

AD-A067 650

DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 19/8
CALCULATION OF THE EFFECT OF A SUPPORTING STRUT AND THE FREE SU--ETC(U)
APR 79 C W DAWSON

UNCLASSIFIED

DTNSRDC-79/043

NL

| OF |
AD
A067850



END
DATE
FILMED
6-79
DDC

DDC FILE COPY

AD A0 67 650

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|-----------------------|---|
| 1. REPORT NUMBER 14 DTNSRDC-79/043 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 6 TITLE (and Subtitle) CALCULATION OF THE EFFECT OF A SUPPORTING STRUT AND THE FREE SURFACE ON THE DRAG ON A TORPEDO MODEL. | | 5. TYPE OF REPORT & PERIOD COVERED 9 Final rept., |
| 7. AUTHOR(s) 10 Charles W. Dawson | | 6. PERFORMING ORG. REPORT NUMBER |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084 | | 8. CONTRACT OR GRANT NUMBER(s) |
| 11. CONTROLLING OFFICE NAME AND ADDRESS 16 F53532, F33301 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (See reverse side) |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 17 SF53532020, SF33301493 | | 12. REPORT DATE 11 Apr 79 |
| | | 13. NUMBER OF PAGES 12 17p. |
| | | 15. SECURITY CLASS. (of this report) UNCLASSIFIED |
| 16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |
| 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) Drag Calculations Free Surface Model Testing Potential Flow | | |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Potential flow calculations were made to determine the effects of a supporting strut and the free surface on the drag on a test model of a torpedo. These calculations show that the strut and free surface had significant effects on the test measurements. These calculations also show that the XYZ Free Surface Program can provide useful results for Froude numbers up to but not much larger than 1.5. | | |

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1 JAN 73EDITION OF 1 NOV 65 IS OBSOLETE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

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

387682 [Signature]

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 10)

Program Element 62760N
Project F53532
Task Area SF53532020
Work Unit 1808-009
Program Element 62633N
Project F33301
Task Area SF33301493
Work Unit 1843-033

ACCESSION for

Write Section

Buff Section

NTIS

DDC

ANNOUNCED

SUBMISSION

EXEMPTION/AVAILABILITY CODES

or SPECIAL

A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

| | Page |
|---------------------------------|------|
| LIST OF FIGURES..... | iii |
| LIST OF TABLES..... | iii |
| ABSTRACT..... | 1 |
| ADMINISTRATIVE INFORMATION..... | 1 |
| INTRODUCTION..... | 1 |
| XYZ FREE SURFACE PROGRAM..... | 3 |
| GEOMETRY OF THE PROBLEM..... | 3 |
| PANELING..... | 5 |
| RESULTS..... | 7 |
| CONCLUSIONS..... | 11 |
| REFERENCES..... | 13 |

LIST OF FIGURES

| | |
|--|---|
| 1 - Model and Supporting Sting and Strut..... | 2 |
| 2 - Panel Arrangement with 208 Panels on the Model and 204 Panels on the Sting and Strut..... | 6 |
| 3 - Results of Drag Calculations with a Free Surface for 20 Knots..... | 8 |

LIST OF TABLES

| | |
|---|----|
| 1 - Values of X and R for the 208-Panel Representation of the Model..... | 4 |
| 2 - Results of Drag Calculations with and without the Strut..... | 9 |
| 3 - Results of Drag Calculations with Free Surface for 20 Knots..... | 10 |

79 04 18 062

ABSTRACT

Potential flow calculations were made to determine the effects of a supporting strut and the free surface on the drag on a test model of a torpedo. These calculations show that the strut and free surface had significant effects on the test measurements. These calculations also show that the XYZ Free Surface Program can provide useful results for Froude numbers up to but not much larger than 1.5.

ADMINISTRATIVE INFORMATION

This work was jointly sponsored by the David W. Taylor Naval Ship Research and Development Center under Program Element 62760N, Project F53532, Task Area SF53532020, Work Unit 1808-009 and by the Naval Underwater Systems Center under the Improved Performance Under Sea Vehicle Program, Program Element 62633N, Project F3301, Task Area SF33301493, Work Unit 1843-033.

INTRODUCTION

When a model is tested in a towing tank, there is always the question of the effect of the test equipment on the results. The test considered here is that of a model torpedo towed beneath the water surface in a towing tank. The model is supported by a sting and strut attached to the towing carriage above (see Figure 1). The calculations reported here were made to obtain values for the effects of the strut and free surface on the drag measurements for the torpedo model.

All calculations were made with the XYZ Free Surface Program^{1*} (XYZFS). This program was designed to handle problems for ships moving at Froude numbers between 0.2 and 0.6. This problem has the largest Froude numbers (1.5 to 3.0) yet attempted with the XYZFS program and thus is a good problem to test the program's limitations. The results clearly demonstrate the limitations as well as the usefulness of the program.

* A complete listing of references is given on page 13.

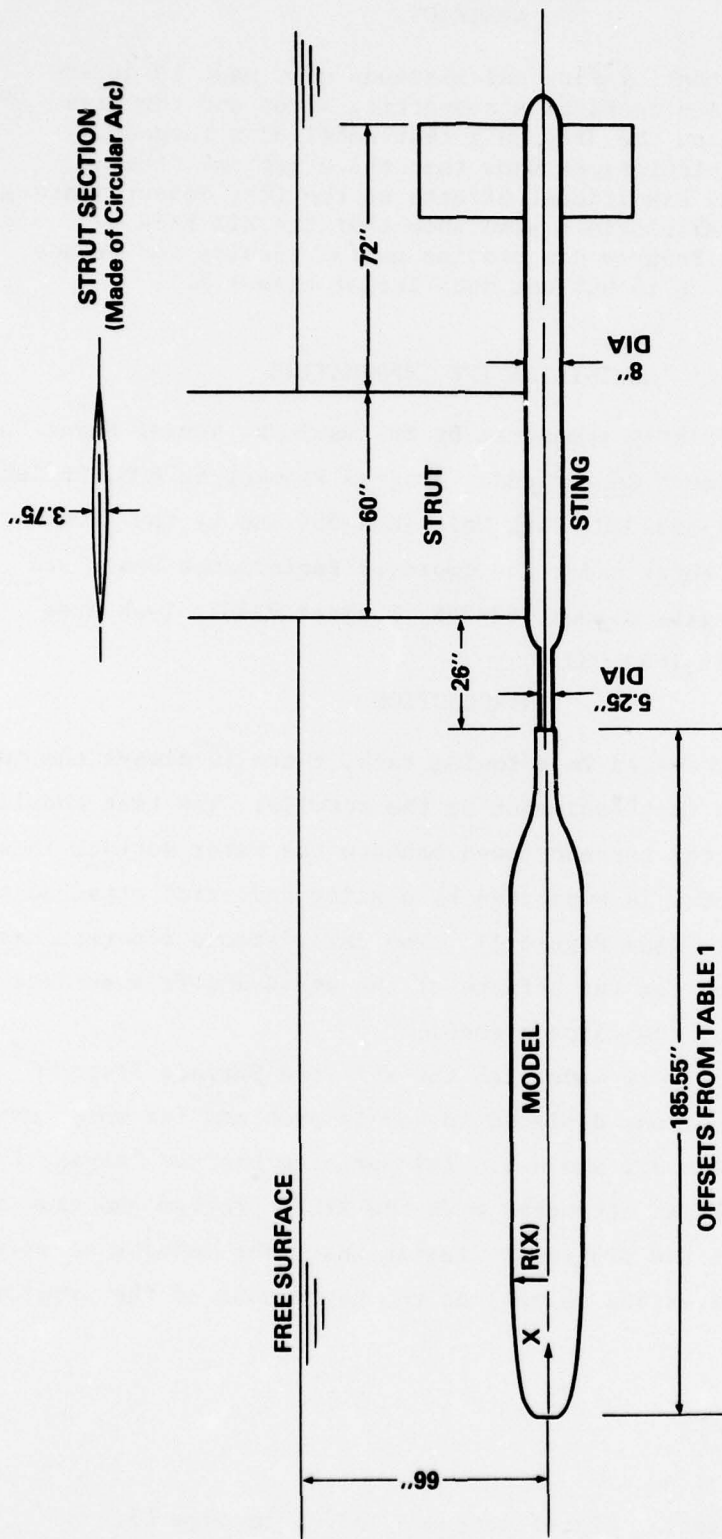


Figure 1 - Model and Supporting Sting and Strut

XYZ FREE SURFACE PROGRAM

The XYZ Free Surface Program (XYZFS), which was used for these calculations, computes the steady state motion of fluid past a body in or near a free surface. Part of the solution process involves solving the double model problem (i.e., the body and its image above a plane of symmetry). When only a double model solution is desired, the program may be stopped at this stage.

The method used is a modification of the source-sink boundary integral method originally developed by Hess and Smith² and used in the XYZ Potential Flow Program.³ The velocity field is written in terms of integrals of a source density over the body surface, the image of the body above the free surface, and a limited region of the undisturbed free surface. The surfaces are approximated by a set of plane quadrilateral panels and the source density is approximated by a constant in each panel so that the integrals are replaced by a sum over the panels.

The free surface condition is linearized in terms of the double model solution and is applied at the undisturbed free surface. The resulting partial differential equation can be written in terms of derivatives taken along streamlines of the double model solution. These derivatives are approximated by a one-sided, special four-point, upstream, finite difference operator applied to the velocity at the centers of the panels. The use of upstream differences prevents waves from developing upstream from the body and the special four-point operator avoids large damping errors.

The free surface equations and the equations for the body boundary condition are solved simultaneously to obtain the source density. Then the velocity is computed from the source density and finally the pressure, drag, and free surface elevation are computed from the velocity.

GEOMETRY OF THE PROBLEM

The model torpedo is axisymmetric with a maximum diameter of 20.8 inches (52.8 cm) and a length of 185.55 inches (471.3 cm). Values of X (the distance from the nose along the axis of symmetry) and R (the local

radius of the model) are given in Table 1. The geometry of the sting and strut is shown in Figure 1.

TABLE 1 - VALUES OF X AND R FOR THE 208-PANEL REPRESENTATION OF THE MODEL

| Offset # | X inches | R inches | Offset # | X inches | R inches |
|----------|----------|----------|----------|----------|----------|
| 1 | 0.0 | 0.0 | 15 | 94.6000 | 10.4000 |
| 2 | 0.0 | 1.1746 | 16 | 114.6000 | 10.4000 |
| 3 | 0.1268 | 3.1662 | 17 | 128.6000 | 10.4000 |
| 4 | 1.1821 | 4.8146 | 18 | 138.6500 | 10.4000 |
| 5 | 3.0535 | 5.9519 | 19 | 146.0141 | 10.3303 |
| 6 | 4.9287 | 6.6516 | 20 | 150.3185 | 9.8106 |
| 7 | 8.8807 | 7.6239 | 21 | 155.5384 | 8.3730 |
| 8 | 11.5272 | 8.0852 | 22 | 160.6131 | 6.4433 |
| 9 | 15.2695 | 8.5920 | 23 | 164.6801 | 4.9260 |
| 10 | 21.4791 | 9.1965 | 24 | 167.8000 | 3.9929 |
| 11 | 28.8355 | 9.6755 | 25 | 173.1417 | 3.1194 |
| 12 | 41.8463 | 10.1512 | 26 | 179.6500 | 3.0000 |
| 13 | 54.8647 | 10.3480 | 27 | 185.5500 | 3.0000 |
| 14 | 73.6000 | 10.4000 | | | |

A number of changes were made in modeling the sting to simplify the calculations. The last part of the sting including the stabilizing fin was omitted and the trailing end of the sting was left open. Fluid thus passes out the open end of the sting so that, in effect, the sting extends to infinity. Also the sudden change in diameter from 6 inches (15.24 cm) to 5.25 inches (13.33 cm) where the sting attaches to the model was changed so that the sting tapers from 6 inches (15.24 cm) to 5.25 inches (13.33 cm) over a length of 8.45 inches (21.46 cm).

Four different configurations were used in the calculations. In case 1 the model without the sting and strut is in an infinite fluid. In case 2 the model is placed below a plane of symmetry which roughly approximates the free surface. In case 3 the model is below the plane of

symmetry and the sting and strut are included. In case 4 the model without the sting and strut is below a free surface. In cases 1, 2, and 4 the end of the model, where the sting would be attached, is left open. Fluid passes out the open end giving the effect of an infinite sting. Thus in all cases the model is in effect attached to an infinite sting.

PANELING

The number of panels that can be used with XYZFS is limited to 568 by the computer memory size, and the computer time required increases as the square of the number of panels. For these reasons the model, sting, strut, and free surface are rather crudely approximated in the calculations and it is necessary to determine to what extent the results are sensitive to the paneling arrangement.

The model was approximated by arrangements of 128, 208, and 416 panels. Because the problem has left-right symmetry, only one side is represented by the panels. (In case 1 only 1/4 of the model need be represented so only half of the stated number of panels was actually used.) The panels for the model were arranged with 8 panels from bottom to top (22.5 deg intervals) and 16, 26, or 52 panels in the X-direction.

Two paneling arrangements for the sting and strut were used. The first used 144 panels and the second 204 panels. The paneling arrangement with 208 panels for the model and 204 panels for the sting and strut is shown in Figure 2.

Calculations with the free surface were made for speeds of 20 and 30 knots. Originally calculations were to be made for a speed of 40 knots, but problems encountered at 30 knots indicated that calculations at 40 knots would be useless.

For a model speed of 20 knots, calculations were made with six different representations of the free surface. In the first representation the region of the free surface represented by panels extended 790 inches (2007 cm) forward, 905 inches (2299 cm) behind, and 520 inches (1321 cm) to the side of the center of the model. This region was represented by a 38 by 8 array of panels. The panels varied in size being smallest near the model where they were 30 inches (76.2 cm) by

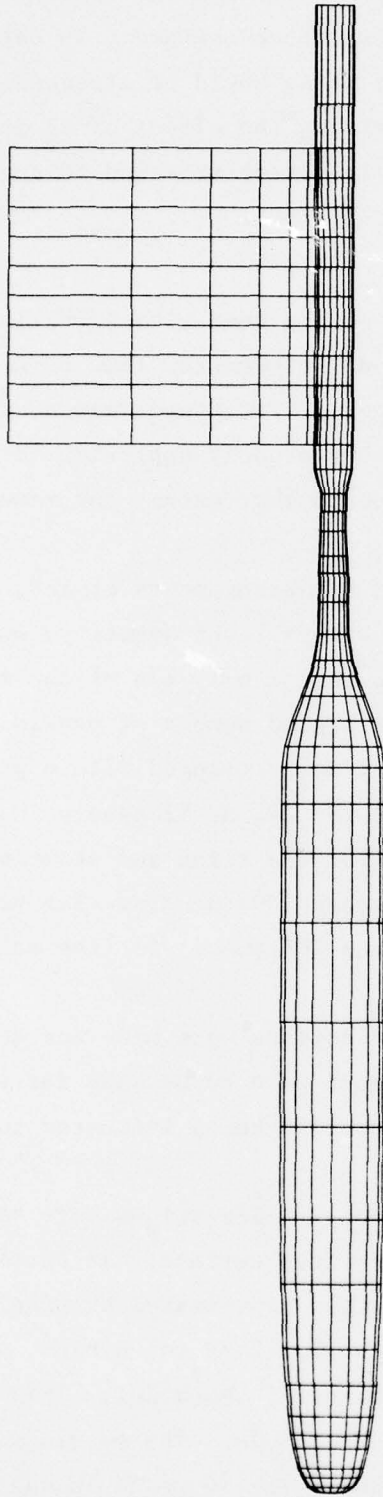


Figure 2 - Panel Arrangement with 208 Panels on the Model and
204 Panels on the Sting and Strut

30 inches. The other representations were similar to the first but the panel arrangements were changed in a systematic way to test the effects of the changes. The other representations used are as follows:

1. A long region with a 48 by 8 array of panels extending 1270 inches (3226 cm) forward and 1390 inches (3531 cm) behind the center of the model.

2. A wider region with a 38 by 10 array of panels extending 620 inches (1574 cm) to the side.

3. The basic region with smaller panels. A 44 by 10 array of panels was used with the panels nearest the model being 25 inches (63.5 cm) by 25 inches. This array of panels is shown in Figure 3.

4. The basic region with larger panels. A 22 by 6 array of panels was used with the panels nearest the model being 50 inches (127 cm) by 50 inches.

5. A short region with a 30 by 8 array of panels extending 540 inches (1372 cm) forward and 710 inches (1803 cm) behind the center of the model.

For a model speed of 30 knots, calculations were made with the different representations of the free surface. The first representation was the same as the first representation for 20 knots. The second representation was longer and wider with a 44 by 10 array of panels extending 1740 inches (4420 cm) forward, 1810 inches (4597 cm) behind, and 1000 inches (2540 cm) to the side. The panels near the model were the same size as for the first representation.

The 128-panel representation of the model was used for all free surface calculations.

RESULTS

The drag coefficient C_d is defined by the following equation:

$$C_d = \frac{1}{\frac{1}{2} \rho V_\infty^2 V^{2/3}} \iint \frac{1}{2} \rho (V_\infty^2 - V^2) N_x \, dA$$

where N_x is the x-component of the unit normal vector to the model surface

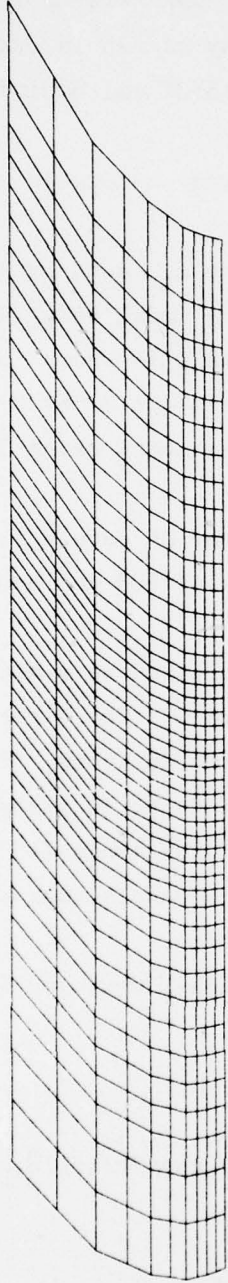


Figure 3 - A Computer Plot of the Model and the Panels
Representing the Free Surface

(Note: The model and panels are viewed from below and to one side. The panels are on the flat, undisturbed free surface. The panels toward the side away from the model are increasingly angled downstream.)

- V is the fluid velocity on the model surface
- V_{∞} is the fluid velocity at infinity
- V is the volume of the model
- ρ is the fluid density

The integration is performed over the surface of the model except for a small hole where the sting attaches.

Normally C_d is zero for potential flow about a body in an infinite fluid. However, since there is a hole where the sting attaches, C_d should have some small but nonzero value. The actual value of C_d is not important since it is the change in C_d produced by the strut or free surface that is wanted. The values of C_d for the model with and without the strut are given in Table 2. The changes in C_d produced by the free surface are given in Table 3.

TABLE 2 - RESULTS OF DRAG CALCULATIONS WITH AND WITHOUT THE STRUT

| No. of Panels on Model | | 128 | 208 | 416 |
|--|-----------------|---------|---------|---------|
| C_d for Model in Infinite Fluid | | .004634 | .001860 | .000920 |
| C_d for Model with Plane of Symmetry | | .004638 | .001861 | |
| Model with 144 Panels on Sting and Strut | C_d | .003599 | .000816 | |
| | Change in C_d | .001039 | .001045 | |
| Model with 204 Panels on Sting and Strut | C_d | | .000813 | |
| | Change in C_d | | .001048 | |

The value of C_d is quite sensitive to the paneling arrangement on the model. However, the effect of the strut on C_d is insensitive to the paneling arrangement. The change in the value of C_d caused by the strut is so insensitive that no additional calculations with the strut were considered necessary.

TABLE 3 - RESULTS OF DRAG CALCULATIONS WITH
A FREE SURFACE FOR 20 KNOTS

| Free Surface Representation | Change in C_d from Double Model Solution |
|-----------------------------|--|
| Base Region 38 by 8 | .00025 |
| Long Region 48 by 8 | .00027 |
| Wide Region 38 by 10 | .00026 |
| Smaller Panels 44 by 10 | .00024 |

The calculations with the free surface were reasonably successful for a speed of 20 knots. However, the number of panels available was barely adequate. Both of the calculations made with the smaller region and the larger panels resulted in unreasonable solutions. The solution for the larger panels had large oscillations in the free surface elevation between neighboring points. The solution with the short region had a depression in the free surface ahead of the model. The other calculations gave solutions that appear reasonable and the changes in C_d are shown in Table 3.

The results of the calculations for a speed of 30 knots are more questionable. The solution obtained with the basic region used for the 20-knot problem had a depression in the free surface ahead of the model and did not appear reasonable. The larger and wider region gave a solution that appeared reasonable and gave a change in C_d from the double model solution of .00004. This value is not much larger than the size of the errors expected on the basis of the calculations at 20 knots. Since the change in C_d is so small and the accuracy obtained with the maximum number of panels is questionable, no additional calculations were made for 30 knots and plans for calculations for 40 knots were dropped.

CONCLUSIONS

These calculations have shown that:

1. the supporting strut reduces the drag coefficient by .00104;
2. for a speed of 20 knots the free surface increases the drag coefficient by .00025;
3. the XYZ Free Surface Program can provide useful results for this type of problem for Froude numbers up to 1.5; and
4. for Froude numbers much larger than 1.5, it is not possible to provide adequate resolution near the model and at the same time cover a large enough part of the free surface to obtain results accurate enough to be useful.

REFERENCES

1. Dawson, C.W., "A Practical Computer Method for Solving Ship-Wave Problems," Proceedings of the Second International Conference on Numerical Ship Hydrodynamics, University of California, Berkeley (Sep 1977).
2. Hess, John L. and A.M.O. Smith, "Calculations of Potential Flow About Arbitrary Bodies," Pergamon Press Series, "Progress in Aeronautical Science," Volume 8 (1966).
3. Dawson, C.W. and Janet S. Dean, "The XYZ Potential Flow Program," NSRDC Report 3892 (Jun 1972).

INITIAL DISTRIBUTION

| Copies | | Copies | |
|--------|--|--------|---|
| 1 | ODDR&E The Pentagon 1 E&PS/W.A. Whitaker | 4 | NUSC NPT 2 D. Goodrich 1 M. Cincotta 1 Library |
| 1 | USA RES OFFICE/CRD-AA-IPL | | |
| 3 | CHONR 1 ONR 430/R.J. Lundegard 1 ONR 430B/M. Cooper 1 ONR 438/R.D. Cooper | 1 | NUSC NLONLAB/Library |
| | | 6 | NAVSEA 1 SEA 03C/J. Smith 1 SEA 0311/B. Orleans 1 SEA 032 1 SEA 03421/E. Liscka 1 SEA 03512/T.E. Peirce 1 SEA 09G32/Library |
| 3 | NRL 1 J. Boris 1 J. Hansen 1 Library | | |
| 1 | DNL | 1 | NAVSHIPYD BREM/Lib |
| 2 | USNA 1 Dept Math 1 Library | 1 | NAVSHIPYD CHASN/Lib |
| | | 1 | NAVSHIPYD MARE/Lib |
| 4 | NAVPGSCHOL 1 T.H. Gawain 1 T. Sarpkaya 1 Math Dept 1 Library | 1 | NAVSHIPYD NORVA/Lib |
| | | 1 | NAVSHIPYD PEARL/Lib |
| | | 1 | NAVSHIPYD PHILA/Lib |
| 1 | NAVWARCOL | 1 | NAVSHIPYD PTSMH/Lib |
| 1 | ROTC, MIT | 3 | NAVSEC 1 SEC 6136 1 SEC 6136B 1 SEC 6136C |
| 2 | NOSC, San Diego 1 J. Logan 1 Library | | |
| | | 12 | DDC |
| 2 | NCSC 1 D. Humphreys 1 Library | 1 | U Calif., Berkeley 1 J. Wehausen |
| 2 | NSWC Dahlgren 1 A. Hershey 1 Library | 1 | U Iowa/L. Landweber |
| | | 1 | MIT/J. Newman |
| 3 | NSWC White Oak 1 K. Bannister 1 A. Van Tuyl 1 Library | | |

Copies

CENTER DISTRIBUTION

| | | Copies | Code | Name |
|---|---|--------|--------|----------------------|
| 1 | U Michigan/T.F. Ogilvie | | | |
| 1 | Austin Res. Assoc., Inc. Austin, TX 78758 | 1 | 11 | W.M. Ellsworth |
| | | 1 | 15 | |
| 2 | Douglas Aircraft Long Beach, CA 90846 | 1 | 1521 | P.C. Pien |
| | 1 T. Cebeci | 2 | 1524 | W.C. Lin |
| | 1 J. Hess | | | J.F. O'Dea |
| 2 | Dynamics Technology 3838 Carson St. Torrance, CA 90503 | 5 | 1552 | K.J. Bai |
| | 1 W. Haigh | | | M. Chang |
| | 1 A.M.O. Smith | | | J. McCarthy |
| | | | | N. Salvesen |
| | | | | H.T. Wang |
| 2 | Hydronautics, Inc. Laurel, MD 20810 | 1 | 16 | H.R. Chaplin |
| | 1 M. Tulin | 1 | 17 | W.W. Murray |
| | 1 P. Van Dyke | 1 | 18 | G.H. Gleissner |
| 1 | Jaycor, Inc. Del Mar, CA 92014 | 1 | 1802.1 | H.J. Lugt |
| | R.K.C. Chan | 1 | 1802.2 | F.N. Frenkiel |
| | | 1 | 1805 | E.H. Cuthill |
| 1 | Newport News Shipbuilding & Drydock Co. Newport News, VA 23607 | 2 | 1809.3 | D. Harris |
| | W.G. Rodgers | 1 | 1830 | A.W. Camara |
| | | 1 | 1840 | J.W. Schot |
| 1 | Nielson Engineering & Res. Inc. Mountain View, CA 94043 | 2 | 1843 | |
| | M.M. Hall | 20 | 1843 | C.W. Dawson |
| | | 1 | 1844 | S.K. Dhir |
| 1 | Science Applications, Inc. 1200 Prospect St. La Jolla, CA 92038 | 1 | 1850 | T. Corin |
| | B. Chapman | 1 | 1870 | M.J. Zubkoff |
| | | 1 | 1890 | G.R. Gray |
| 1 | Sun Shipbuilding & Drydock Co. Chester, PA 19013 | 1 | 19 | M. Sevik |
| 2 | Westinghouse | 10 | 5211.1 | Reports Distribution |
| | Oceanics Division | 1 | 522.1 | Unclassified Lib (C) |
| | Annapolis, MD 21404 | | | |
| | 1 R. Mons | 1 | 522.2 | Unclassified Lib (A) |
| | Marine Division | | | |
| | Sunnyvale, CA 94088 | | | |
| | 1 M. Curl | | | |