parallel to those two axes, i.e., from equations (9) and (2)

$$\bar{T} = \bar{V}'_t \times \bar{V}_{t/s}$$

$$\bar{T} = (A'\hat{i} + B'\hat{j} + C\hat{k}) \times (A\hat{i} + B\hat{j} + C\hat{k})$$

Performing the indicated operation and simplifyi[illegible] using equation (6)

$$\bar{T} = C(B-B')\hat{i} + (V_sC)\hat{j} + (AB' - A'B)\hat{k} \qquad (14)$$

The desired launcher post roll angle is the angle between the two vectors just obtained. Using the vector dot product to obtain that angle,

$$\bar{H} \cdot \bar{T} = |\bar{H}|\,|\bar{T}| \cos \phi$$

$$\phi = \arc\cos \frac{\bar{H} \cdot \bar{T}}{|\bar{H}|\,|\bar{T}|}$$

or

$$\phi = \arc\cos \frac{-C^2(B-B') + A'(AB'-A'B)}{\sqrt{C^2 + (A')^2}\sqrt{C^2(B-B')^2 + V_B{}^2C^2 + (AB'-A'B)^2}} \qquad (15)$$

Roll of Model in Launcher, ϕ': The model must be rolled in the launcher to restore its proper orientation which was affected by the launcher post roll angle, ϕ. For a reference, a horizontal vector perpendicular to the model axis is generated by taking the vector cross product of the model axis direction, $\bar{V}_{t/s}$ and a vertical unit vector, $\hat{j}$. Defining this vector as $\bar{J}$,

$$\bar{J} = \bar{V}_{t/s} \times \hat{j}$$

and substituting from equation (2)

$$\bar{J} = (A\hat{i} + B\hat{j} + C\hat{k}) \times \hat{j}$$

or

$$\bar{J} = -C\hat{i} + A\hat{k}$$

The angle between this vector and the previously obtained vector $\bar{T}$, which is also perpendicular to the model axis as well as to the launcher axis, is the desired model roll angle ϕ'. This angle can be determined by again making use of the vector dot product

$$\bar{J} \cdot \bar{T} = |\bar{J}|\,|\bar{T}| \cos \phi'$$

$$\phi' = \arc\cos \frac{\bar{J} \cdot \bar{T}}{|\bar{J}|\,|\bar{T}|}$$

$$\phi' = \arc\cos \frac{C^2(B'-B) + A(AB'-A'B)}{\sqrt{C^2+A^2}\sqrt{C^2(B-B')^2+V_S{}^2C^2+(AB'-A'B)^2}} \qquad (16)$$

MODEL SCALING

The tests were done with a geometrically scaled model which was six inches in diameter as compared to the Mk 46 full-scale torpedo diameter of 12.75. The scale factor was thus

$$\lambda = \frac{d_m}{d_p} = \frac{6}{12.75} = \frac{1}{2.125}$$

where d is diameter and the subscripts m and p refer to the model and prototype respectively. The model was built to have the same center of gravity, mass, and moment of inertial characteristics as if all the internal components were modeled exactly. Hence,

$$m_m = \lambda^3 m_p$$

and

$$I_m = \lambda^5 I_p$$

where m and I are the mass and moment of inertia.

In order for the trajectory of the model to be similar to that of the prototype, all of the forces, i.e,. inertial, gravitational and hydrodynamic, must be identically scaled and the ratio of velocities between the ship and launcher ejection must be constant. Froude scaling maintains the required relationship between inertial and gravitational forces and also with the aerodynamic and hydrodynamic forces if those coefficients are the same for model and prototype. The Froude number, which is kept constant for model and prototype, is defined as

$$F = \frac{V^2}{dg}$$

where V, d, and g are velocity, a characteristic length such as diameter, and gravity, respectively.

Aerodynamic and hydrodynamic coefficients because of viscous effects are a function of Reynolds number. Froude and Reynolds number scaling cannot be done simultaneously with the same fluid, but in this case with the model and prototype velocities differing by a factor of only 1.46, it was felt that no significant errors would be introduced by considering the coefficients to be constant.

Exact model scaling at water impact is complex. At the initial instant of impact the pressures are proportional to velocity rather than velocity squared as the hydrodynamic coefficients and Froude scaling require. However, the area of the body in contact with the water for this instant is so small that the total force is not significant (Ref. (2)).

In conclusion, it is believed that Froude scaling with the geometrically scaled model provides a valid simulation of trajectory and acceleration for the air flight, water entry, and underwater travel. The Froude relationships for velocity, acceleration, and time, respectively, are

$$V_m = \sqrt{\lambda}\ V_p$$

$$a_m = a_p$$

$$t_m = \sqrt{\lambda}\ t_p$$

LABORATORY SETUP AND EXPERIMENTAL MODEL

The experimental tests were conducted in the NAVSURFWPNCEN, White Oak Laboratory's Hydroballistics Facility which has a water tank measuring 35 feet by 100 feet. For these tests water depths of 60 to 64 feet were used. High-speed framing cameras, using 16mm and 35mm film, recorded the model air and underwater trajectories in three planes.

The model launcher used was an air gun (see Figures 1 or 3) into the barrel of which an aluminum tubular post was inserted. The post was tied to the inside of the gun with a length of nylon rope which allowed the post to be accelerated by the firing of the gun, but restrained it close to the end of the barrel so it could not leave the gun. Rigidly affixed to the end of the post was a model carrying fixture capable of being adjusted to hold the model at the desired pitch angle. The model was held in the fixture with a fiberglass clothband which broke and released the model when the nylon rope in the gun stopped the post/fixture assembly.

Figure 4 is a diagram of the Mk 46 model used. It was made of aluminum, and designed in such a way that the weight, c.g., and moment of inertia characteristics were correctly scaled.

---

[2]Baldwin, J. L., and Steves, H. K., "Vertical Water Entry of Spheres", NSWC/WOL/TR 75-49, 7 May 1975

Six Kistler Instrument Corporation Model 303B servo-type accelerometers were installed in the model in the locations indicated. The accelerometers were connected through a cable trailing from the model to recording instrumentation. Outputs from all six accelerometers were recorded simultaneously on a visicorder, analog magnetic tape, and through an analog to digital converter onto digital magnetic tape.

TEST PLAN

A test matrix was developed for simulated tests at ship speeds of 30 and 60 knots, launcher azimuth angles of 0, 30, 90, and 180 degrees (0 degrees being a bow shot and 180 degrees being a stern shot) and launcher depression angles of 0, 15, and 30 degrees measured from the horizontal. The first three data columns of Table 1 show this matrix. In the Laboratory test facility it was necessary to reduce the launcher height above the water from the shipboard scaled value of 20 feet to shorten the air-flight distance to an acceptable value; further, for convenience it was desired to limit the number of water level changes which would result from launcher angle changes. The Laboratory test conditions were accordingly calculated with equations (10) through (16) using an iterative computer program with inputs being the shipboard conditions and one of several convenient Laboratory water heights. The Laboratory simulation was thus exact, but started at a point on the torpedo trajectory some distance from the shipboard launch point.

Because the ship speed was in all cases greater than the launcher ejection velocity, the stern launch was made as a tail-first launch. This is required if the torpedo is to travel in the direction it is pointed, rather than backward.

Test Results: Trajectory

The model was instrumented with six accelerometers - one for each degree of freedom. Data was recorded from these digitally on magnetic tape with the expectation that computer processing would yield plotted trajectories as well as maximum acceleration vectors. Unfortunately the resolution of the roll sensing accelerometers was not sufficient for tracking of the roll position which made the trajectory calculation impossible. Trajectories were accordingly read from the high-speed camera film.

Figure 5 shows a plan view trajectory plot for the 30-degree azimuth 30-knot ship speed launch. Each arrow length is scaled to the torpedo length and the arrow positions represent sequential torpedo positions relative to the ship position at launch. The phantom line in the figure is the resultant direction of the ship and torpedo launch velocities. It is seen that in this case the torpedo aligns itself with the resultant velocity direction and follows along that line. For the bow and stern launches the trajectory was straight along a line coincident with the ship centerline as would be expected. Figure 6 shows a plan view of three broadside launches. In this case it is seen that the torpedo trajectory is not along the initial resultant velocity vector, but rather is more in line with the initial torpedo axis at right angles to the ship.

Vertical plane trajectories for all off-beam launches, i.e., 30-and 90-degrees azimuth, were with a shallow, increasing dive angle. Both bow and stern launches, however, gave trajectories which curved upward after a short distance of underwater travel - the worst case being the 60-knot stern launch at 30-degrees launcher depression angle which resulted in broaching.

Test Results: Acceleration Loads

The accelerometer outputs were recorded on a visicorder and also digitally on magnetic tape. Figure 7, from test condition six (30 knots, 90-degrees azimuth, 15-degrees launcher depression), is a typical record. The magnitudes of the maximum water-entry accelerations were obtained from the digital data directly for the axial loads and for the transverse loads by resolving the pitch and yaw components at both the nose and tail accelerometer locations. These maxima are listed in Table 1. Perhaps the most important thing to be noted from this data is that the accelerations experienced from a "flat" entry (0-degree launch tube depression) are considerably higher than when the torpedo enters with an angle of inclination and also are rather erratic in magnitude. Accelerations resulting from launches at 90-degrees azimuth are higher than those with azimuth angles giving lower crossflow velocities, but with a non-zero launcher depression angle these accelerations are less than 50g.

SUMMARY OF TEST RESULTS

The following observations are felt to be accurate, although based on data from a rather limited test matrix.

1. Bow and especially stern launches (0 and 180-degrees azimuth tube angles) have a tendency to produce broaching of the torpedo. Amidship launches do not have this tendency.

2. At a 30-degree off-beam launch tube azimuth and 30-knot ship speed the torpedo aligns itself with and follows the resultant velocity vector of the ship and launch tube vectors.

3. At a 90-degree off-beam launch tube azimuth and a 60-knot ship speed, the torpedo follows a trajectory roughly in line with the launcher axis, i.e., at 90 degrees to the direction of ship motion.

4. Launches from a horizontal launch tube produce erratic transverse accelerations at water entry which are generally higher than those resulting from a launch with the tube depressed. The peak transverse deceleration observed was 100g.

5. Transverse accelerations at water entry increase as the crossflow angle increases, i.e., as a broadside launch is approached.

6. Axial accelerations at water entry never exceeded 7g.

CONCLUSIONS

1. The Mk 46 torpedo is structurally capable of withstanding the water-entry loads experienced from the launch conditions tested.

2. Peak water-entry accelerations which might affect the torpedo gyros may be reduced by depressing the launch tube angle below the horizontal.

3. Bow and stern launches should be avoided to preclude broaching problems.

TABLE 1

Test Matrix and Water-Entry Acceleration Levels

	Shipboard Parameters*			Max Accelerations at Water Entry		
Test Condition Number	Launcher Azimuth, Ψ, Degrees	Ship Speed Vs, Knots	Launcher Depression, θ, Degrees	Nose Transverse g's	Tail Transverse g's	Axial g's
1	0	30	0	36	31	5
2	0	30	-15	15	8	5
3	30	30	0	30	21	4
4	30	30	-15	10	11	7
5	90	60	0	62	82	6
6	90	30	-15	25	40	5
7	90	60	-15	30	43	3
8	90	30	-30	18	24	3
9	90	60	-30	28	43	4
10	180**	30	0	40-100	35-75	4
11	180**	60	0	14-24	5-14	4
12	180**	30	-15	3	9	1
13	180**	60	-15	16	32	3
14	180**	30	-30	17	29	2
15	180**	60	-30	21	15	7

*Launch tube ejection velocity equals 40 fps for all tests; launch tube muzzle 20 ft above water

**Tail first out of launcher

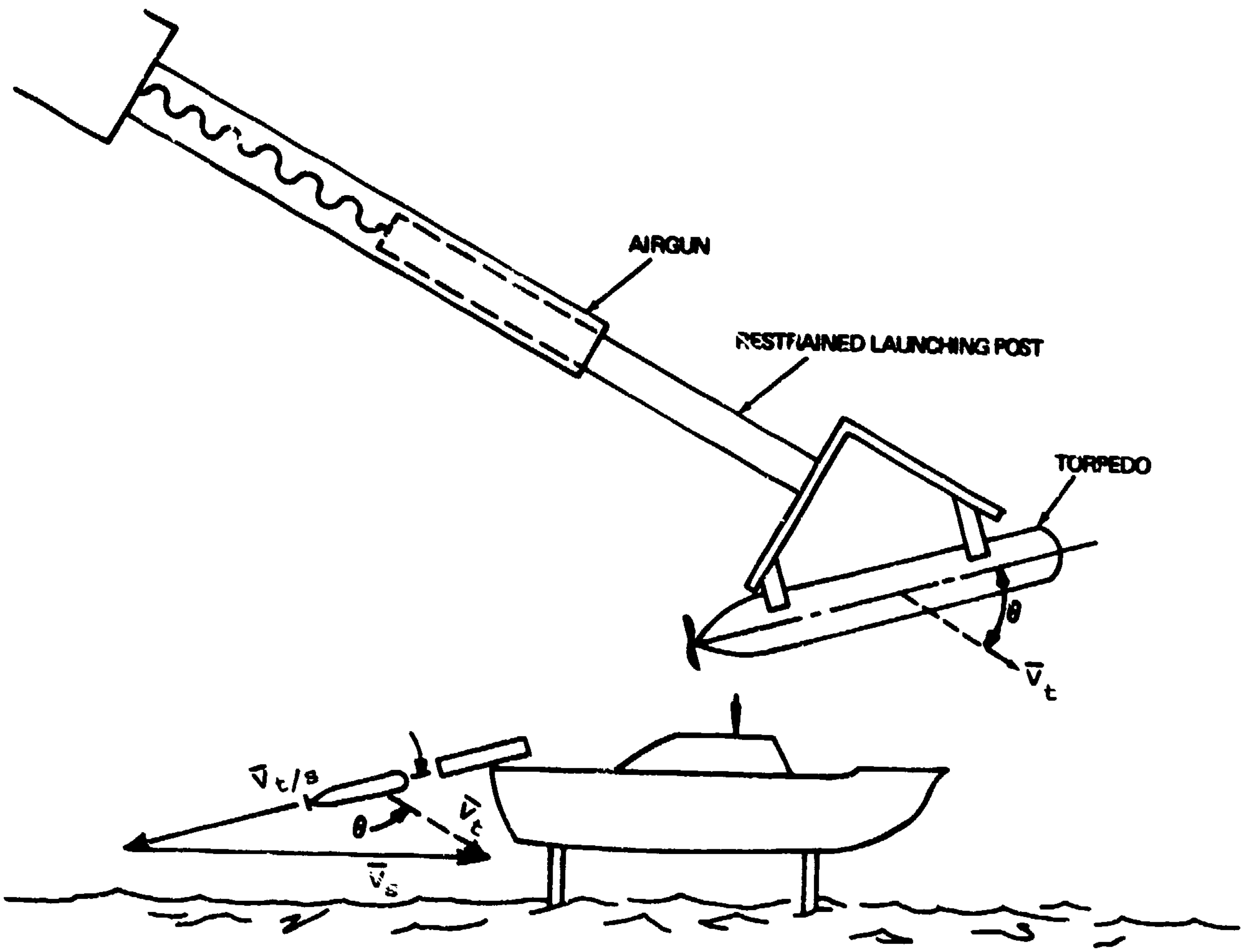


FIG. 1 TORPEDO LAUNCH SIMULATION

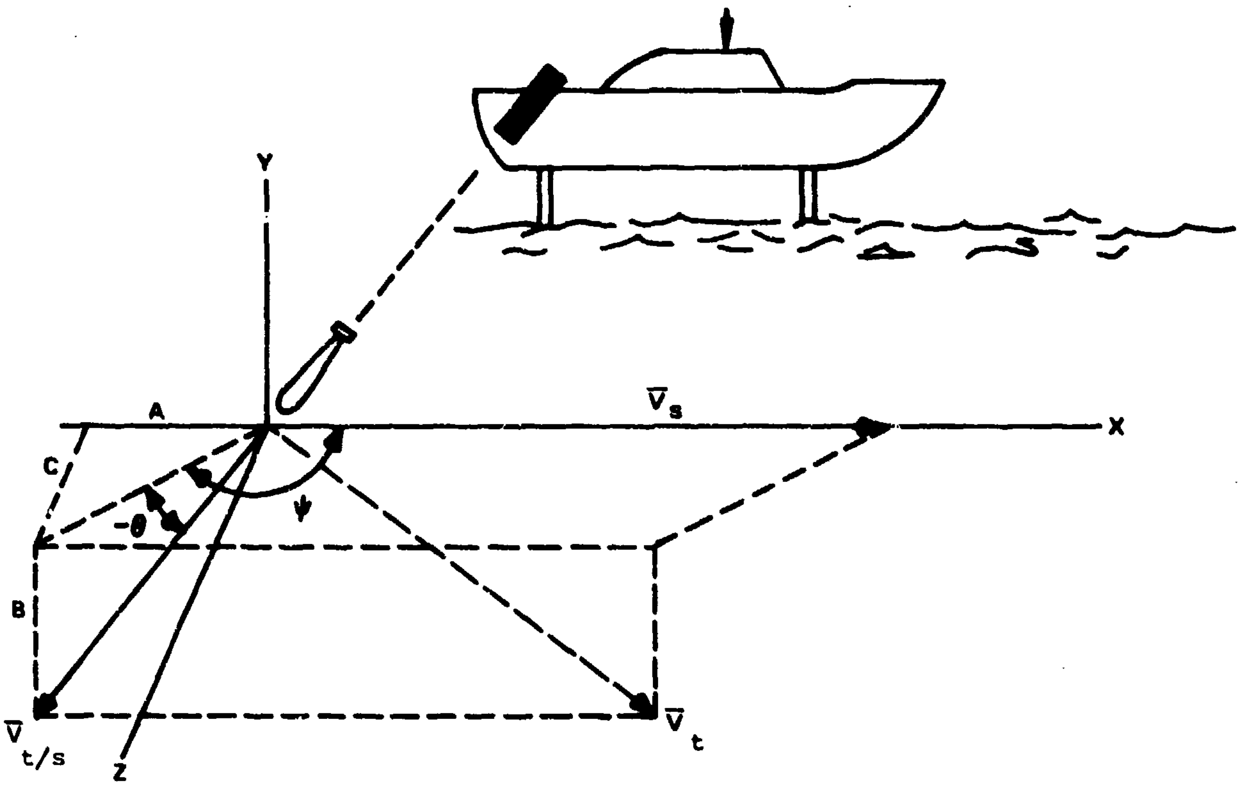


FIG. 2 SHIP LAUNCH COORDINATE SYSTEM

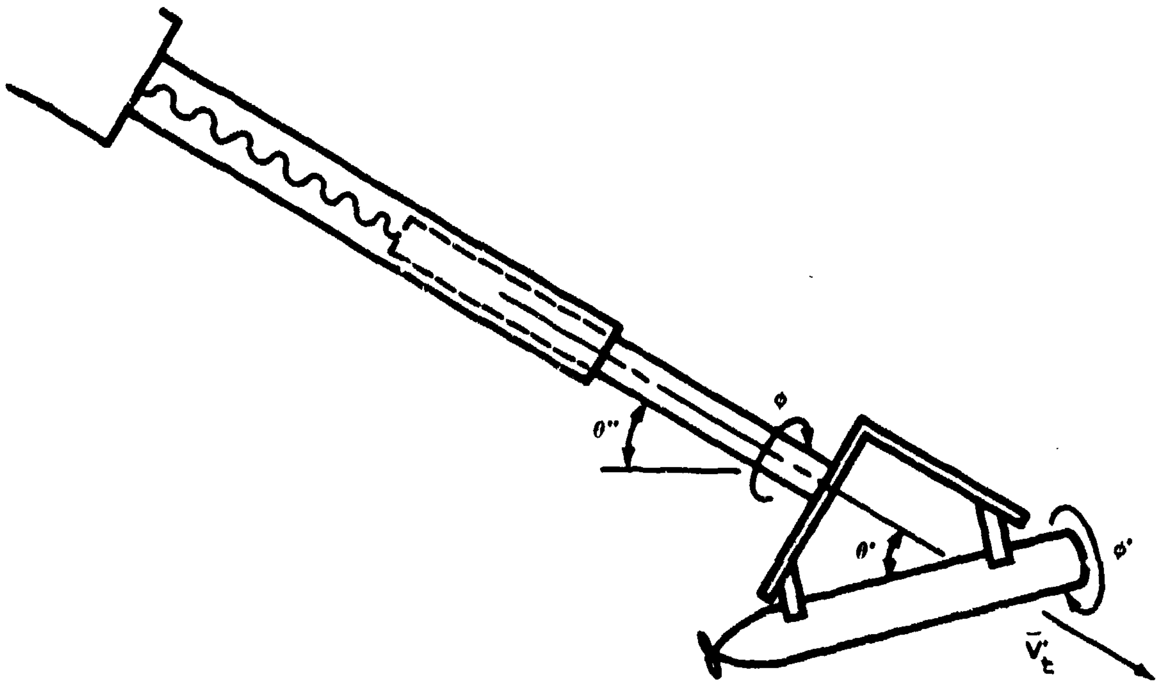


FIG. 3 LABORATORY LAUNCH COORDINATE SYSTEM

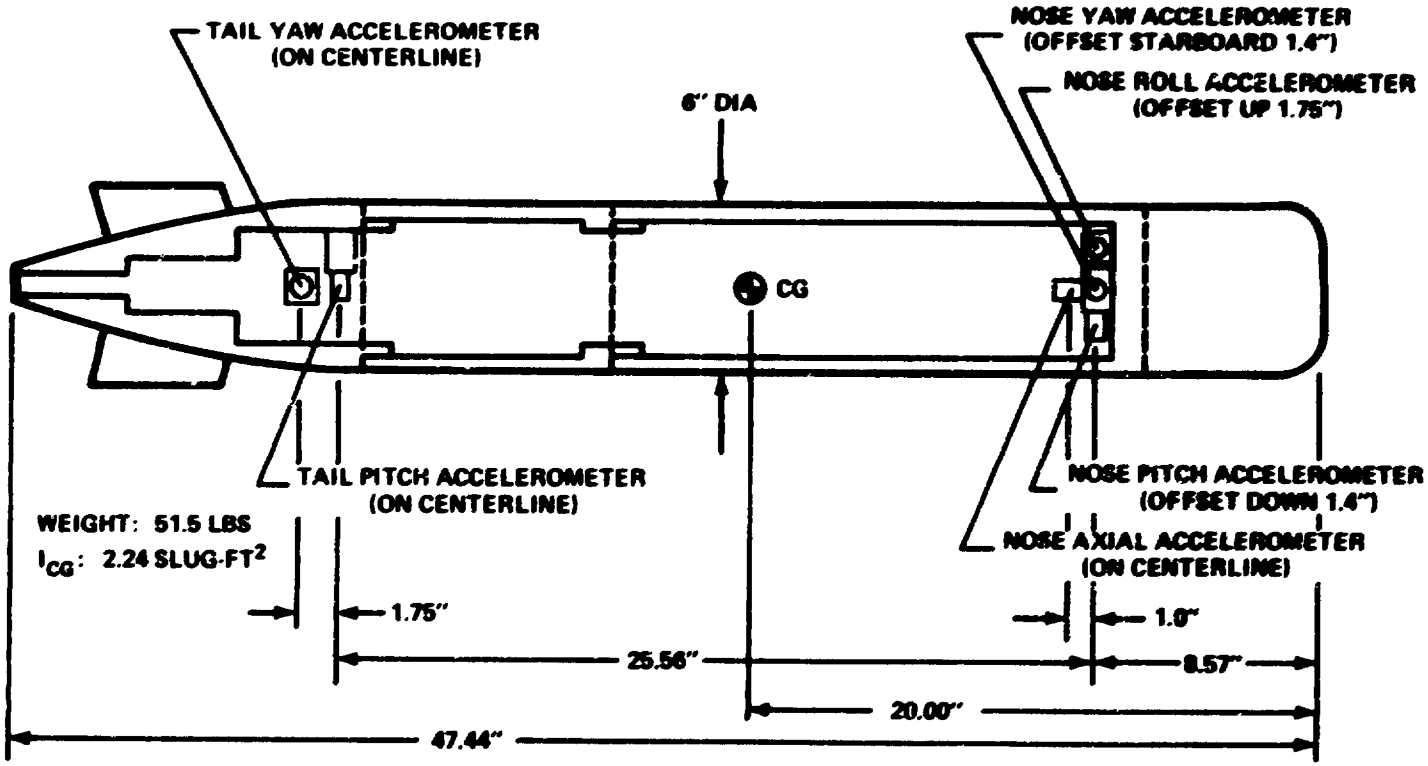


FIG. 4 MK 46 TORPEDO TEST MODEL

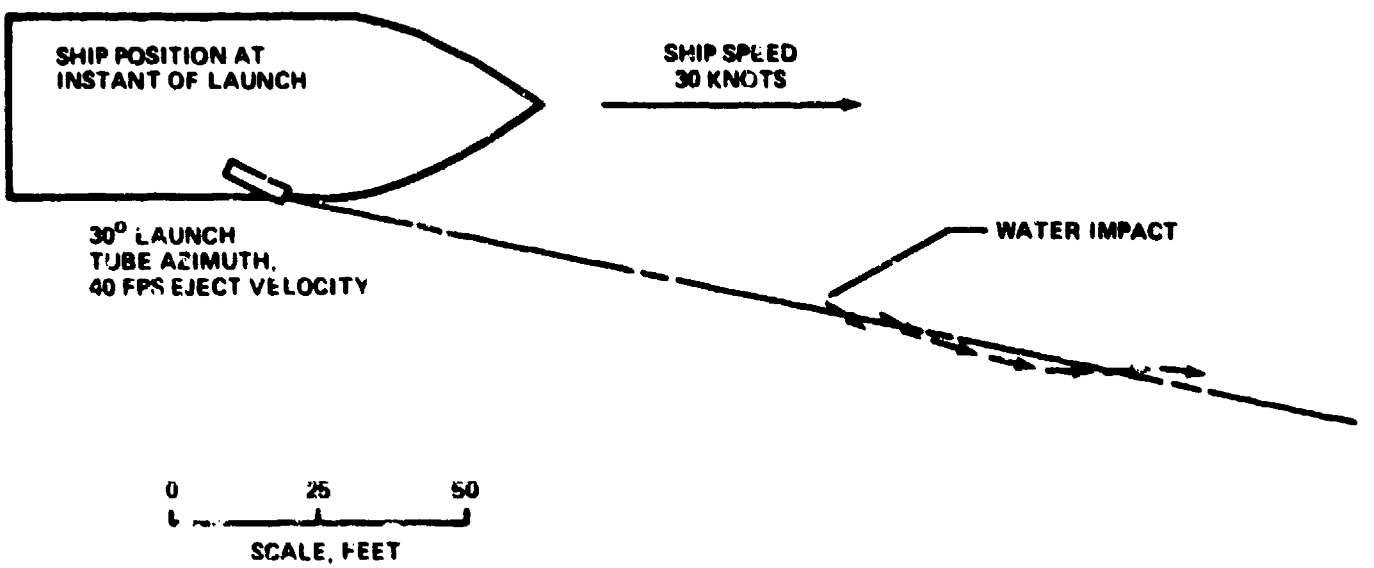


FIG. 5 TORPEDO LAUNCH WITH 30° TUBE AZIMUTH
TRAJECTORY PLAN VIEW

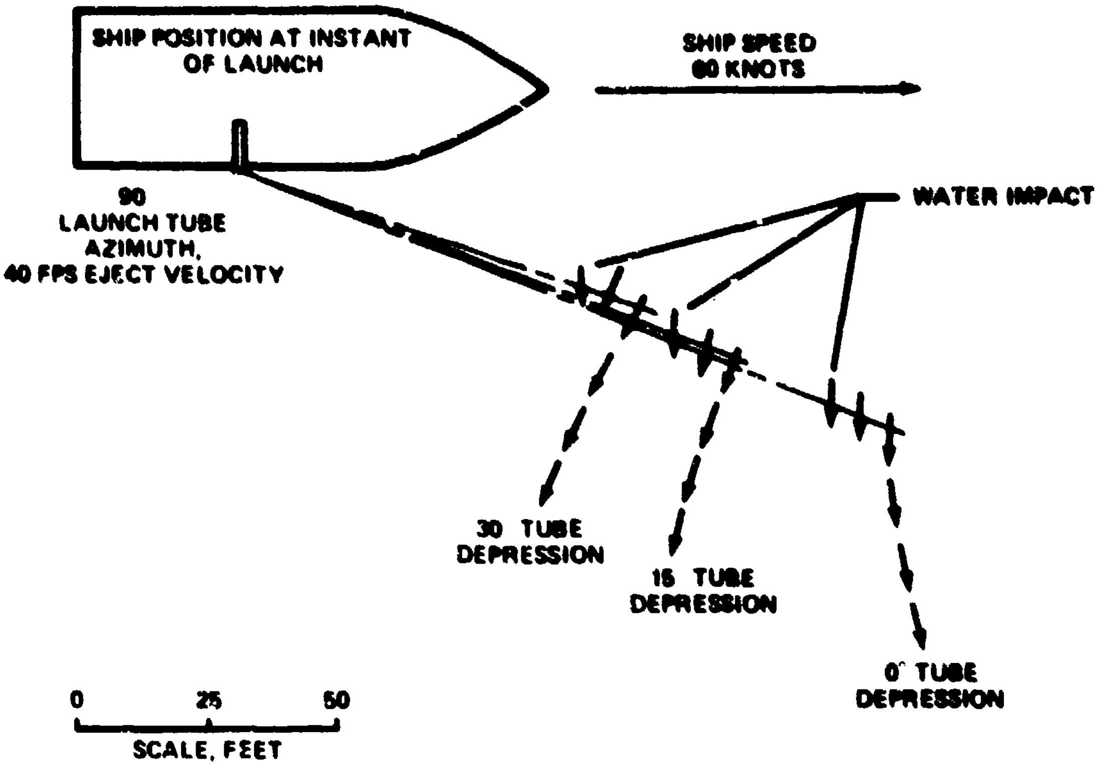
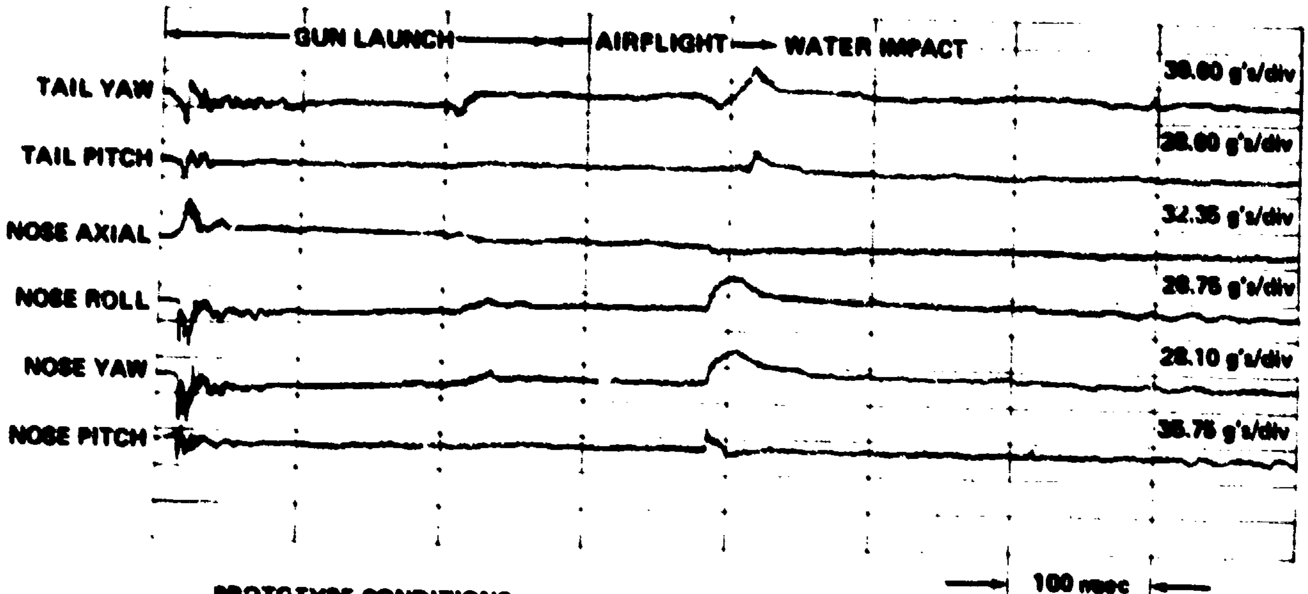


FIG. 6 TORPEDO LAUNCHES WITH 90 TUBE AZIMUTH TRAJECTORY PLAN VIEW



PROTOTYPE CONDITIONS

SHIP SPEED	30 KNOTS
EJECT VELOCITY	40 FPS
LAUNCH AZIMUTH	90 DEGREES
LAUNCHER DEPRESSION	15 DEGREES

FIG. 7 MODEL ACCELERATION TRACES