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## GEOMETRIC CHARACTERISTICS OF DARPA SUBOFF MODELS (DTRC MODEL NOS. 5470 and 5471)

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An axisymmetric body, fairwater, symmetric stern appendages, two ring wings and ring wing support struts were designed for the Defense Advanced Research Projects Agency (DARPA) SUBOFF Project. Two geometrically identical models, designed to a linear scale ratio ($\lambda$) of 24, will be constructed to allow simultaneous testing in different facilities. Geometrical details of all components, including defining equations with computer code listings, are provided. The locations of velocity measurement stations and of surface pressure taps are also given. This information is intended for use by the model test engineer and the CFD engineer.


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## ABSTRACT

An axisymmetric body, fairwater, symmetric stern appendages, two ring wings and ring wing support struts were designed for the Defense Advanced Research Projects Agency (DARPA) SUBOFF project. Two geometrically identical models, designed to a linear scale ratio (λ) of 24, will be constructed to allow simultaneous testing in different facilities. Geometrical details of all components, including defining equations with computer code listings, are provided. The locations of velocity measurement stations and of surface pressure taps are also given. This information is intended for use by both the model test engineer and the CFD engineer.



Keywords: Submarine hull models; shroud struts; Pressure measurement; Geometric forms, (edc)


## ADMINISTRATIVE INFORMATION


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## INTRODUCTION

The Submarine Technology Program (STP) Office of DARPA funded a concerted and coordinated Computational Fluid Dynamics (CFD) Program to assist in the development of advanced submarines for the future. The DARPA SUBOFF project will evaluate, in a competitive environment directly against model test results, flow field predictions of an axisymmetric hull model with and without appendages. The model configurations were designed at DTRC and are given in this report.

The SUBOFF project will provide a forum for the CFD community to compare the numerical predictions of the flow field over an axisymmetric hull model with and without various typical appendage components with experimental data. The CFD predictions of flow fields of typical submarine configurations will be made without the prior knowledge of the actual experimental data. Experimental and computational comparisons can then be made to demonstrate the current CFD capability on design problems relevant to STP problem areas.

The three-dimensional steady flow field for several geometrical configurations will be investigated. These configurations are (1) axisymmetric body at zero angle of attack and drift, (2) axisymmetric body with fairwater at several angles of attack and zero drift, (3) axisymmetric body with symmetric stern appendages at several angles of attack and zero drift, (4) axisymmetric body with two different ring wings at zero angle of attack and drift, and (5) cambered body of circular cross section in a uniform stream with fairwater. Configuration 1 will serve as a baseline geometry for the numerical evaluations. Configurations 2, 3, and 5 will evaluate the non-axisymmetric properties of the numerical codes. The ring wing of Configuration 4 is added to alter the pressure distribution and to assess its influence on flow separation. Configurations 2 through 5 are designed to test the numerical prediction codes to the maximum extent.

Two geometrically identical models, DTRC MODEL Nos. 5470 and 5471, will be constructed to allow for simultaneous testing in different facilities. The models differ only in the location of the surface pressure taps. It is planned that DTRC MODEL No. 5470 will be used in the Boeing Wind Tunnel, the DTRC Towing Tank, and the Hydronautics Ship Model Basin and that DTRC MODEL No. 5471 will be used in the DTRC Anechoic Flow Facility.

The equations and model details to define the axisymmetric body, fairwater, symmetric stern appendages, two ring wings, and ring wing support struts are given in the main body of this report. The computer code listings to define the geometric components are given in the Appendices. The detailed experimental test agenda will be given in a separate report.

## MODEL GEOMETRY

The overall model geometry for the two SUBOFF models, DTRC MODEL Nos. 5470 and 547,1 are identical. The two models differ only in the location of the surface pressure taps. Each model component is described by equations giving either the axial and radial values for an axisymmetric component or the Cartesian coordinates (x, y, z) of nonaxisymmetric components. All equations and computer code listings give model scale coordinates in units of feet. A grid representation of the axisymmetric hull, fairwater, and stern appendages is shown in Figure 1.

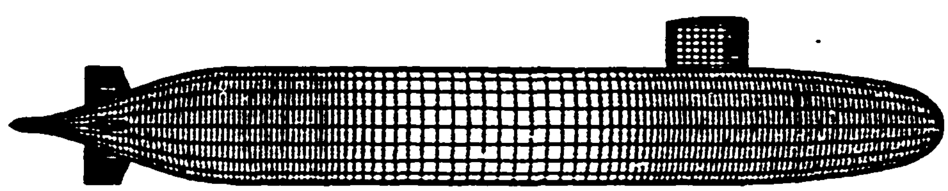


Figure 1. Sample grid representation of MODEL Nos. 5470 and 5471

### AXISYMMETRIC HULL

The axisymmetric hull has an overall length of 14.291667 Ft (4.356 m) and a maximum diameter of 1.666667 Ft (0.508 m). The

TABLE 1. Equations to define axisymmetric hull

x = Model Scale Axial Length in Feet
R = Model Scale Radial Length in Feet

Forebody Length = 3.333333 Ft (1.016 m)
Parallel Middle Body Length = 7.3125 Ft (2.229 m)
Afterbody Length = 3.645833 Ft (1.111 m)
Aft Perpendicular at x = 13.979167 Ft (4.461 m)
Total Body Length = 14.291666 (4.356 m)
Maximum Body Diameter = 1.666667 Ft (0.508 m)
$\lambda$ = (FULL/MODEL) SCALE RATIO = 24

**BOW EQUATION**

For 0 Ft $\leq x \leq$ 3.333333 Ft

$$R = R_{MAX}\left\{1.126395101x(0.3x-1)^4 + 0.442874707x^2(0.3x-1)^3 + 1-(0.3x-1)^4(1.2x+1)\right\}^{1/2.1}$$

$$R_{MAX} = \frac{5}{6}\text{ Ft}$$

**PARALLEL MIDDLE BODY EQUATION**

For 3.333333 Ft $\leq x \leq$ 10.645833 Ft

$$R = R_{MAX}$$

**AFTERBODY EQUATION**

(valid up to and including aft perpendicular x = 13.979167 Ft)

For 10.645833 Ft $\leq x \leq$ 13.979167 Ft

$$\begin{aligned} R = R_{MAX}\Big\{ & r_h^2 + r_hK_o\xi^2 + (20 - 20r_h^2 - 4r_hK_o - \tfrac{1}{3}K_1)\,\xi^3 \\ & + (-45 + 45r_h^2 + 6r_hK_o + K_1)\,\xi^4 + (36-36r_h^2 - 4r_hK_o - K_1)\,\xi^5 \\ & + (-10 + 10r_h^2 + r_hK_o + \tfrac{1}{3}K_1)\,\xi^6\Big\}^{1/2} \end{aligned}$$

$$r_h = 0.1175 \qquad K_o = 10 \qquad K_1 = 44.6244$$

$$\xi = \frac{13.979167 - x}{3.333333}\text{, x in Feet}$$

**AFTERBODY CAP**

For 13.979167 Ft $\leq x \leq$ 14.291667 Ft

$$R = 0.1175\,R_{MAX}\left[1 - (3.2x - 44.733333)^2\right]^{1/2}$$

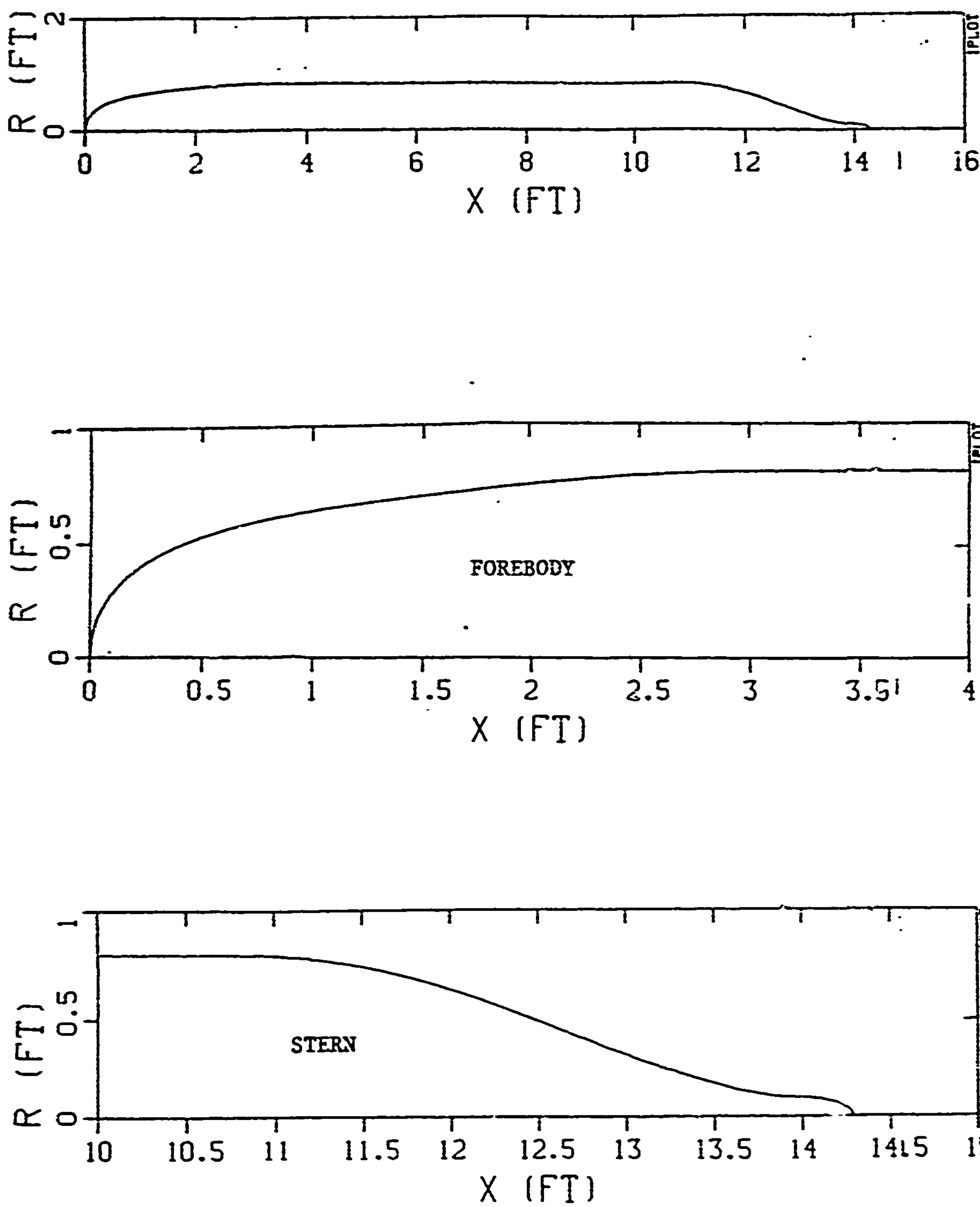



Figure 2. Hull profile

hull is composed of a forebody of length 3.333333 Ft (1.016 m), a parallel middle body section of length 7.3125 Ft (2.229 m), an afterbody of length 3.645833 Ft (1.111 m) and an afterbody cap of length 0.3125 Ft (0.095 m). The equation for each hull component, in terms of axial and radial length, is provided in Table 1. Figure 2 shows the hull profile and Appendix 1 lists the computer program to generate the hull offsets.

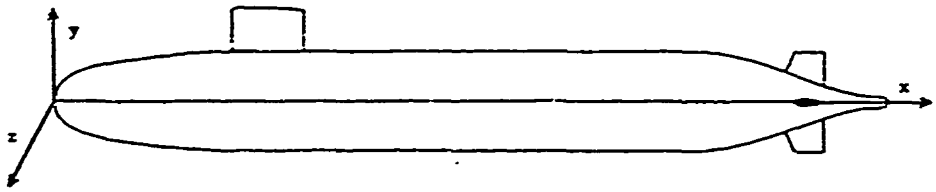
## FAIRWATER

The fairwater is located on the hull at top dead center with its leading edge positioned at x=3.032986 Ft (0.924 m) and trailing edge at x=4.241319 Ft (1.293 m) for a total length of 1.208333 Ft (0.368 m). A sail cap attaches to the top of the sail at a height y=1.507813 Ft (0.460 m). In addition to the sail cap, the fairwater is defined in terms of a forebody, a parallel middle body, and an afterbody region. Table 2 gives the equations as well as pertinent geometric details for the fairwater. Figure 3 shows the fairwater section profile and Figure 4 gives the cross-sectional shape of the cap over the length of the fairwater. The computer code listing of the fairwater equations is given in Appendix 2

## STERN APPENDAGES

The stern appendages consist of four identical appendages mounted on the model hull at angles of 0 degrees (top dead center), 90 degrees, 180 degrees, and 270 degrees. The basic stern appendage assembly can be shifted to attach to the hull at

Table 2. Equations to define fairwater




$(x,y,z)$ = Cartesian coordinates in Ft

The sail is defined by 4 sections: the forebody, parallel middle body, afterbody and cap. The sail dimensions and equations follow.

Sail Forebody Length = .325521 Ft (.099m)

Sail Parallel Middle Body Length = .200521 Ft (.061m)

Sail Afterbody Length = .682292 Ft (.208m)

Total Sail Length = 1.208333 Ft (.368m)

Span of Sail with Uniform Profile = .674479 Ft (.206m)

$Z_{max}$ = One-Half the Maximum Sail Thickness = 0.109375 (.033m)

## SAIL FOREBODY EQUATION

For $3.032986 \text{ Ft} \leq x \leq 3.358507 \text{ Ft}$

$y \leq 1.507813$ Ft

$$Z_1 = Z_{max}\left[2.094759(A) + .2071781(B) + (C)\right]^{1/2}$$

$$A = 2D\,(D-1)^4$$

$$B = 1/3\,(D^2)\,(D-1)^3$$

$$C = 1-(D-1)^4\,(4D+1)$$

$$D = 3.072000\,(x-3.032986)$$

Table 2. (Continued)

## SAIL PARALLEL MIDDLE BODY EQUATION

For $3.358507 \text{ Ft} \leq x \leq 3.559028 \text{ Ft}$

$y \leq 1.507813 \text{ Ft}$

$Z_1 = Z_{max} = .109375 \text{ Ft} = 1.3125 \text{ inch}$

## SAIL AFTERBODY EQUATION

(Revised 11 January 1989)

For $3.559028 \text{ Ft} \leq x \leq 4.241319 \text{ Ft}$

$y \leq 1.507813 \text{ Ft}$

$$z_1 = .1093750 \left[2.238361 \left(E(E-1)^4\right) + \right.$$
$$+ 3.106529 \left(E^2(E-1)^3\right) +$$
$$\left. \left(1-(E-1)^4(4E+1)\right)\right]$$

$E = (4.241319-x)/0.6822917$

## SAIL CAP EQUATION

The sail is closed at top with an ellipsoid defined as

For $3.032986 \text{ Ft} \leq x \leq 4.241319 \text{ Ft}$

$1.507813 \text{ Ft} \leq y \leq (Z_1/2) + 1.507813 \text{ Ft}$

$$Z_2 = \left[Z_1^2 - (2(y-1.507813))^2\right]^{1/2}$$

$Z_1$ is defined previously as a function of x.

## HULL/SAIL INTERSECTION

$$[R_{HB}(x)]^2 = y^2 + Z_1^2$$

where $R_{HB}(x)$ = the hull bow equation (See Table 1)

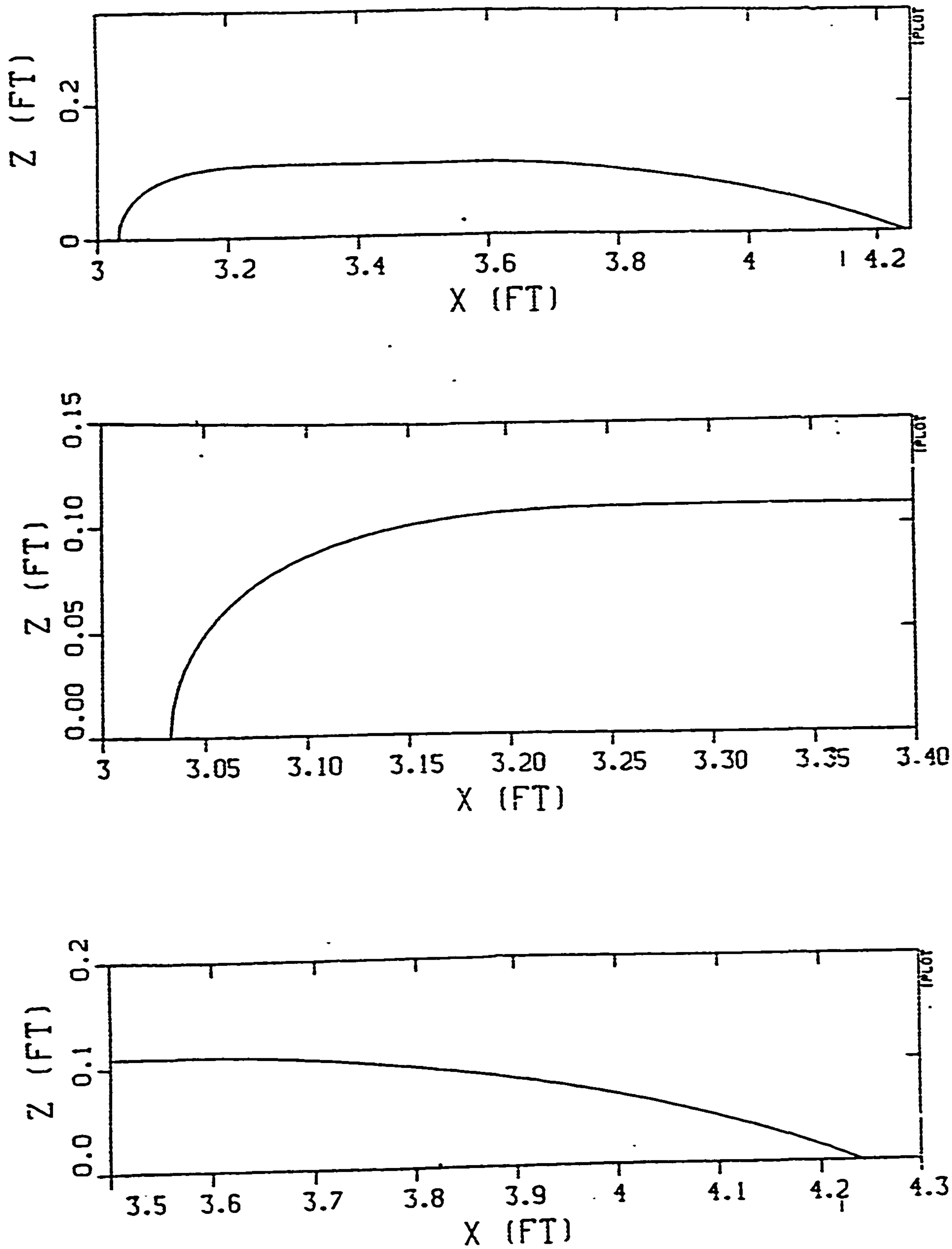



Figure 3. Fairwater section profile

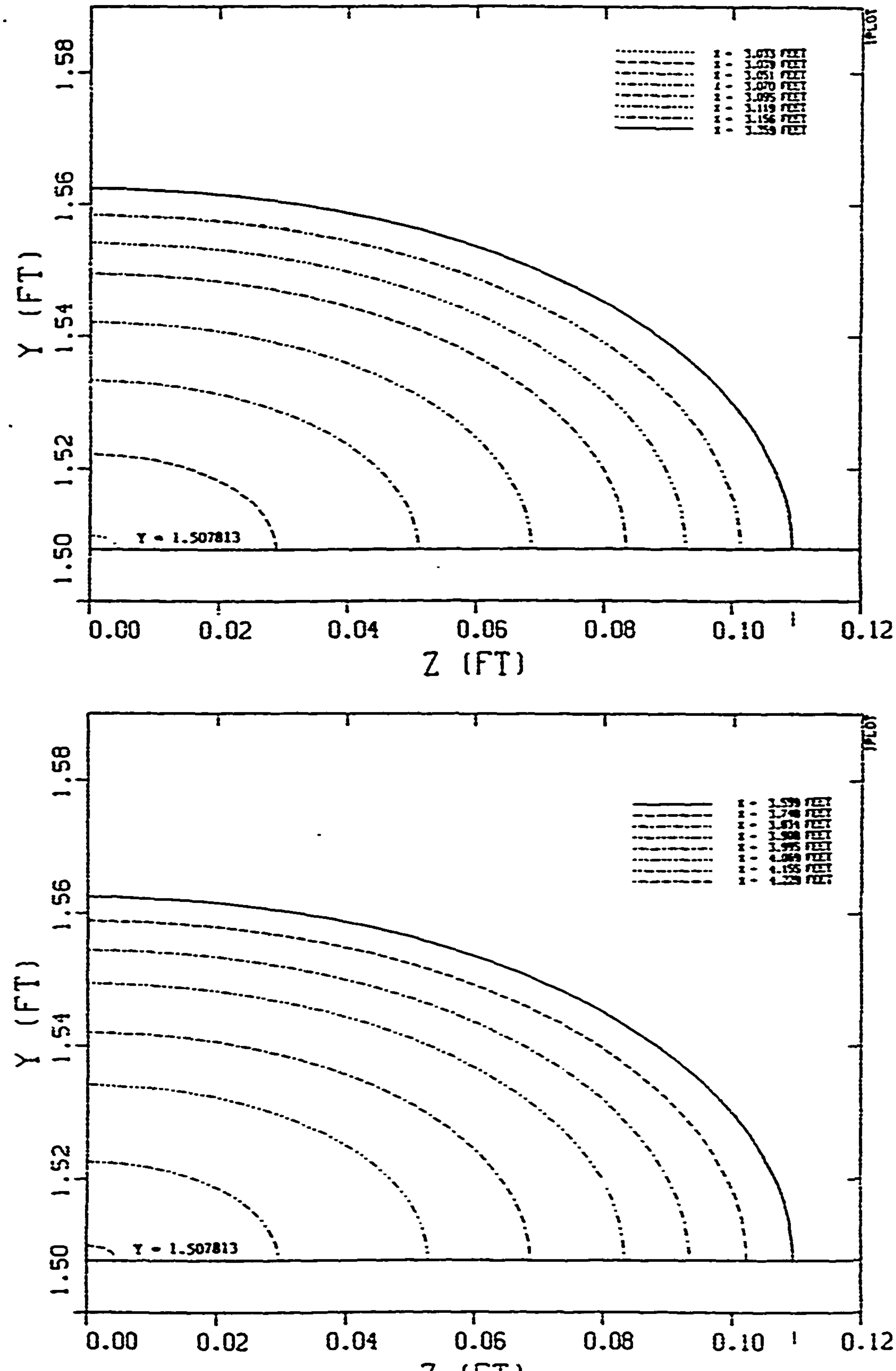



Figure 4. Cross sectional shape of fairwater cap

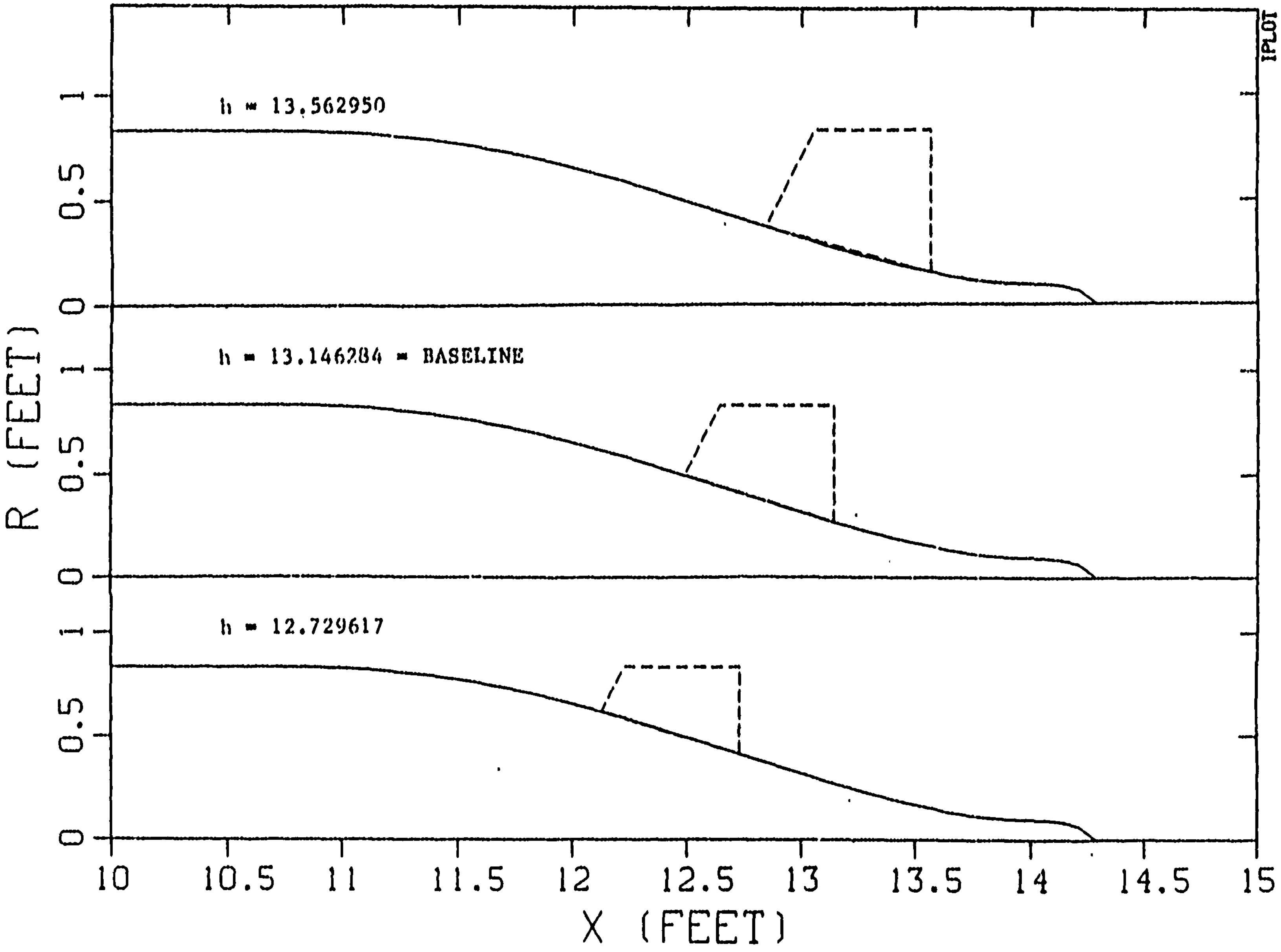


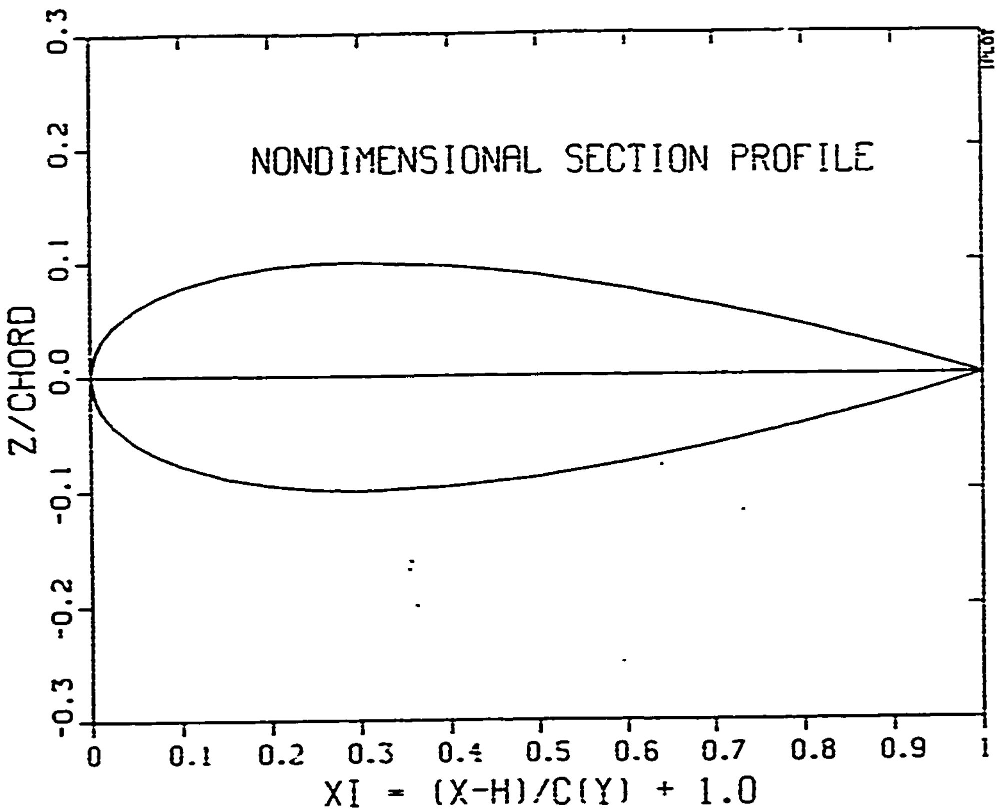

Figure 5. Stern appendage locations

three different axial positions as shown in Figure 5. The stern appendage position with the appendage trailing edge at x=13.146284 Ft (4.007 m) is denoted the baseline stern appendage location. To provide for stern appendage movement to different sternplane angles, the appendages are offset slightly from the axisymmetric hull surface. The stern appendage with trailing edge at x=13.562950 Ft (4.134 m) is contoured to fit the axisymmetric hull centerline exactly with a uniform clearance at the centerline of 0.05 in (1.524 cm). The stern appendages at the remaining two axial positions are cut along a straight plane and the clearance between the hull and the appendage centerlines varies with axial distance x. The gap between the hull and the forward stern appendage, trailing edge at x=12.729167 Ft (3.880 m), is 0.0584 in (1.780 cm) at the leading edge centerline and 0.0632 in (1.928 cm) at the trailing edge centerline. The gaps for the baseline stern appendage location are 0.0287 in (0.875 cm) and 0.0355 in (1.082 cm) for the leading and trailing edge centerlines, respectively.

Both the nondimensional and dimensional section profiles are given in Figure 6. The stern appendage equation is given in Table 3 and the computer code listing is in Appendix 3.

## RING WINGS

Two ring wings have been designed for the SUBOFF models. The wings, designated Ring Wing 1 and Ring Wing 2, have the same section shape and differ only in their angle of attack. Table 4 gives the defining equations for the two wings, Figure 7 shows the placement



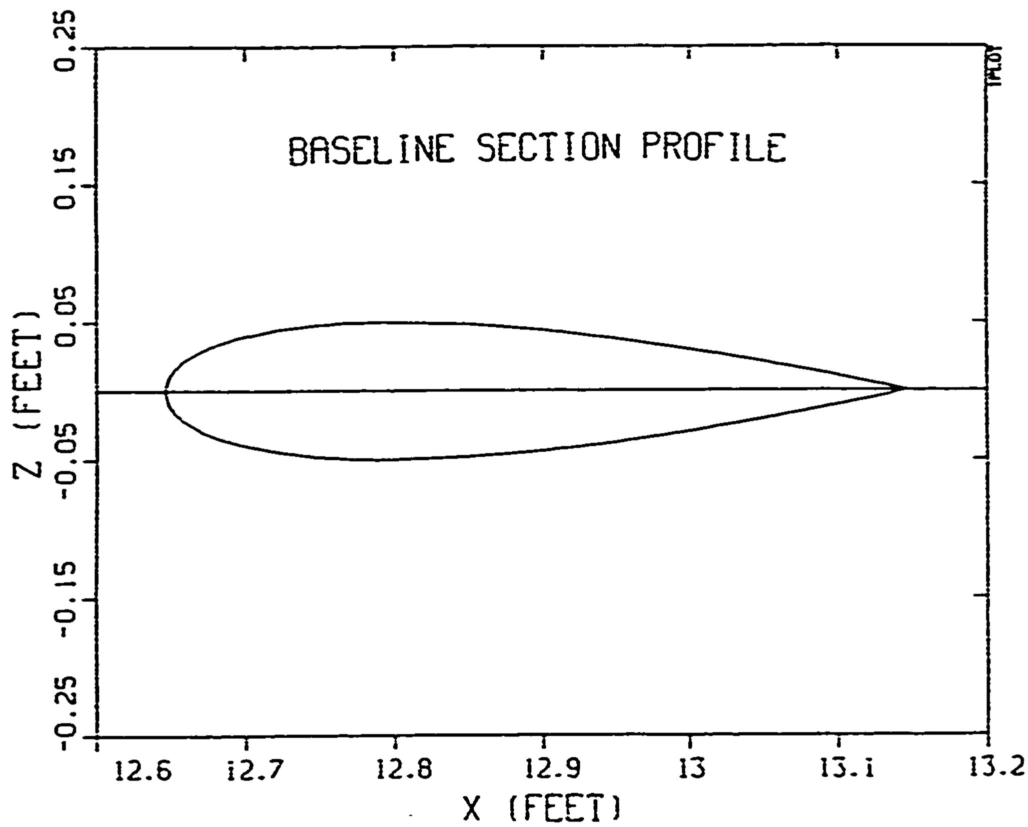
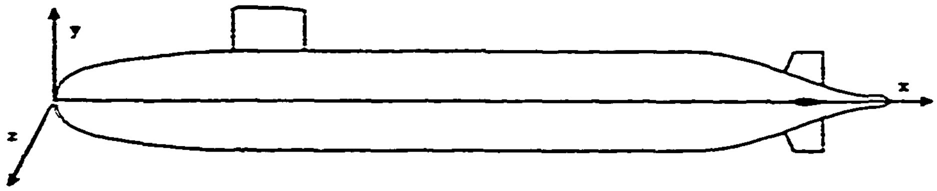




Figure 6. Stern appendage section profile

Table 3. Equations to define stern appendages

These equations define the upper rudder stern appendage.
The three remaining stern appendages are located
on the hull at 90° azimuthal increments.




$(x,y,z)$ = Cartesian coordinates in ft.

<u>**STERN APPENDAGE EQUATION**</u>

$$\frac{z(\xi)}{c(y)} = 0.29690\sqrt{\xi} - 0.12600\xi - 0.35160\xi^2 + 0.28520\xi^3 - 0.10450\xi^4$$

$$\text{for } 0 \leq \xi = \frac{x-h}{c(y)} + 1.0 \leq 1$$

where $h$ = $x$ coordinate of the stern appendage trailing edge

$$c(y) = -0.466308y + 0.88859$$

= chord length

Three values of $h$ are considered:

$h = 12.729617$

$h = 13.146284$ = BASELINE

$h = 13.562950$

<u>**HULL/STERN APPENDAGE INTERSECTION**</u>

$$[R_{HA}(\bar{\xi})]^2 = y^2 + [z(\xi)]^2$$

where $R_{HA}(\bar{\xi})$ = the hull afterbody equation (See Table 1)

Table 4. Equations to define ring wings

x = Model Scale Axial Length in Feet
R = Model Scale Radial Length in Feet

Two Ring Wings are Defined:

Ring Wing 1: $(x_{LE} = 13.46990, \quad R_{LE} = 0.43004)$

$(x_{TE} = 14.21661, \quad R_{TE} = 0.35659)$

Ring Wing 2: $(x_{LE} = 13.46990, \quad R_{LE} = 0.47681)$

$(x_{TE} = 14.2074, \quad R_{TE} = 0.33856)$

**BASIC GEOMETRY FOR RING WING**

Camber:

$$y_c(x) = -0.049921 \left[0.5D^2 \ln|D| - 0.5 E^2 \ln (E) + 0.25 E^2 - 0.25D^2\right] + 0.029953 \left[x \ln x + 0.227828 = 0.531076x\right]$$

where $0 \leq x \leq 1$

$D = 0.4 - x$

$E = 1.0 - x$

Thickness:

$$y_t(x) = 0.1 \left[\sum_{n=1}^{17} b_n \sin nw\right] \quad \text{for} \quad 0.0 \leq x \leq 0.45$$

where $w = \cos^{-1} [2x-1]$

| n | $b_n$ | n | $b_n$ | n | $b_n$ |
|---|---|---|---|---|---|
| 1 | 0.43756 | 7 | 0.00156 | 13 | -0.00027 |
| 2 | -0.08136 | 8 | -0.00113 | 14 | -0.00033 |
| 3 | -0.06495 | 9 | -0.00058 | 15 | 0.00005 |
| 4 | -0.01926 | 10 | 0.00027 | 16 | 0.00014 |
| 5 | -0.00185 | 11 | 0.00080 | 17 | 0.00008 |
| 6 | 0.00348 | 12 | 0.00006 | | |

Table 4. (Continued)

$$y_t(x) = 0.1 \left[0.033333 + 1.696969\ (1-x) - 1.441945\ (1-x)^2 - 0.366363\ (1-x)^3 + 0.333049\ (1-x)^4\right] \quad \text{for } 0.45 \leq x \leq 1.0$$

Upper and Lower Surfaces:

$$x_U(x) = x - y_t(x) \sin\theta$$

$$R_U(x) = y_c(x) + y_t(x) \cos\theta$$

$$x_L(x) = x + y_t(x) \sin\theta$$

$$R_L(x) = y_c(x) - y_t(x) \cos\theta$$

Physical Ring Wing Geometry:

$$x_{DU} = x_{LE} + C\ (x_U(x) \cos\phi - R_U(x) \sin\phi)$$

$$R_{DU} = R_{LE} + C\ (x_U(x) \sin\phi + R_U(x) \cos\phi)$$

$$x_{DL} = x_{LE} + C\ (x_L(x) \cos\phi - R_L(x) \sin\phi)$$

$$R_{DU} = R_{LE} + C\ (x_L(x) \sin\phi + R_L(x) \cos\phi)$$

where

$$\phi = \tan^{-1} \left(\frac{R_{TE} - R_{LE}}{x_{TE} - x_{LE}}\right)$$

$$C = \left[(R_{TE} - R_{LE})^2 + (x_{TE} - x_{LE})^2\right]^{1/2}$$

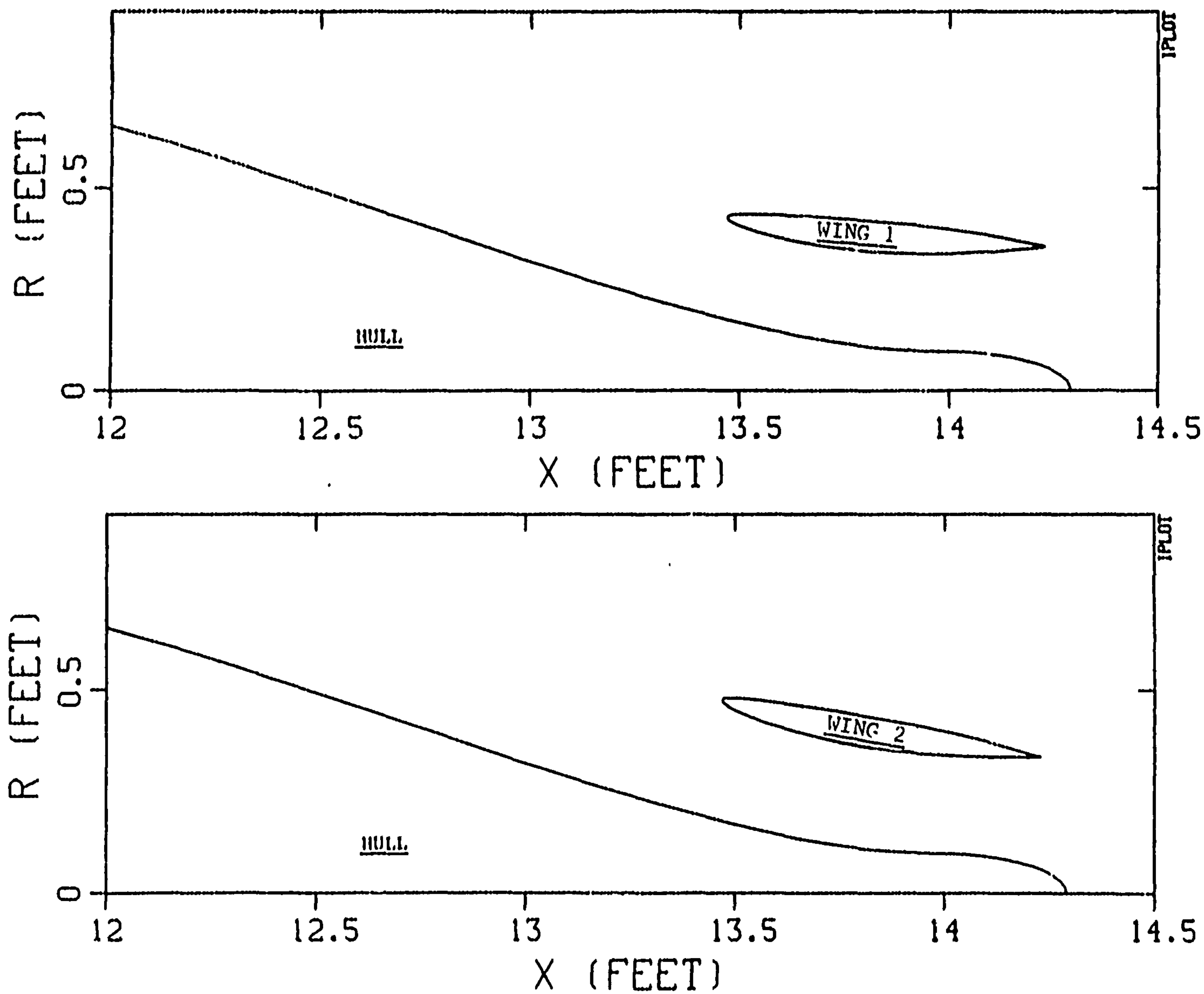



Figure 7. Ring wing section profile and placement

of the wings relative to the axisymmetric hull and baseline stern appendage location, and Appendix 4 gives the computer code listing used to define the wing geometries.

## RING WING STRUTS

Strut supports are necessary to mount the ring wings to the hull. Four separate, identical struts are mounted equally-spaced along the hull girth. The struts attach at the same axial position on the hull, x=13.589 Ft (4.142 m) and have the same secton profile for each ring wing. At the inner surface of each wing, the struts are contoured to match each wing. The strut equations and attachment locations to the hull and wings are given in Table 5. Figure 8a shows the nondimensional section profile of the strut and Figures 8b and 8c show the placement of the strut on Ring Wing 1 and Ring Wing 2, respectively. Figure 9 gives a typical cross section showing the arrangement of the strut to the hull and the ring wing. Also indicated in Figure 9 are the placement and designation of surface pressure taps on the wings relative to the struts. Finally, the computer code listing for the strut geometry is given in Appendix 5.

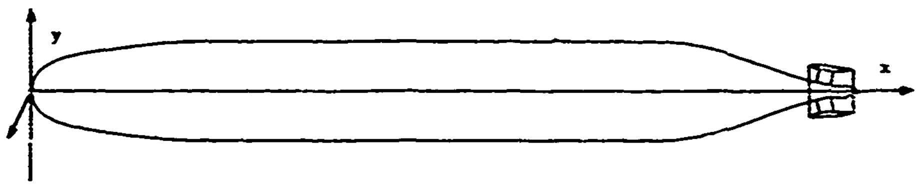
## VELOCITY MEASUREMENT STATIONS

A critical goal of the DARPA SUBOFF project is to evaluate the CFD code predictions of velocities relative to experimental velocity data. These measurements will include axial and radial mean velocities, three components of turbulence intensities and one Reynolds stress (axial-radial) on the transverse plane at five axial locations. These locations are the aft perpendicular

Table 5. Equations to define ring wing struts

**DEFINITION DARPA2 STRUT**

**MODEL SCALE EQUATIONS**




(x,y,z) Cartesian coordinates in Ft

These equations define a single strut which attaches to the DARPA2 axisymmetric hull along the upper surface (i.e., the surface with the fairwater). Four identical, equally-spaced struts will attach the hull to the ring wing at a 45° increment from the wing surface pressure tap locations.

$$x = x_0 + 0.243995\ \xi$$

$$y = y_0 - 0.054465\ \xi$$

$$z = \pm\ 0.15\ (0.29690\ \sqrt{\xi} - 0.12600\ \xi$$
$$- 0.35160\ \xi^2 + 0.28520\xi^2 - 0.10450\ \xi^4)$$

where $x_0 = 0.223221\ y_0 + 13.556128$

$$R_1 \leq y_0 \leq R_2$$

Ring Wing 1: R1 = 0.14726 , R2 = 0.36886

Ring Wing 2: R1 = 0.14726 , R2 = 0.39755

$$0 \leq \xi = \frac{x - x_0}{0.243995} \leq 1$$

Table 5. (Continued)

Strut leading edge attaches to:

| | | | | |
|---|---|---|---|---|
| Hull | at | $x = 13.589$, | $R = 0.14726$ | |
| Ring Wing 1 | at | $x = 13.63845$, | $R = 0.36886$ | $(x/c = 0.233)$ |
| Ring Wing 2 | at | $x = 13.64487$, | $R = 0.39755$ | $(x/c = 0.25)$ |

Strut trailing edge attaches to:

| | | | | |
|---|---|---|---|---|
| Hull | at | $x = 13.83582$, | $R = 0.10547$ | |
| Ring Wing 1 | at | $x = 13.88818$, | $R = 0.34002$ | $(x/c = 0.5651)$ |
| Ring Wing 2 | at | $x = 13.89023$, | $R = 0.34932$ | $(x/c = 0.5804)$ |

### HULL/STRUT INTERSECTION

$$[R_{HA}(x)]^2 = y^2 + z^2$$

where $R_{HA}(x)$ = the hull afterbody equation

(See Table 1)

### RING WING/STRUT INTERSECTION

$$[R_{WL}(x)]^2 = y^2 + z^2$$

where $R_{WL}(x)$ = the ring wing lower surface equation

(See Table 4)

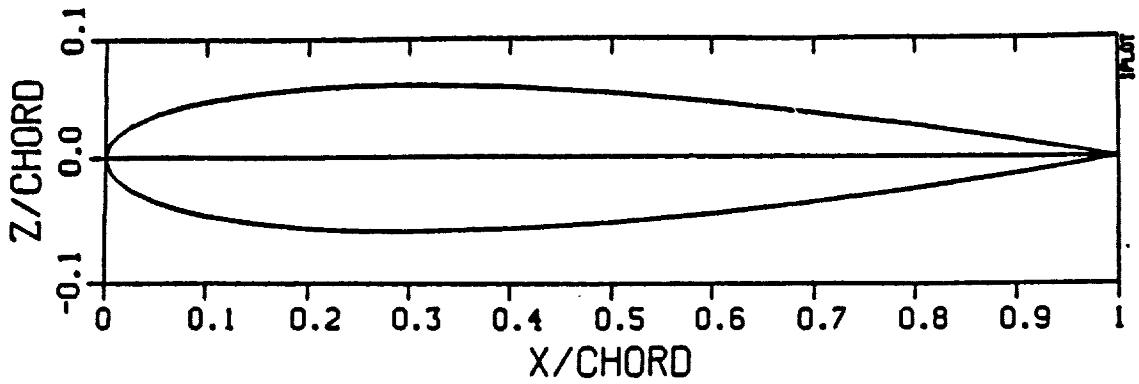



Figure 8a. Nondimensional section profile

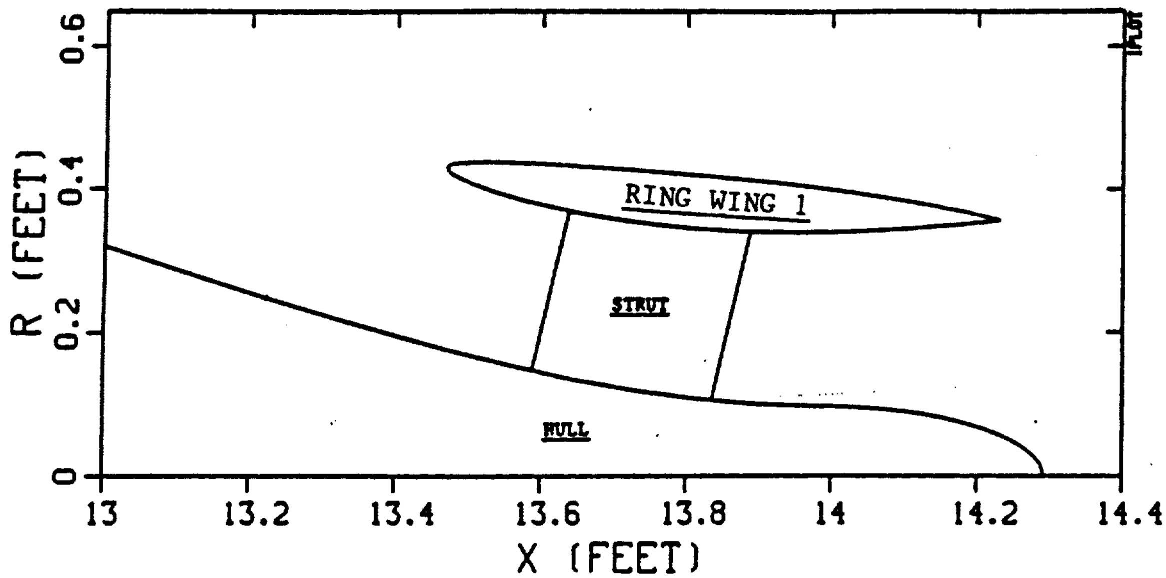



Figure 8b. Placement of strut on Ring Wing 1

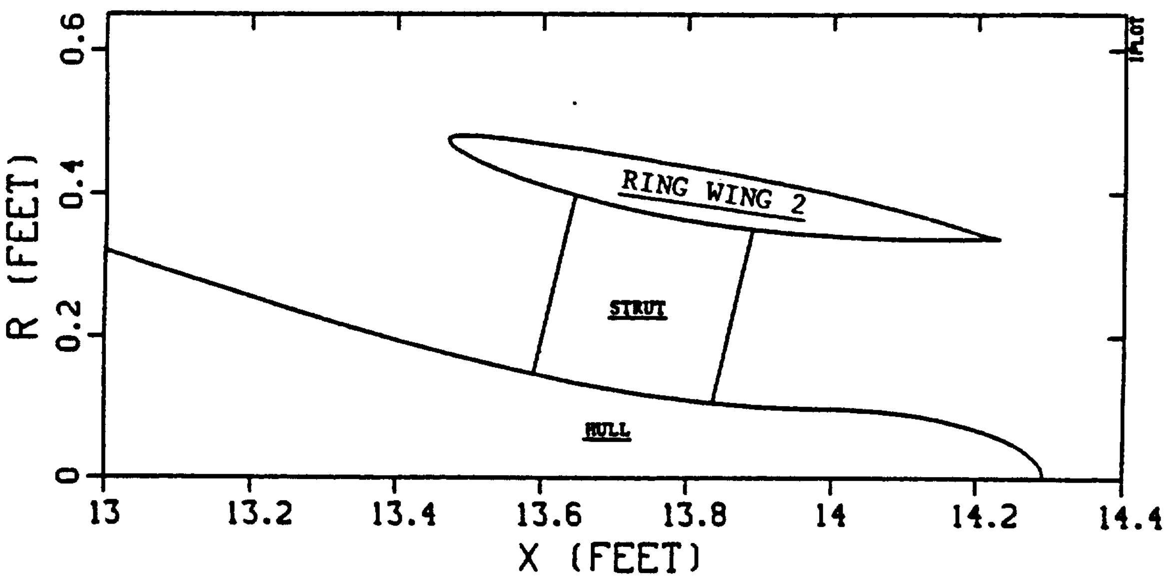



Figure 8c. Placement of strut on Ring Wing 2

Figure 8. Ring wing struts

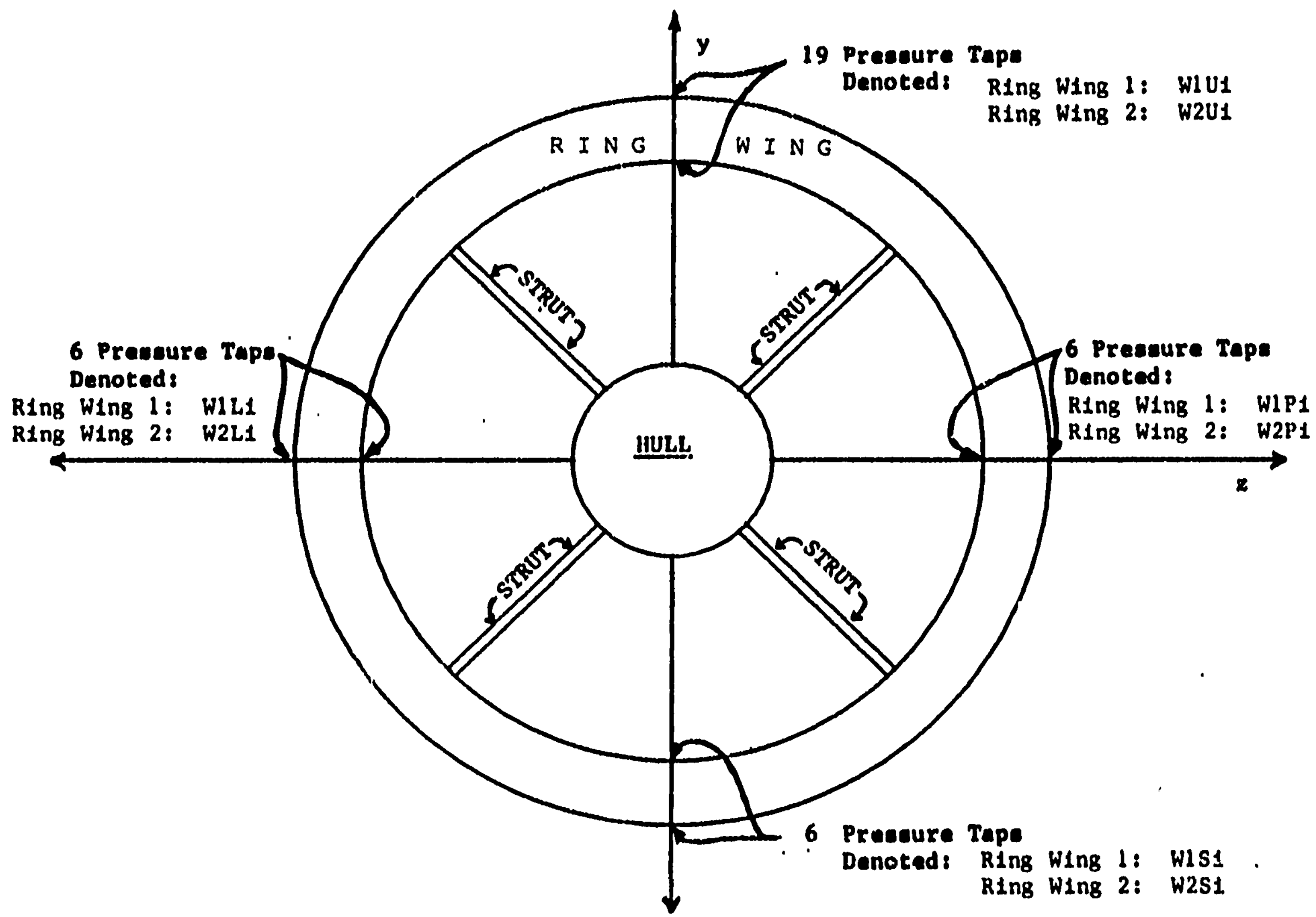



Figure 9. Typical cross section showing ring wing strut arrangement

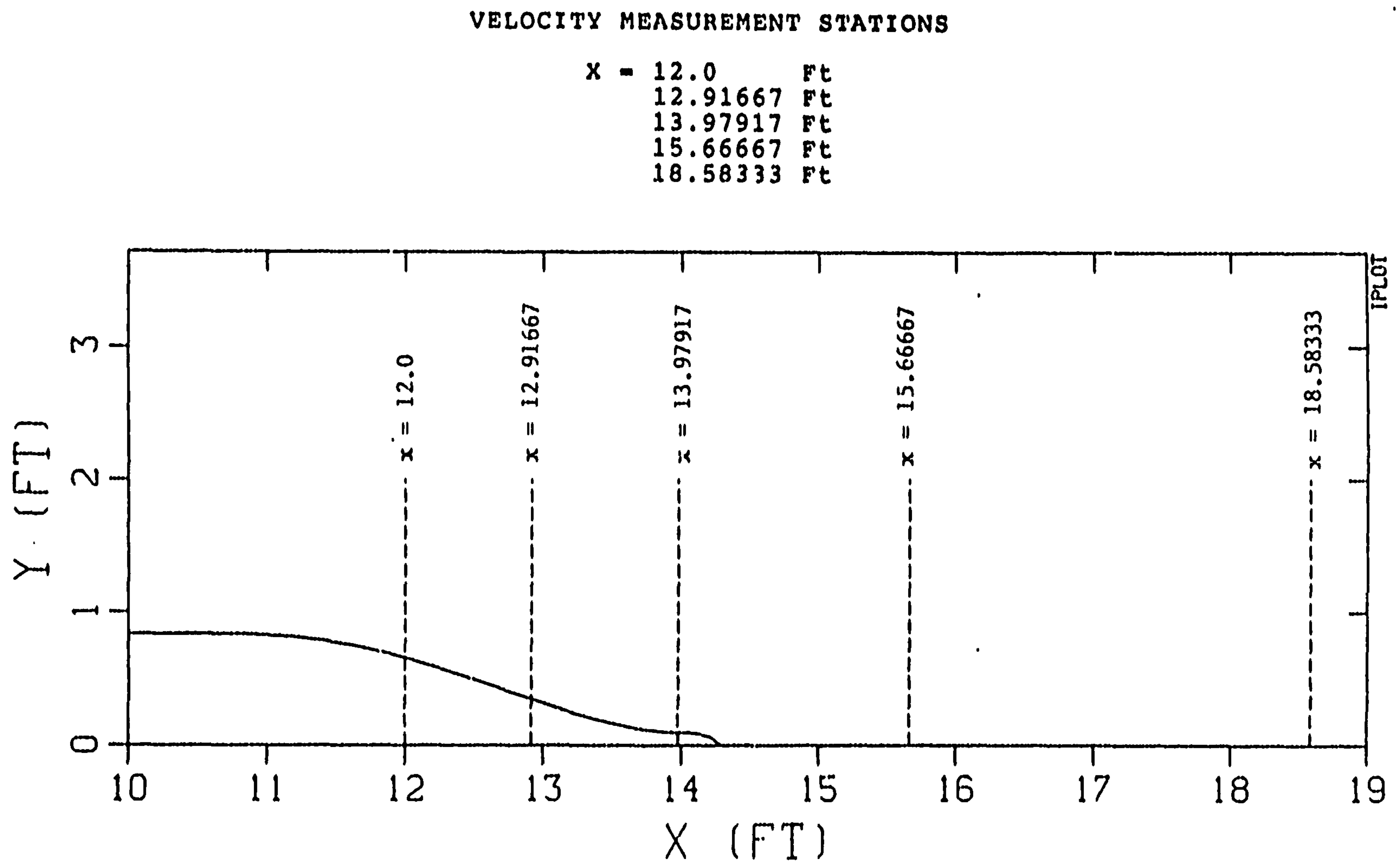



Figure 10. Velocity measurement planes

x=13.979167 Ft (4.261 m), two stations [x=12.0 Ft (3.658 m) and x=12.916667 Ft (3.937 m)] upstream of and two stations [x=15.666667 Ft (4.775 m) and x=18.583333 Ft (5.664 m)] downstream from the aft perpendicular. The relative positions of the velocity measurement stations on the hull are shown in Figure 10. The location of boundary-layer transition from laminar to turbulent flow will be artificially induced by a 0.025 in (0.0635 cm) trip wire located at x=8.5 in (21.59 cm).

## PRESSURE TAP LOCATIONS

For both DTRC MODEL No. 5471 (the wind tunnel model) and DTRC MODEL No. 5470 (the towing basin model), a number of pressure taps are located on the hull surface. On both models, the pressure taps are located on the hull surface (H), the fairwater surface (FW) and the baseline stern appendage surface (SA). On MODEL No. 5471, taps are also located on the fairwater/hull intersection surface (FH) and the baseline stern appendage/hull intersection surface (AH). In addition, surface pressure taps are located on both Ring Wing 1 and Ring Wing 2.

An alphanumeric identification system is adopted to identify each surface pressure tap. Pressure taps on MODEL No. 5470 (the towing basin model) are prefixed with a 'TB' to easily distinguish them from MODEL No. 5471 (the wind tunnel model). Pressure taps on Ring Wing 1 are prefixed with a 'W1' and taps on Ring Wing 2 are prefixed with a 'W2'. Model scale Cartesian offsets in units of feet are given for each surface pressure tap location.

MODEL NO. 5471

A total of 222 surface pressure taps are located on the wind tunnel MODEL No. 5471. Table 6 presents the surface pressure tap identification scheme used for MODEL No. 5471. Table 7 and Figure 11 identify the tap locations on the axisymmetric hull, Table 8 and Figure 12 identify the tap locations on the fairwater surface, Table 9 and Figure 13 show the tap locations in the fairwater/hull intersection region, Table 10 and Figure 14 give the tap locations on the baseline stern appendage, and, finally, Table 11 and Figure 15 identify the taps locations in the baseline

Table 6. Surface pressure tap identification scheme - MODEL No. 5471

| Pressure Tap Identification | Pressure Tap Location | Number of Pressure Taps |
|---|---|---|
| HUi | Upper hull surface | 21 |
| HPi | Port side hull surface | 7 |
| HLi | Lower hull surface | 7 |
| HSi | Starboard side hull surface | 7 |
| FWi | Fairwater (sail) surface | 30 |
| FHi | Fairwater/hull intersection region | 76 |
| SAi | Upper rudder stern appendage | 33 |
| AHi | Stern appendage/hull intersection region | 41 |
| | Total surface pressure taps DTRC MODEL No. 5471 (wind tunnel model) | 222 |

stern appendage/hull region.

Table 7. Axisymmetric hull pressure tap locations - MODEL No. 5471

| Tap No. | x | y | z |
|---|---|---|---|
| HU1 | 0.00000 | 0.00000 | 0.00000 |
| HU2 | 0.50000 | 0.53273 | 0.00000 |
| HP2 | 0.50000 | 0.00000 | 0.53273 |
| HL2 | 0.50000 | -0.53273 | 0.00000 |
| HS2 | 0.50000 | 0.00000 | -0.53273 |
| HU3 | 1.00000 | 0.64836 | 0.00000 |
| HU4 | 1.50000 | 0.71857 | 0.00000 |
| HU5 | 2.58333 | 0.81862 | 0.00000 |
| HP5 | 2.58333 | 0.00000 | 0.81862 |
| HL5 | 2.58333 | -0.81862 | 0.00000 |
| HS5 | 2.58333 | 0.00000 | -0.81862 |
| HU6 | 3.41667 | 0.83333 | 0.00000 |
| HU7 | 5.75000 | 0.83333 | 0.00000 |
| HU8 | 7.16667 | 0.83333 | 0.00000 |
| HP8 | 7.16667 | 0.00000 | 0.83333 |
| HL8 | 7.16667 | -0.83333 | 0.00000 |
| HS8 | 7.16667 | 0.00000 | -0.83333 |
| HU9 | 8.58333 | 0.83333 | 0.00000 |
| HU10 | 10.00000 | 0.83333 | 0.00000 |
| HU11 | 10.58333 | 0.83333 | 0.00000 |
| HP11 | 10.58333 | 0.00000 | 0.83333 |
| HL11 | 10.58333 | -0.83333 | 0.00000 |
| HS11 | 10.58333 | 0.00000 | -0.83333 |
| HU12 | 11.16667 | 0.81635 | 0.00000 |
| HP12 | 11.16667 | 0.00000 | 0.81635 |
| HL12 | 11.16667 | -0.81635 | 0.00000 |
| HS12 | 11.16667 | 0.00000 | -0.81635 |
| HU13 | 11.50000 | 0.77254 | 0.00000 |
| HU14 | 12.00000 | 0.65467 | 0.00000 |
| HP14 | 12.00000 | 0.00000 | 0.65467 |
| HL14 | 12.00000 | -0.65467 | 0.00000 |
| HS14 | 12.00000 | 0.00000 | -0.65467 |
| HU15 | 12.25000 | 0.57766 | 0.00000 |
| HU16 | 12.50000 | 0.49338 | 0.00000 |
| HU17 | 12.91667 | 0.34795 | 0.00000 |
| HP17 | 12.91667 | 0.00000 | 0.34795 |
| HL17 | 12.91667 | -0.34795 | 0.00000 |
| HS17 | 12.91667 | 0.00000 | -0.34795 |
| HU18 | 13.25000 | 0.23871 | 0.00000 |
| HU19 | 13.66667 | 0.13103 | 0.00000 |
| HU20 | 13.97917 | 0.09792 | 0.00000 |
| HU21 | 14.29167 | 0.00000 | 0.00000 |

Note: All dimensions are model scale in feet

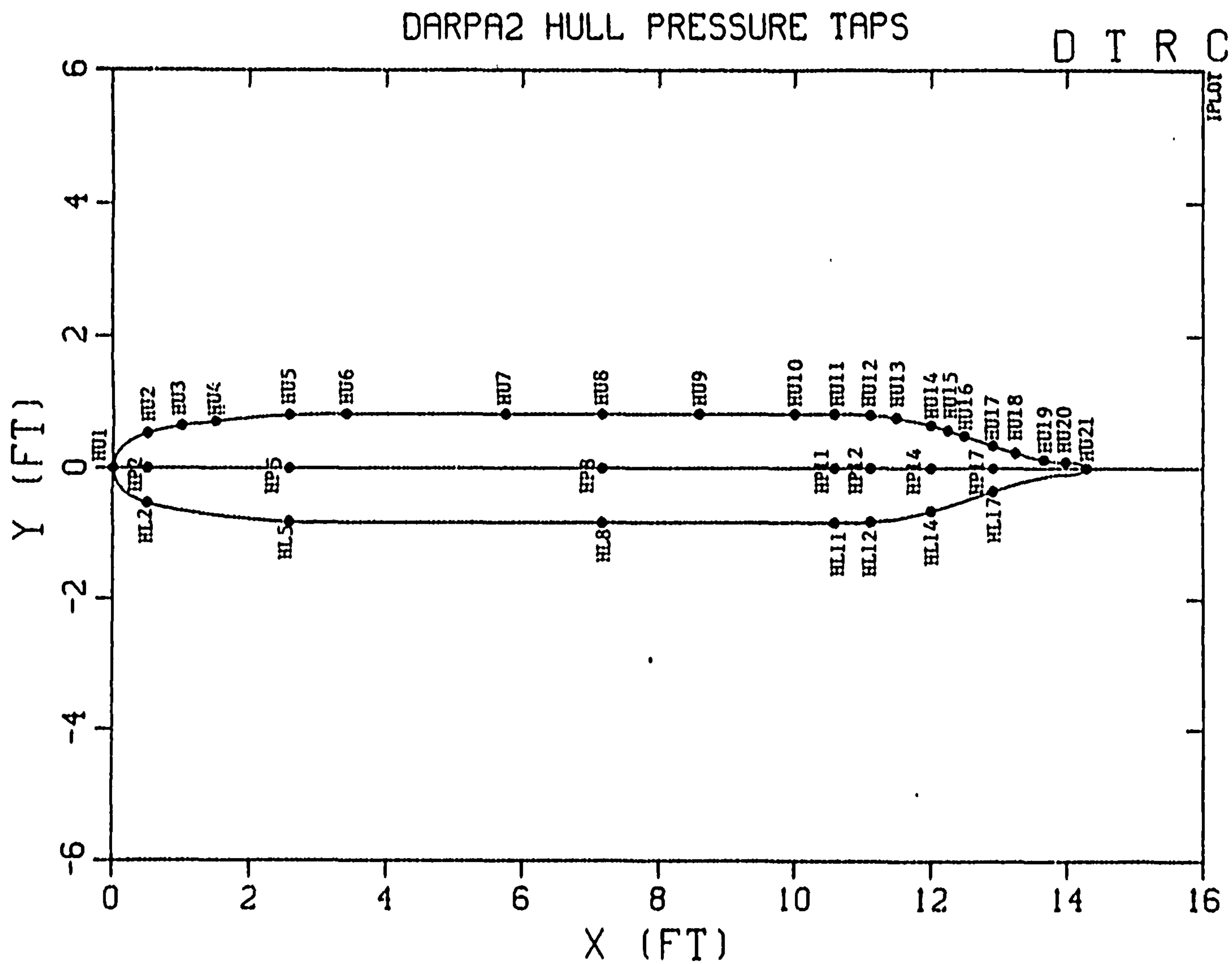



Figure 11. Axisymmetric hull pressure taps - MODEL No. 5471

Table 8. Fairwater pressure tap locations - MODEL No. 5471

| Tap No. | x | y | z |
|---|---|---|---|
| FW1 | 3.03299 | 1.44036 | 0.00000 |
| FW2 | 3.03299 | 1.30549 | 0.00000 |
| FW3 | 3.03299 | 1.17057 | 0.00000 |
| FW4 | 3.03299 | 1.03567 | 0.00000 |
| FW5 | 3.03299 | 0.90078 | 0.00000 |
| FW6 | 3.12965 | 1.44036 | 0.09581 |
| FW7 | 3.12965 | 1.30549 | 0.09581 |
| FW8 | 3.12965 | 1.17057 | 0.09581 |
| FW9 | 3.12965 | 1.03567 | 0.09581 |
| FW10 | 3.12965 | 0.90078 | 0.09581 |
| FW11 | 3.33507 | 1.44036 | 0.10937 |
| FW12 | 3.33507 | 1.30549 | 0.10937 |
| FW13 | 3.33507 | 1.17057 | 0.10937 |
| FW14 | 3.33507 | 1.03567 | 0.10937 |
| FW15 | 3.33507 | 0.90078 | 0.10937 |
| FW16 | 3.63715 | 1.44036 | 0.10893 |
| FW17 | 3.63715 | 1.30549 | 0.10893 |
| FW18 | 3.63715 | 1.17057 | 0.10893 |
| FW19 | 3.63715 | 1.03567 | 0.10893 |
| FW20 | 3.63715 | 0.90078 | 0.10893 |
| FW21 | 3.93924 | 1.44036 | 0.07908 |
| FW22 | 3.93924 | 1.30549 | 0.07908 |
| FW23 | 3.93924 | 1.17057 | 0.07908 |
| FW24 | 3.93924 | 1.03567 | 0.07908 |
| FW25 | 3.93924 | 0.90078 | 0.07908 |
| FW26 | 4.24132 | 1.44036 | 0.00000 |
| FW27 | 4.24132 | 1.30549 | 0.00000 |
| FW28 | 4.24132 | 1.17057 | 0.00000 |
| FW29 | 4.24132 | 1.03567 | 0.00000 |
| FW30 | 4.24132 | 0.90078 | 0.00000 |

Note: All dimensions are model scale in feet

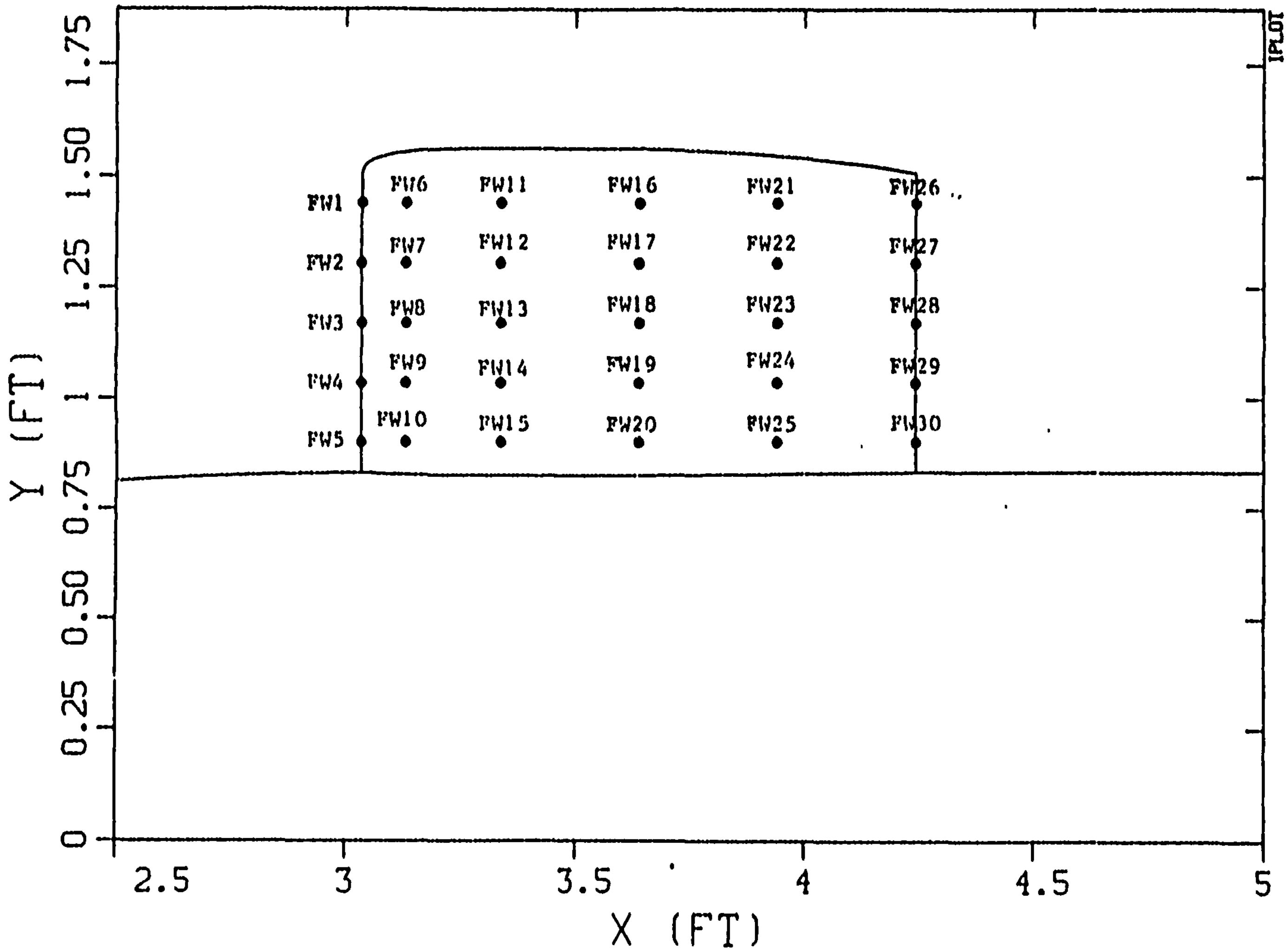



Figure 12. Fairwater pressure taps - MODEL No. 5471

Table 9. Fairwater/hull intersection region pressure tap locations - MODEL No. 5471

| Tap No. | x | y | z |
|---|---|---|---|
| FH1 | 3.03299 | 0.87379 | 0.00000 |
| FH2 | 3.03299 | 0.85295 | 0.00000 |
| FH3 | 3.03299 | 0.84045 | 0.00000 |
| FH4 | 3.02466 | 0.83202 | 0.00000 |
| FH5 | 3.01632 | 0.83192 | 0.00000 |
| FH6 | 3.00799 | 0.83181 | 0.00000 |
| FH7 | 2.99132 | 0.83158 | 0.00000 |
| FH8 | 2.97049 | 0.83126 | 0.00000 |
| FH9 | 2.94966 | 0.83091 | 0.00000 |
| FH10 | 2.90799 | 0.83011 | 0.00000 |
| FH11 | 2.86632 | 0.82917 | 0.00000 |
| FH12 | 3.01325 | 0.83102 | 0.03782 |
| FH13 | 2.98770 | 0.83025 | 0.04612 |
| FH14 | 2.96221 | 0.82934 | 0.05440 |
| FH15 | 2.91136 | 0.82715 | 0.07093 |
| FH16 | 3.04311 | 0.82985 | 0.06288 |
| FH17 | 3.03168 | 0.82905 | 0.07118 |
| FH18 | 3.02028 | 0.82816 | 0.07946 |
| FH19 | 2.99752 | 0.82611 | 0.09600 |
| FH20 | 3.07036 | 0.82849 | 0.08161 |
| FH21 | 3.06434 | 0.82758 | 0.08989 |
| FH22 | 3.05833 | 0.82658 | 0.09816 |
| FH23 | 3.04633 | 0.82433 | 0.11468 |
| FH24 | 3.09835 | 0.82732 | 0.09479 |
| FH25 | 3.09616 | 0.82631 | 0.10307 |
| FH26 | 3.09347 | 0.82521 | 0.11135 |
| FH27 | 3.08812 | 0.82278 | 0.12782 |
| FH28 | 3.12965 | 0.86908 | 0.09581 |
| FH29 | 3.12965 | 0.84824 | 0.09581 |
| FH30 | 3.12965 | 0.83574 | 0.09581 |
| FH31 | 3.12965 | 0.82641 | 0.10408 |
| FH32 | 3.12965 | 0.82533 | 0.11234 |
| FH33 | 3.12965 | 0.82416 | 0.12060 |
| FH34 | 3.12965 | 0.82158 | 0.13706 |
| FH35 | 3.33507 | 0.86779 | 0.10937 |
| FH36 | 3.33507 | 0.84695 | 0.10937 |
| FH37 | 3.33507 | 0.83445 | 0.10937 |
| FH38 | 3.33507 | 0.82247 | 0.13409 |
| FH39 | 3.33507 | 0.81962 | 0.15052 |
| FH40 | 3.33507 | 0.81561 | 0.17095 |

Note: All dimensions are model scale in feet

Table 9. (Continued)

| Tap No. | x | y | z |
|---|---|---|---|
| FH41 | 3.33507 | 0.81108 | 0.19128 |
| FH42 | 3.63715 | 0.86788 | 0.10877 |
| FH43 | 3.63715 | 0.84704 | 0.10877 |
| FH44 | 3.63715 | 0.83454 | 0.10877 |
| FH45 | 3.63715 | 0.82257 | 0.13351 |
| FH46 | 3.63715 | 0.81973 | 0.14993 |
| FH47 | 3.63715 | 0.81573 | 0.17037 |
| FH48 | 3.63715 | 0.81122 | 0.19070 |
| FH49 | 3.93924 | 0.87130 | 0.07850 |
| FH50 | 3.93924 | 0.85046 | 0.07850 |
| FH51 | 3.93924 | 0.83796 | 0.07850 |
| FH52 | 3.93924 | 0.82690 | 0.10335 |
| FH53 | 3.93924 | 0.82467 | 0.11987 |
| FH54 | 3.93924 | 0.82141 | 0.14044 |
| FH55 | 3.93924 | 0.81765 | 0.16092 |
| FH56 | 4.84549 | 0.72169 | 0.41667 |
| FH57 | 5.44965 | 0.72169 | 0.41667 |
| FH58 | 4.84549 | 0.75525 | 0.35218 |
| FH59 | 5.44965 | 0.75525 | 0.35218 |
| FH60 | 4.84549 | 0.78307 | 0.28502 |
| FH61 | 5.44965 | 0.78307 | 0.28502 |
| FH62 | 4.84549 | 0.80493 | 0.21568 |
| FH63 | 5.44965 | 0.80493 | 0.21568 |
| FH64 | 4.84549 | 0.82067 | 0.14471 |
| FH65 | 5.44965 | 0.82067 | 0.14471 |
| FH66 | 4.84549 | 0.83016 | 0.07263 |
| FH67 | 5.44965 | 0.83016 | 0.07263 |
| FH68 | 4.24132 | 0.87501 | 0.00000 |
| FH69 | 4.24132 | 0.85417 | 0.00000 |
| FH70 | 4.24132 | 0.84167 | 0.00000 |
| FH71 | 4.24965 | 0.83333 | 0.00000 |
| FH72 | 4.26215 | 0.83333 | 0.00000 |
| FH73 | 4.28299 | 0.83333 | 0.00000 |
| FH74 | 4.32365 | 0.83333 | 0.00000 |
| FH75 | 4.84549 | 0.83333 | 0.00000 |
| FH76 | 5.44965 | 0.83333 | 0.00000 |

Note: All dimensions are model scale in feet

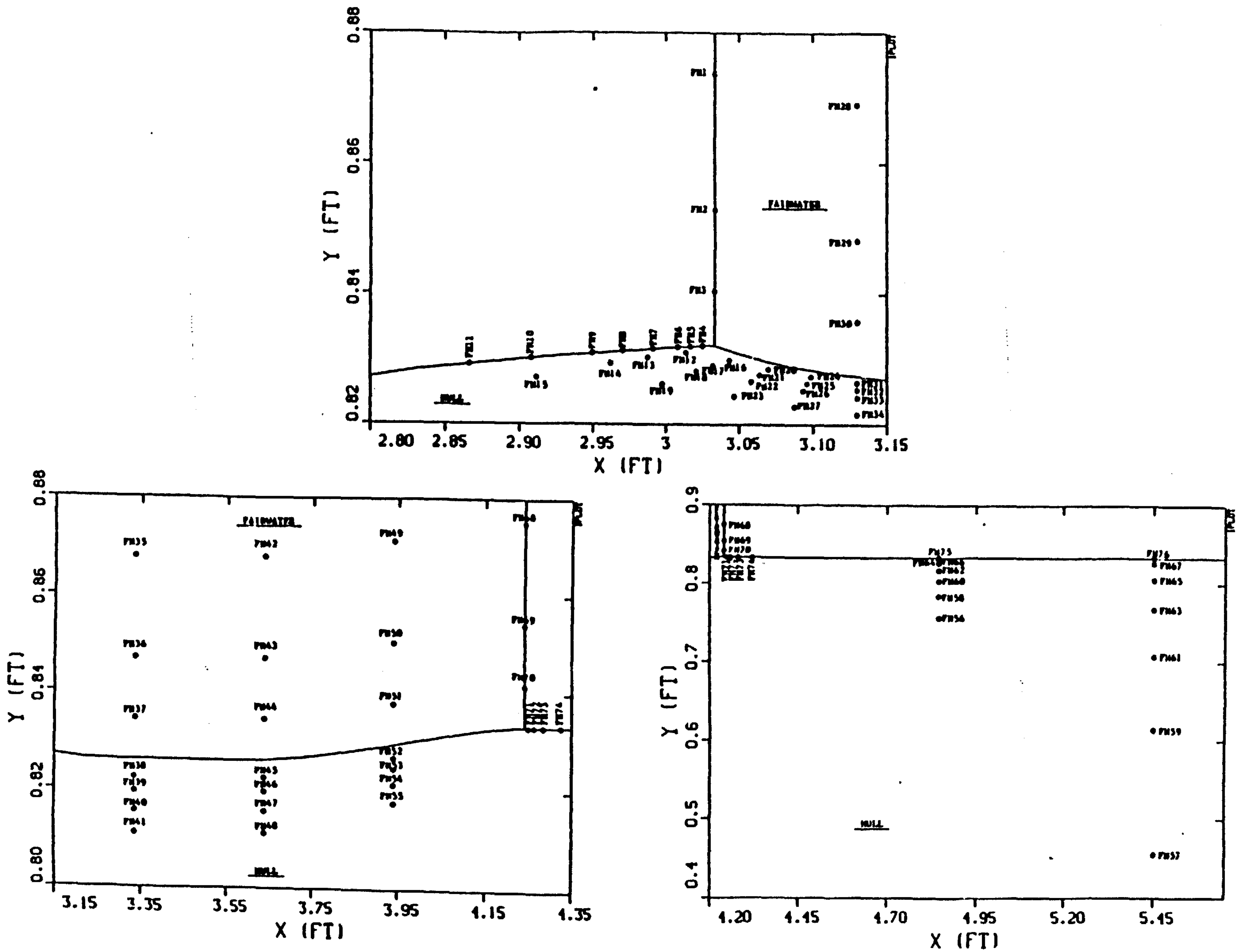



Figure 13. Hull/fairwater intersection region pressure taps - MODEL No. 5471

Table 10. Baseline stern appendage pressure tap locations - MODEL No. 5471

| Tap No. | x | y | z |
|---|---|---|---|
| SA1 | 12.62576 | 0.78932 | 0.00000 |
| SA2 | 12.58471 | 0.70129 | 0.00000 |
| SA3 | 12.54366 | 0.61327 | 0.00000 |
| SA4 | 12.52255 | 0.56799 | 0.00000 |
| SA5 | 12.50435 | 0.52896 | 0.00000 |
| SA6 | 12.60283 | 0.61327 | 0.04672 |
| SA7 | 12.58388 | 0.55745 | 0.04999 |
| SA8 | 12.56691 | 0.50746 | 0.05285 |
| SA9 | 12.69903 | 0.78932 | 0.04552 |
| SA10 | 12.67951 | 0.70129 | 0.05167 |
| SA11 | 12.66000 | 0.61327 | 0.05721 |
| SA12 | 12.64528 | 0.54690 | 0.06112 |
| SA13 | 12.63161 | 0.48522 | 0.06459 |
| SA14 | 12.77128 | 0.78932 | 0.05199 |
| SA15 | 12.77128 | 0.70129 | 0.05596 |
| SA16 | 12.77128 | 0.61327 | 0.05903 |
| SA17 | 12.77128 | 0.52525 | 0.06149 |
| SA18 | 12.77128 | 0.43722 | 0.06352 |
| SA19 | 12.89628 | 0.78932 | 0.04476 |
| SA20 | 12.89628 | 0.70129 | 0.04595 |
| SA21 | 12.89628 | 0.61327 | 0.04694 |
| SA22 | 12.89628 | 0.50376 | 0.04797 |
| SA23 | 12.89628 | 0.39426 | 0.04884 |
| SA24 | 13.02184 | 0.78932 | 0.02621 |
| SA25 | 13.02184 | 0.70129 | 0.02648 |
| SA26 | 13.02128 | 0.61327 | 0.02672 |
| SA27 | 13.02128 | 0.48229 | 0.02703 |
| SA28 | 13.02128 | 0.35130 | 0.02729 |
| SA29 | 13.14628 | 0.78932 | 0.00000 |
| SA30 | 13.14628 | 0.70129 | 0.00000 |
| SA31 | 13.14628 | 0.61327 | 0.00000 |
| SA32 | 13.14628 | 0.46081 | 0.00000 |
| SA33 | 13.14628 | 0.30834 | 0.00000 |

Note: All dimensions are model scale in feet

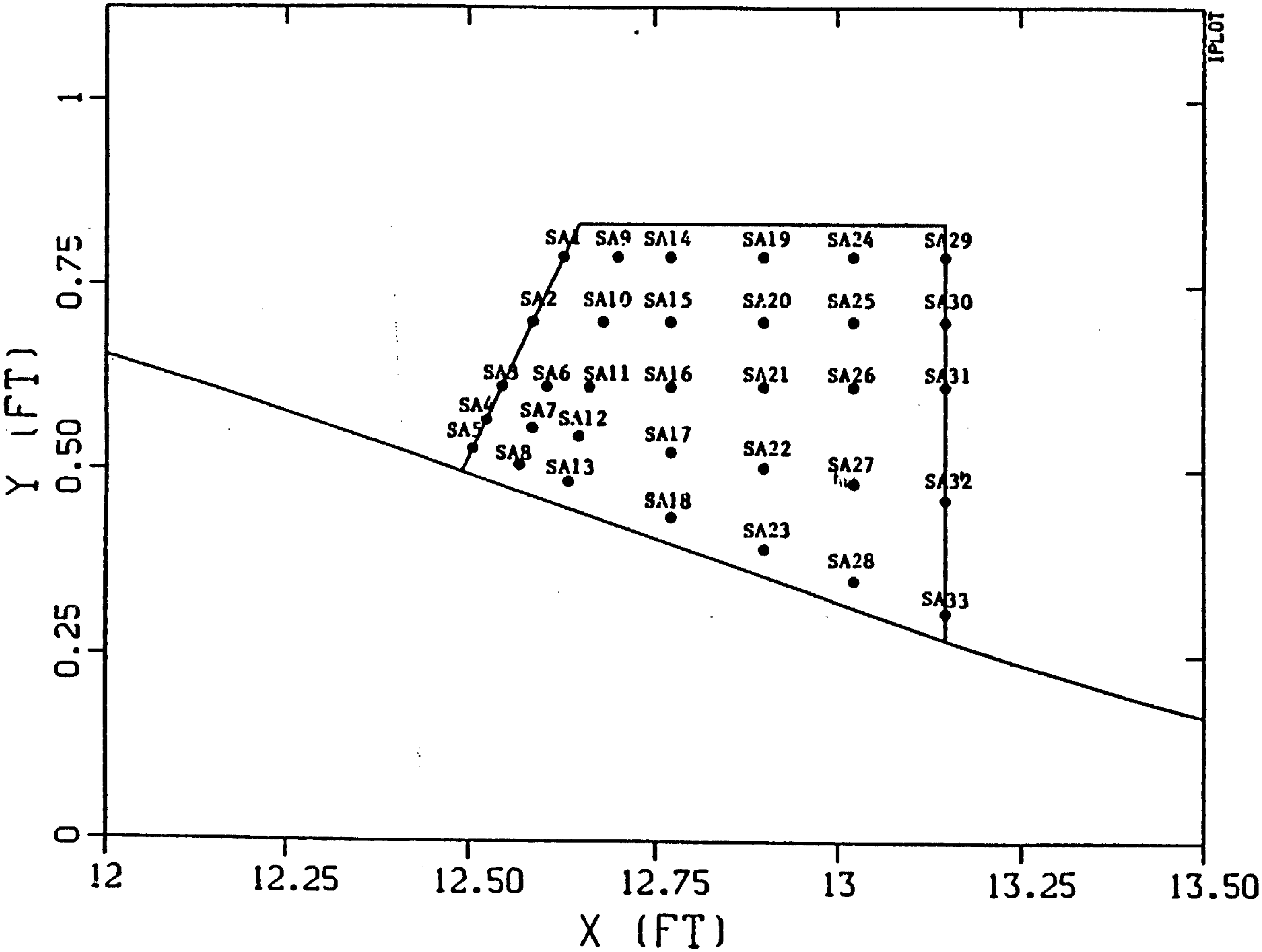



Figure 14. Baseline stern appendage pressure taps - MODEL No. 5471

Table 11. Baseline stern appendage/hull region pressure tap locations - MODEL No. 5471

| Tap No. | x | y | z |
|---|---|---|---|
| AH1 | 12.50707 | 0.53479 | 0.00000 |
| AH2 | 12.49827 | 0.51591 | 0.00000 |
| AH3 | 12.46977 | 0.50382 | 0.00000 |
| AH4 | 12.45006 | 0.51060 | 0.00000 |
| AH5 | 12.41065 | 0.52408 | 0.00000 |
| AH6 | 12.37119 | 0.53746 | 0.00000 |
| AH7 | 12.77128 | 0.43490 | 0.06357 |
| AH8 | 12.77128 | 0.41406 | 0.06400 |
| AH9 | 12.77128 | 0.38218 | 0.11278 |
| AH10 | 12.77128 | 0.36519 | 0.15941 |
| AH11 | 12.77128 | 0.34255 | 0.20356 |
| AH12 | 12.77128 | 0.31460 | 0.24456 |
| AH13 | 12.77128 | 0.28176 | 0.28176 |
| AH14 | 12.89628 | 0.39322 | 0.04885 |
| AH15 | 12.89628 | 0.37238 | 0.04900 |
| AH16 | 12.89628 | 0.34228 | 0.09407 |
| AH17 | 12.89628 | 0.32729 | 0.13742 |
| AH18 | 12.89628 | 0.30684 | 0.17847 |
| AH19 | 12.89628 | 0.28127 | 0.21654 |
| AH20 | 12.89628 | 0.25100 | 0.25100 |
| AH21 | 13.02182 | 0.35286 | 0.02718 |
| AH22 | 13.02182 | 0.33202 | 0.02722 |
| AH23 | 13.02182 | 0.30436 | 0.07038 |
| AH24 | 13.02182 | 0.29161 | 0.11203 |
| AH25 | 13.02182 | 0.27320 | 0.15150 |
| AH26 | 13.02182 | 0.24947 | 0.18802 |
| AH27 | 13.02182 | 0.22089 | 0.22089 |
| AH28 | 13.16711 | 0.22916 | 0.13230 |
| AH29 | 13.18795 | 0.22343 | 0.12900 |
| AH30 | 13.22961 | 0.21216 | 0.12249 |
| AH31 | 13.16711 | 0.24865 | 0.09050 |
| AH32 | 13.18795 | 0.24244 | 0.08824 |
| AH33 | 13.22961 | 0.23021 | 0.08379 |
| AH34 | 13.16711 | 0.26059 | 0.04595 |
| AH35 | 13.18795 | 0.25408 | 0.04480 |
| AH36 | 13.22961 | 0.24126 | 0.04254 |
| AH37 | 13.14628 | 0.31296 | 0.00000 |
| AH38 | 13.14628 | 0.29212 | 0.00000 |
| AH39 | 13.16711 | 0.26461 | 0.00000 |
| AH40 | 13.18795 | 0.25800 | 0.00000 |
| AH41 | 13.22961 | 0.24498 | 0.00000 |

Note: All dimensions are model scale in feet

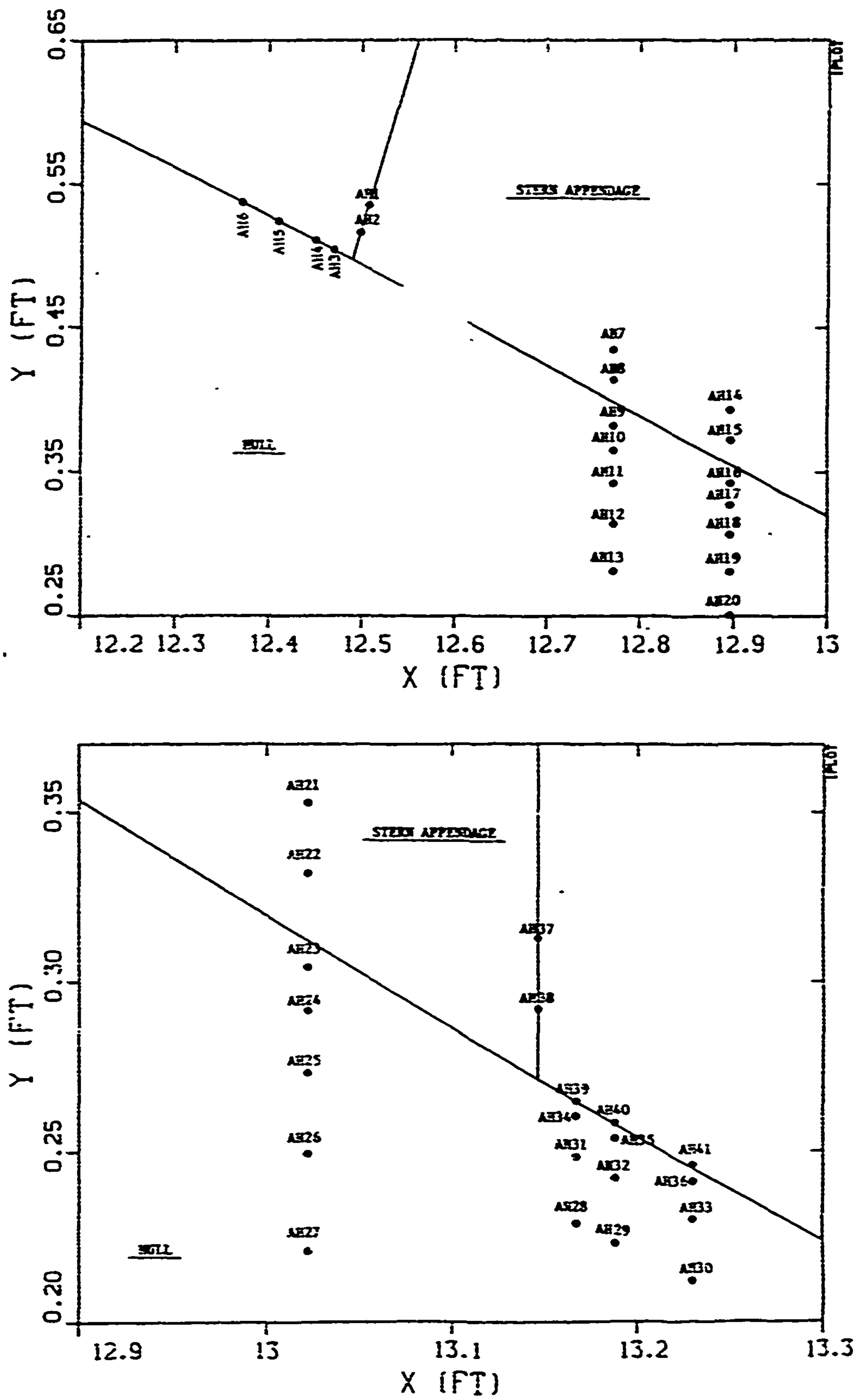



Figure 15. Baseline stern appendage/hull region pressure taps - MODEL No. 5471

MODEL NO. 5470

The pressure taps on DTRC MODEL No. 5470 (the towing basin model) are located on the hull surface (TBH-), the port side of the fairwater (TBFWP), the starboard side of the fairwater (TBFWS), the port side of the baseline upper rudder stern appendage (TBSAP), and the starboard side of the baseline upper rudder stern appendage (TBSAS). A total of 266 pressure taps are located on MODEL No. 5470 as given in Table 12. The axisymmetric hull surface pressure taps are located at 8 axial positions and up to 32 azimuthal positions as shown in Figure 16. The port side pressure taps on the fairwater are located at the

Table 12. Surface pressure tap identification scheme - MODEL No. 5470

| Pressure Tap Identification | Pressure Tap Location | Number of Pressure Taps |
|---|---|---|
| TBH-ij | Hull surface i is an alphabetic character denoting axial position and j is a numerical character denoting azimuthal position | 170 |
| TBFWPi | Port side fairwater (sail) surface | 30 |
| TBFWSi | Starboard side fairwater (sail) surface | 20 |
| TBSAPi | Port side of upper rudder stern appendage | 28 |
| TBSASi | Starboard side of upper rudder stern appendage | 18 |
| | Total surface pressure taps DTRC MODEL No. 5470 (towing basin model) | 266 |

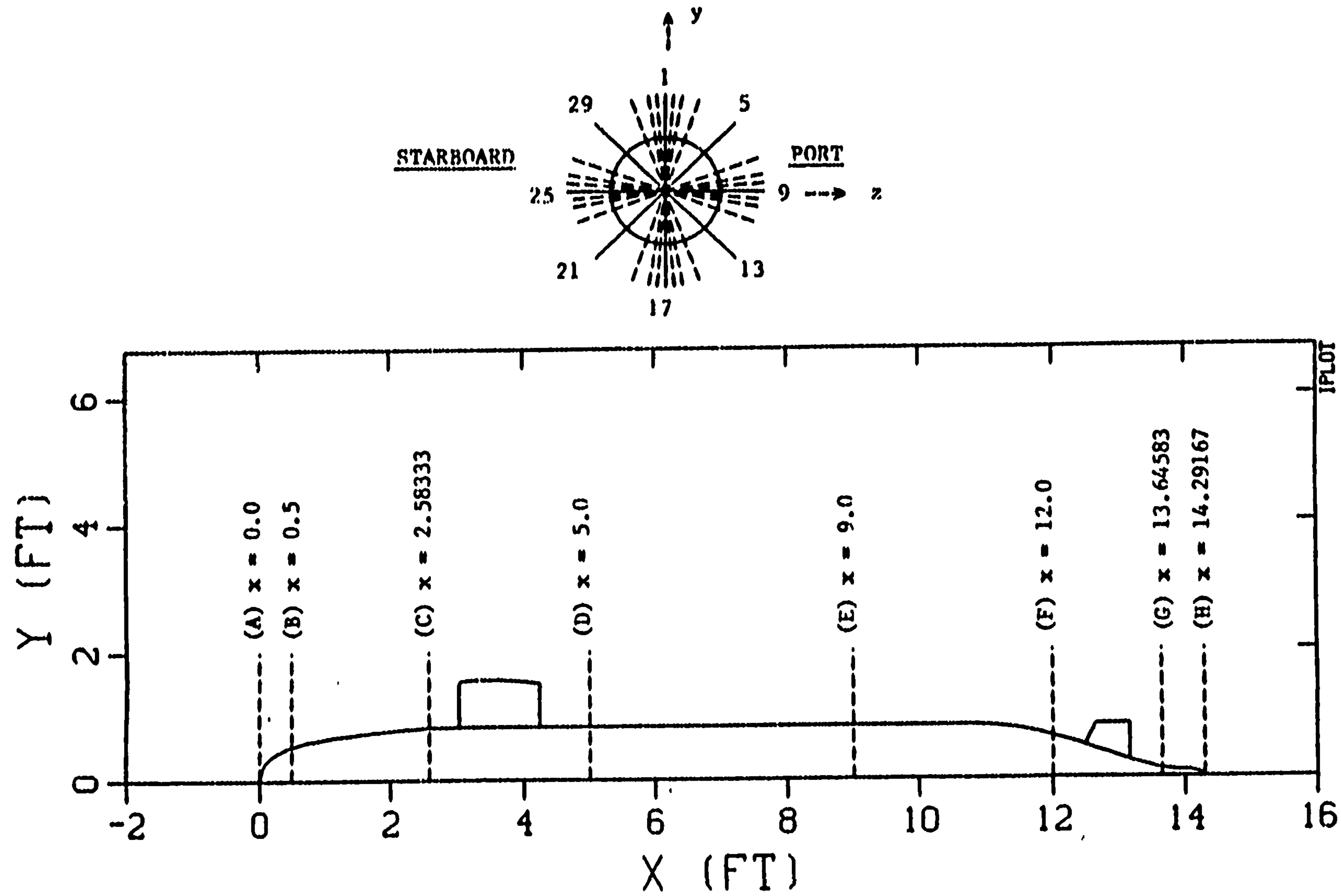



**Figure 16. Surface pressure tap identificaton scheme on MODEL No. 5470 axisymmetric hull**

Table 13. Axisymmetric hull pressure tap locations - MODEL NO. 5470

| Tap No. | x | y | z |
|---|---|---|---|
| TBH-A1 | 0.00000 | 0.00000 | 0.00000 |
| TBH-B1 | 0.50000 | 0.53273 | 0.00000 |
| TBH-B2 | 0.50000 | 0.53070 | 0.04643 |
| TBH-B3 | 0.50000 | 0.52464 | 0.09251 |
| TBH-B4 | 0.50000 | 0.50060 | 0.18220 |
| TBH-B5 | 0.50000 | 0.37670 | 0.37670 |
| TBH-B6 | 0.50000 | 0.18220 | 0.50060 |
| TBH-B7 | 0.50000 | 0.09251 | 0.52464 |
| TBH-B8 | 0.50000 | 0.04643 | 0.53070 |
| TBH-B9 | 0.50000 | 0.00000 | 0.53273 |
| TBH-B10 | 0.50000 | -0.04643 | 0.53070 |
| TBH-B11 | 0.50000 | -0.09251 | 0.52464 |
| TBH-B12 | 0.50000 | -0.18220 | 0.50060 |
| TBH-B13 | 0.50000 | -0.37670 | 0.37670 |
| TBH-B14 | 0.50000 | -0.50060 | 0.18220 |
| TBH-B15 | 0.50000 | -0.52464 | 0.09251 |
| TBH-B16 | 0.50000 | -0.53070 | 0.04643 |
| TBH-B17 | 0.50000 | -0.53273 | 0.00000 |
| TBH-B18 | 0.50000 | -0.53070 | -0.04643 |
| TBH-B19 | 0.50000 | -0.52464 | -0.09251 |
| TBH-B20 | 0.50000 | -0.50060 | -0.18220 |
| TBH-B21 | 0.50000 | -0.37670 | -0.37670 |
| TBH-B22 | 0.50000 | -0.18220 | -0.50060 |
| TBH-B23 | 0.50000 | -0.09251 | -0.52464 |
| TBH-B24 | 0.50000 | -0.04643 | -0.53070 |
| TBH-B25 | 0.50000 | 0.00000 | -0.53273 |
| TBH-B26 | 0.50000 | 0.04643 | -0.53070 |
| TBH-B27 | 0.50000 | 0.09251 | -0.52464 |
| TBH-B28 | 0.50000 | 0.18220 | -0.50060 |
| TBH-B29 | 0.50000 | 0.37670 | -0.37670 |
| TBH-B30 | 0.50000 | 0.50060 | -0.18220 |
| TBH-B31 | 0.50000 | 0.52464 | -0.09251 |
| TBH-B32 | 0.50000 | 0.53070 | -0.04643 |
| TBH-C1 | 2.58333 | 0.81862 | 0.00000 |
| TBH-C2 | 2.58333 | 0.81550 | 0.07135 |
| TBH-C3 | 2.58333 | 0.80618 | 0.14215 |
| TBH-C4 | 2.58333 | 0.76925 | 0.27998 |
| TBH-C5 | 2.58333 | 0.57885 | 0.57885 |
| TBH-C6 | 2.58333 | 0.27998 | 0.76925 |
| TBH-C7 | 2.58333 | 0.14215 | 0.80618 |
| TBH-C8 | 2.58333 | 0.07135 | 0.81550 |
| TBH-C9 | 2.58333 | 0.00000 | 0.81862 |
| TBH-C10 | 2.58333 | -0.07135 | 0.81550 |
| TBH-C11 | 2.58333 | -0.14215 | 0.80618 |

Note: All dimensions are model scale in feet

Table 13. (Continued)

| Tap No. | x | y | z |
|---|---|---|---|
| TBH-C12 | 2.58333 | -0.27998 | 0.76925 |
| TBH-C13 | 2.58333 | -0.57885 | 0.57885 |
| TBH-C14 | 2.58333 | -0.76925 | 0.27998 |
| TBH-C15 | 2.58333 | -0.80618 | 0.14215 |
| TBH-C16 | 2.58333 | -0.81550 | 0.07135 |
| TBH-C17 | 2.58333 | -0.81862 | 0.00000 |
| TBH-C18 | 2.58333 | -0.81550 | -0.07135 |
| TBH-C19 | 2.58333 | -0.80618 | -0.14215 |
| TBH-C20 | 2.58333 | -0.76925 | -0.27998 |
| TBH-C21 | 2.58333 | -0.57885 | -0.57885 |
| TBH-C22 | 2.58333 | -0.27998 | -0.76925 |
| TBH-C23 | 2.58333 | -0.14215 | -0.80618 |
| TBH-C24 | 2.58333 | -0.07135 | -0.81550 |
| TBH-C25 | 2.58333 | 0.00000 | -0.81862 |
| TBH-C26 | 2.58333 | 0.07135 | -0.81550 |
| TBH-C27 | 2.58333 | 0.14215 | -0.80618 |
| TBH-C28 | 2.58333 | 0.27998 | -0.76925 |
| TBH-C29 | 2.58333 | 0.57885 | -0.57885 |
| TBH-C30 | 2.58333 | 0.76925 | -0.27998 |
| TBH-C31 | 2.58333 | 0.80618 | -0.14215 |
| TBH-C32 | 2.58333 | 0.81550 | -0.07135 |
| TBH-D1 | 5.00000 | 0.83333 | 0.00000 |
| TBH-D2 | 5.00000 | 0.83016 | 0.07263 |
| TBH-D3 | 5.00000 | 0.82067 | 0.14471 |
| TBH-D4 | 5.00000 | 0.78307 | 0.28502 |
| TBH-D5 | 5.00000 | 0.58925 | 0.58925 |
| TBH-D6 | 5.00000 | 0.28502 | 0.78307 |
| TBH-D7 | 5.00000 | 0.14471 | 0.82067 |
| TBH-D8 | 5.00000 | 0.07263 | 0.83016 |
| TBH-D9 | 5.00000 | 0.00000 | 0.83333 |
| TBH-D10 | 5.00000 | -0.07263 | 0.83016 |
| TBH-D11 | 5.00000 | -0.14471 | 0.82067 |
| TBH-D12 | 5.00000 | -0.28502 | 0.78307 |
| TBH-D13 | 5.00000 | -0.58925 | 0.58925 |
| TBH-D14 | 5.00000 | -0.78307 | 0.28502 |
| TBH-D15 | 5.00000 | -0.82067 | 0.14471 |
| TBH-D16 | 5.00000 | -0.83016 | 0.07263 |
| TBH-D17 | 5.00000 | -0.83333 | 0.00000 |
| TBH-D18 | 5.00000 | -0.83016 | -0.07263 |
| TBH-D19 | 5.00000 | -0.82067 | -0.14471 |
| TBH-D20 | 5.00000 | -0.78307 | -0.28502 |
| TBH-D21 | 5.00000 | -0.58925 | -0.58925 |
| TBH-D22 | 5.00000 | -0.28502 | -0.78307 |
| TBH-D23 | 5.00000 | -0.14471 | -0.82067 |

Note: All dimensions are model scale in feet

Table 13. (Continued)

| Tap No. | x | y | z |
|---|---|---|---|
| TBH-D24 | 5.00000 | -0.07263 | -0.83016 |
| TBH-D25 | 5.00000 | 0.00000 | -0.83333 |
| TBH-D26 | 5.00000 | 0.07263 | -0.83016 |
| TBH-D27 | 5.00000 | 0.14471 | -0.82067 |
| TBH-D28 | 5.00000 | 0.28502 | -0.78307 |
| TBH-D29 | 5.00000 | 0.58925 | -0.58925 |
| TBH-D30 | 5.00000 | 0.78307 | -0.28502 |
| TBH-D31 | 5.00000 | 0.82067 | -0.14471 |
| TBH-D32 | 5.00000 | 0.83016 | -0.07263 |
| TBH-E1 | 9.00000 | 0.83333 | 0.00000 |
| TBH-E2 | 9.00000 | 0.83016 | 0.07263 |
| TBH-E3 | 9.00000 | 0.82067 | 0.14471 |
| TBH-E4 | 9.00000 | 0.78307 | 0.28502 |
| TBH-E5 | 9.00000 | 0.58925 | 0.58925 |
| TBH-E6 | 9.00000 | 0.28502 | 0.78307 |
| TBH-E7 | 9.00000 | 0.14471 | 0.82067 |
| TBH-E8 | 9.00000 | 0.07263 | 0.83016 |
| TBH-E9 | 9.00000 | 0.00000 | 0.83333 |
| TBH-E10 | 9.00000 | -0.07263 | 0.83016 |
| TBH-E11 | 9.00000 | -0.14471 | 0.82067 |
| TBH-E12 | 9.00000 | -0.28502 | 0.78307 |
| TBH-E13 | 9.00000 | -0.58925 | 0.58925 |
| TBH-E14 | 9.00000 | -0.78307 | 0.28502 |
| TBH-E15 | 9.00000 | -0.82067 | 0.14471 |
| TBH-E16 | 9.00000 | -0.83016 | 0.07263 |
| TBH-E17 | 9.00000 | -0.83333 | 0.00000 |
| TBH-E18 | 9.00000 | -0.83016 | -0.07263 |
| TBH-E19 | 9.00000 | -0.82067 | -0.14471 |
| TBH-E20 | 9.00000 | -0.78307 | -0.28502 |
| TBH-E21 | 9.00000 | -0.58925 | -0.58925 |
| TBH-E22 | 9.00000 | -0.28502 | -0.78307 |
| TBH-E23 | 9.00000 | -0.14471 | -0.82067 |
| TBH-E24 | 9.00000 | -0.07263 | -0.83016 |
| TBH-E25 | 9.00000 | 0.00000 | -0.83333 |
| TBH-E26 | 9.00000 | 0.07263 | -0.83016 |
| TBH-E27 | 9.00000 | 0.14471 | -0.82067 |
| TBH-E28 | 9.00000 | 0.28502 | -0.78307 |
| TBH-E29 | 9.00000 | 0.58925 | -0.58925 |
| TBH-E30 | 9.00000 | 0.78307 | -0.28502 |
| TBH-E31 | 9.00000 | 0.82067 | -0.14471 |
| TBH-E32 | 9.00000 | 0.83016 | -0.07263 |
| TBH-F1 | 12.00000 | 0.65467 | 0.00000 |
| TBH-F2 | 12.00000 | 0.65218 | 0.05706 |
| TBH-F3 | 12.00000 | 0.64472 | 0.11368 |

Note: All dimensions are model scale in feet

Table 13. (Continued)

| Tap No. | x | y | z |
|---|---|---|---|
| TBH-F4 | 12.00000 | 0.61519 | 0.22391 |
| TBH-F5 | 12.00000 | 0.46292 | 0.46292 |
| TBH-F6 | 12.00000 | 0.22391 | 0.61519 |
| TBH-F7 | 12.00000 | 0.11368 | 0.64472 |
| TBH-F8 | 12.00000 | 0.05706 | 0.65218 |
| TBH-F9 | 12.00000 | 0.00000 | 0.65467 |
| TBH-F10 | 12.00000 | -0.05706 | 0.65218 |
| TBH-F11 | 12.00000 | -0.11368 | 0.64472 |
| TBH-F12 | 12.00000 | -0.22391 | 0.61519 |
| TBH-F13 | 12.00000 | -0.46292 | 0.46292 |
| TBH-F14 | 12.00000 | -0.61519 | 0.22391 |
| TBH-F15 | 12.00000 | -0.64472 | 0.11368 |
| TBH-F16 | 12.00000 | -0.65218 | 0.05706 |
| TBH-F17 | 12.00000 | -0.65467 | 0.00000 |
| TBH-F18 | 12.00000 | -0.65218 | -0.05706 |
| TBH-F19 | 12.00000 | -0.64472 | -0.11368 |
| TBH-F20 | 12.00000 | -0.61519 | -0.22391 |
| TBH-F21 | 12.00000 | -0.46292 | -0.46292 |
| TBH-F22 | 12.00000 | -0.22391 | -0.61519 |
| TBH-F23 | 12.00000 | -0.11368 | -0.64472 |
| TBH-F24 | 12.00000 | -0.05706 | -0.65218 |
| TBH-F25 | 12.00000 | 0.00000 | -0.65467 |
| TBH-F26 | 12.00000 | 0.05706 | -0.65218 |
| TBH-F27 | 12.00000 | 0.11368 | -0.64472 |
| TBH-F28 | 12.00000 | 0.22391 | -0.61519 |
| TBH-F29 | 12.00000 | 0.46292 | -0.46292 |
| TBH-F30 | 12.00000 | 0.61519 | -0.22391 |
| TBH-F31 | 12.00000 | 0.64472 | -0.11368 |
| TBH-F32 | 12.00000 | 0.65218 | -0.05706 |
| TBH-G1 | 13.64583 | 0.13515 | 0.00000 |
| TBH-G5 | 13.64583 | 0.09557 | 0.09557 |
| TBH-G9 | 13.64583 | 0.00000 | 0.13515 |
| TBH-G13 | 13.64583 | -0.09557 | 0.09557 |
| TBH-G17 | 13.64583 | -0.13515 | 0.00000 |
| TBH-G21 | 13.64583 | -0.09557 | -0.09557 |
| TBH-G25 | 13.64583 | 0.00000 | -0.13515 |
| TBH-G29 | 13.64583 | 0.09557 | -0.09557 |
| TBH-H1 | 14.29167 | 0.00000 | 0.00000 |

Note: All dimensions are model scale in feet

Table 14. Fairwater pressure tap locations - MODEL No. 5470

Table 14a. Port side

| Tap No. | x | y | z |
|---|---|---|---|
| TBFWP1 | 3.03299 | 1.44036 | 0.00000 |
| TBFWP2 | 3.03299 | 1.30549 | 0.00000 |
| TBFWP3 | 3.03299 | 1.17057 | 0.00000 |
| TBFWP4 | 3.03299 | 1.03567 | 0.00000 |
| TBFWP5 | 3.03299 | 0.90078 | 0.00000 |
| TBFWP6 | 3.12965 | 1.44036 | 0.09581 |
| TBFWP7 | 3.12965 | 1.30549 | 0.09581 |
| TBFWP8 | 3.12965 | 1.17057 | 0.09581 |
| TBFWP9 | 3.12965 | 1.03567 | 0.09581 |
| TBFWP10 | 3.12965 | 0.90078 | 0.09581 |
| TBFWP11 | 3.33507 | 1.44036 | 0.10937 |
| TBFWP12 | 3.33507 | 1.30549 | 0.10937 |
| TBFWP13 | 3.33507 | 1.17057 | 0.10937 |
| TBFWP14 | 3.33507 | 1.03567 | 0.10937 |
| TBFWP15 | 3.33507 | 0.90078 | 0.10937 |
| TBFWP16 | 3.63715 | 1.44036 | 0.10893 |
| TBFW1P7 | 3.63715 | 1.30549 | 0.10893 |
| TBFWP18 | 3.63715 | 1.17057 | 0.10893 |
| TBFWP19 | 3.63715 | 1.03567 | 0.10893 |
| TBFWP20 | 3.63715 | 0.90078 | 0.10893 |
| TBFWP21 | 3.93924 | 1.44036 | 0.07908 |
| TBFWP22 | 3.93924 | 1.30549 | 0.07908 |
| TBFWP23 | 3.93924 | 1.17057 | 0.07908 |
| TBFWP24 | 3.93924 | 1.03567 | 0.07908 |
| TBFWP25 | 3.93924 | 0.90078 | 0.07908 |
| TBFWP26 | 4.24132 | 1.44036 | 0.00000 |
| TBFWP27 | 4.24132 | 1.30549 | 0.00000 |
| TBFWP28 | 4.24132 | 1.17057 | 0.00000 |
| TBFWP29 | 4.24132 | 1.03567 | 0.00000 |
| TBFWP30 | 4.24132 | 0.90078 | 0.00000 |

Note: All dimensions are model scale in feet

Table 14. (Continued)

Table 14b. Starboard side

| Tap No. | x | y | z |
|---|---|---|---|
| TBFWS6 | 3.12965 | 1.44036 | -0.09581 |
| TBFWS7 | 3.12965 | 1.30549 | -0.09581 |
| TBFWS8 | 3.12965 | 1.17057 | -0.09581 |
| TBFWS9 | 3.12965 | 1.03567 | -0.09581 |
| TBFWS10 | 3.12965 | 0.90078 | -0.09581 |
| TBFWS11 | 3.33507 | 1.44036 | -0.10937 |
| TBFWS12 | 3.33507 | 1.30549 | -0.10937 |
| TBFWS13 | 3.33507 | 1.17057 | -0.10937 |
| TBFWS14 | 3.33507 | 1.03567 | -0.10937 |
| TBFWS15 | 3.33507 | 0.90078 | -0.10937 |
| TBFWS16 | 3.63715 | 1.44036 | -0.10893 |
| TBFWS17 | 3.63715 | 1.30549 | -0.10893 |
| TBFWS18 | 3.63715 | 1.17057 | -0.10893 |
| TBFWS19 | 3.63715 | 1.03567 | -0.10893 |
| TBFWS20 | 3.63715 | 0.90078 | -0.10893 |
| TBFWS21 | 3.93924 | 1.44036 | -0.07908 |
| TBFWS22 | 3.93924 | 1.30549 | -0.07908 |
| TBFWS23 | 3.93924 | 1.17057 | -0.07908 |
| TBFWS24 | 3.93924 | 1.03567 | -0.07908 |
| TBFWS25 | 3.93924 | 0.90078 | -0.07908 |

Note: All dimensions are model scale in feet

Table 15. Baseline stern appendage pressure tap locations - MODEL No. 5470

Table 15a. Port side

| Tap No. | x | y | z |
|---|---|---|---|
| TBSAP1 | 12.62576 | 0.78932 | 0.00000 |
| TBSAP2 | 12.58471 | 0.70129 | 0.00000 |
| TBSAP3 | 12.54366 | 0.61327 | 0.00000 |
| TBSAP4 | 12.52255 | 0.56799 | 0.00000 |
| TBSAP5 | 12.50435 | 0.52896 | 0.00000 |
| TBSAP6 | 12.60283 | 0.61327 | 0.04672 |
| TBSAP7 | 12.58388 | 0.55745 | 0.04999 |
| TBSAP8 | 12.56691 | 0.50746 | 0.05285 |
| TBSAP9 | 12.69903 | 0.78932 | 0.04552 |
| TBSAP10 | 12.67951 | 0.70129 | 0.05167 |
| TBSAP11 | 12.66000 | 0.61327 | 0.05721 |
| TBSAP12 | 12.64528 | 0.54690 | 0.06112 |
| TBSAP13 | 12.63161 | 0.48522 | 0.06459 |
| TBSAP19 | 12.89628 | 0.78932 | 0.04476 |
| TBSAP20 | 12.89628 | 0.70129 | 0.04595 |
| TBSAP21 | 12.89628 | 0.61327 | 0.04694 |
| TBSAP22 | 12.89628 | 0.50376 | 0.04797 |
| TBSAP23 | 12.89628 | 0.39426 | 0.04884 |
| TBSAP24 | 13.02184 | 0.78932 | 0.02621 |
| TBSAP25 | 13.02184 | 0.70129 | 0.02648 |
| TBSAP26 | 13.02128 | 0.61327 | 0.02672 |
| TBSAP27 | 13.02128 | 0.48229 | 0.02703 |
| TBSAP28 | 13.02128 | 0.35130 | 0.02729 |
| TBSAP29 | 13.14628 | 0.78932 | 0.00000 |
| TBSAP30 | 13.14628 | 0.70129 | 0.00000 |
| TBSAP31 | 13.14628 | 0.61327 | 0.00000 |
| TBSAP32 | 13.14628 | 0.46081 | 0.00000 |
| TBSAP33 | 13.14628 | 0.30834 | 0.00000 |

Note: All dimensions are model scale in feet

Table 15. (Continued)

Table 15b. Starboard side

| Tap No. | x | y | z |
|---|---|---|---|
| TBSAS6 | 12.60283 | 0.61327 | -0.04672 |
| TBSAS7 | 12.58388 | 0.55745 | -0.04999 |
| TBSAS8 | 12.56691 | 0.50746 | -0.05285 |
| TBSAS9 | 12.69903 | 0.78932 | -0.04552 |
| TBSAS10 | 12.67951 | 0.70129 | -0.05167 |
| TBSAS11 | 12.66000 | 0.61327 | -0.05721 |
| TBSAS12 | 12.64528 | 0.54690 | -0.06112 |
| TBSAS13 | 12.63161 | 0.48522 | -0.06459 |
| TBSAS19 | 12.89628 | 0.78932 | -0.04476 |
| TBSAS20 | 12.89628 | 0.70129 | -0.04595 |
| TBSAS21 | 12.89628 | 0.61327 | -0.04694 |
| TBSAS22 | 12.89628 | 0.50376 | -0.04797 |
| TBSAS23 | 12.89628 | 0.39426 | -0.04884 |
| TBSAS24 | 13.02184 | 0.78932 | -0.02621 |
| TBSAS25 | 13.02184 | 0.70129 | -0.02648 |
| TBSAS26 | 13.02128 | 0.61327 | -0.02672 |
| TBSAS27 | 13.02128 | 0.48229 | -0.02703 |
| TBSAS28 | 13.02128 | 0.35130 | -0.02729 |

Note: All dimensions are model scale in feet

same positions as on the wind tunnel model. On the MODEL No. 5470 baseline stern appendage, there are no sur.˙ ·e pressure taps at the location x=12.77128 Ft (3.893 m) whereas there are pressure taps at this location on the MODEL No. 5471 baseline stern appendage. However, for convenience, the tap identification scheme remains the same as on MODEL No.5471. The starboard side pressure taps on these two appendages occur at the same positions as on the port surface. Therefore, figures of the surface pressure taps on the fairwater and baseline stern appendage of MODEL No. 5470 are not given. However, to avoid any confusion, Cartesian offsets are given for each surface pressure tap location on MODEL No. 5470 in Tables 13 through 15 for the axisymmetric hull, the fairwater, and the baseline stern appendage, respectively.

RING WINGS

There are 37 surface pressure taps located on the surface of both Ring Wing 1 and Ring Wing 2 as indicated in Tables 16 and 17, respectively. Taps identified as 'W1Ui' and 'W2Ui' are located on the section profile, both inner and outer wing surface at 19 locations. Pressure taps prefixed 'W1Pi' and 'W2Pi', 'W1Li' and 'W2Li', and 'W1Si' and 'W2Si' are located at 90 degree girthwise increments at six locations along the section profile. The pressure taps are arranged on the wings at a 45 degree angle from the support struts, as shown in Figure 9 for a typical cross section. Table 18 and Figure 17 identify the surface pressure taps on Ring Wing 1 and Table 1 and Figure 18 identify the surface pressure taps on Ring Wing 2.

Table 16. Surface pressure tap identification scheme - Ring Wing 1

| Pressure Tap Identification | Pressure Tap Location | Number of Pressure Taps |
|---|---|---|
| W1Ui | Ring Wing 1, top of submarine, both inner & outer wing surface | 19 |
| W1Pi | Ring Wing 1, port side of submarine, both inner & outer wing surface | 6 |
| W1Li | Ring Wing 1, bottom of submarine, both inner & outer wing surface | 6 |
| W1Si | Ring Wing 1, starboard side of submarine, both inner & outer wing surface | 6 |
| | Total surface pressure taps Ring Wing 1 | 37 |

Table 17. Surface pressure tap identification scheme - Ring Wing 2

| Pressure Tap Identification | Pressure Tap Location | Number of Pressure Taps |
|---|---|---|
| W2Ui | Ring Wing 2, top of submarine, both inner & outer wing surface | 19 |
| W2Pi | Ring Wing 2, port side of submarine, both inner & outer wing surface | 6 |
| W2Li | Ring Wing 2, bottom of submarine, both inner & outer wing surface | 6 |
| W2Si | Ring Wing 2, starboard side of submarine, both inner & outer wing surface | 6 |
| | Total surface pressure taps Ring Wing 2 | 37 |

ACKNOWLEDGMENTS

The authors would like to thank Mr. Gary Jones of DARPA for for his support in this project. We also thank Larry Mulvihill and Ken Ward for their participation in the generation of various components of the geometry.

Table 18. Ring wing 1 pressure tap locations

| Tap No. | x | y | z | x/c |
|---|---|---|---|---|
| W1U1 | 13.46990 | 0.43004 | 0.00000 | 0.0000 |
| W1U2 | 13.49061 | 0.43627 | 0.00000 | 0.0250 |
| W1U3 | 13.50970 | 0.43700 | 0.00000 | 0.0500 |
| W1U4 | 13.54744 | 0.43669 | 0.00000 | 0.1000 |
| W1P4 | 13.54744 | 0.00000 | 0.43669 | 0.1000 |
| W1L4 | 13.54744 | -0.43669 | 0.00000 | 0.1000 |
| W1S4 | 13.54744 | 0.00000 | -0.43669 | 0.1000 |
| W1U5 | 13.62227 | 0.43351 | 0.00000 | 0.2000 |
| W1U6 | 13.77071 | 0.42301 | 0.00000 | 0.4000 |
| W1P6 | 13.77071 | 0.00000 | 0.42301 | 0.4000 |
| W1L6 | 13.77071 | -0.42301 | 0.00000 | 0.4000 |
| W1S6 | 13.77071 | 0.00000 | -0.42301 | 0.4000 |
| W1U7 | 13.91906 | 0.40936 | 0.00000 | 0.6000 |
| W1U8 | 14.06802 | 0.38895 | 0.00000 | 0.8000 |
| W1P8 | 14.06802 | 0.00000 | 0.38895 | 0.8000 |
| W1L8 | 14.06802 | -0.38895 | 0.00000 | 0.8000 |
| W1S8 | 14.06802 | 0.00000 | -0.38895 | 0.8000 |
| W1U9 | 14.14250 | 0.37536 | 0.00000 | 0.9000 |
| W1U10 | 14.17968 | 0.36759 | 0.00000 | 0.9500 |
| W1U11 | 14.17862 | 0.35043 | 0.00000 | 0.9500 |
| W1U12 | 14.14085 | 0.34715 | 0.00000 | 0.9000 |
| W1U13 | 14.06538 | 0.34211 | 0.00000 | 0.8000 |
| W1P13 | 14.06538 | 0.00000 | 0.34211 | 0.8000 |
| W1L13 | 14.06538 | -0.34211 | 0.00000 | 0.8000 |
| W1S13 | 14.06538 | 0.00000 | -0.34211 | 0.8000 |
| W1U14 | 13.91452 | 0.33951 | 0.00000 | 0.6000 |
| W1U15 | 13.76358 | 0.34903 | 0.00000 | 0.4000 |
| W1P15 | 13.76358 | 0.00000 | 0.34903 | 0.4000 |
| W1L15 | 13.76358 | -0.34903 | 0.00000 | 0.4000 |
| W1S15 | 13.76358 | 0.00000 | -0.34903 | 0.4000 |
| W1U16 | 13.61394 | 0.37413 | 0.00000 | 0.2000 |
| W1U17 | 13.54022 | 0.39366 | 0.00000 | 0.1000 |
| W1P17 | 13.54022 | 0.00000 | 0.39366 | 0.1000 |
| W1L17 | 13.54022 | -0.39366 | 0.00000 | 0.1000 |
| W1S17 | 13.54022 | 0.00000 | -0.39366 | 0.1000 |
| W1U18 | 13.50387 | 0.40656 | 0.00000 | 0.0500 |
| W1U19 | 13.48600 | 0.41476 | 0.00000 | 0.0250 |

Note: All dimensions are model scale in feet

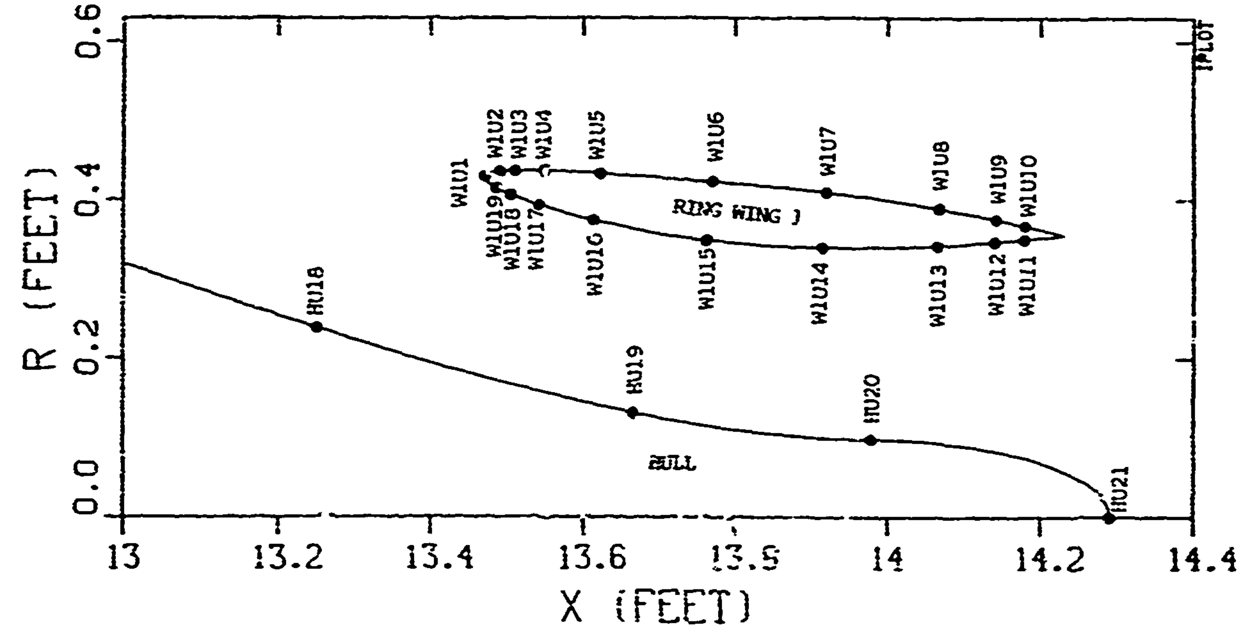



Figure 17. Ring Wing 1 pressure taps

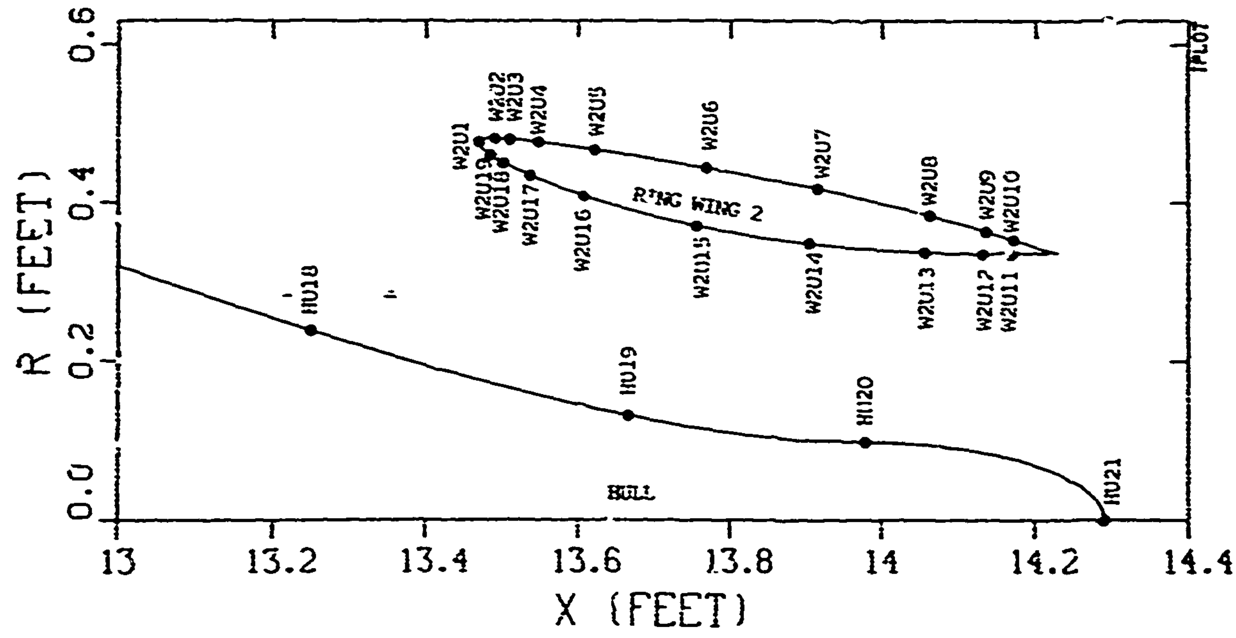



Figure 18. Ring Wing 2 pressure taps

Table 19. Shroud 2 pressure tap locations

| Tap No. | x | y | z | x/c |
|---|---|---|---|---|
| S2U1 | 13.46990 | 0.47681 | 0.00000 | 0.0000 |
| S2U2 | 13.49107 | 0.48121 | 0.00000 | 0.0250 |
| S2U3 | 13.51016 | 0.48028 | 0.00000 | 0.0500 |
| S2U4 | 13.54773 | 0.47667 | 0.00000 | 0.1000 |
| S2P4 | 13.54773 | 0.00000 | 0.47667 | 0.1000 |
| S2L4 | 13.54773 | -0.47667 | 0.00000 | 0.1000 |
| S2S4 | 13.54773 | 0.00000 | -0.47667 | 0.1000 |
| S2U5 | 13.62200 | 0.46698 | 0.00000 | 0.2000 |
| S2U6 | 13.76897 | 0.44359 | 0.00000 | 0.4000 |
| S2P6 | 13.76897 | 0.00000 | 0.44359 | 0.4000 |
| S2L6 | 13.76897 | -0.44359 | 0.00000 | 0.4000 |
| S2S6 | 13.76897 | 0.00000 | -0.44359 | 0.4000 |
| S2U7 | 13.91557 | 0.41706 | 0.00000 | 0.6000 |
| S2U8 | 14.06219 | 0.38375 | 0.00000 | 0.8000 |
| S2P8 | 14.06219 | 0.00000 | 0.38375 | 0.8000 |
| S2L8 | 14.06219 | -0.38375 | 0.00000 | 0.8000 |
| S2S8 | 14.06219 | 0.00000 | -0.38375 | 0.8000 |
| S2U9 | 14.13520 | 0.36372 | 0.00000 | 0.9000 |
| S2U10 | 14.17157 | 0.35274 | 0.00000 | 0.9500 |
| S2U11 | 14.16902 | 0.33574 | 0.00000 | 0.9500 |
| S2U12 | 14.13110 | 0.33576 | 0.00000 | 0.9000 |
| S2U13 | 14.05548 | 0.33731 | 0.00000 | 0.8000 |
| S2P13 | 14.05548 | 0.00000 | 0.33731 | 0.8000 |
| S2L13 | 14.05548 | -0.33731 | 0.00000 | 0.8000 |
| S2S13 | 14.05548 | 0.00000 | -0.33731 | 0.8000 |
| S2U14 | 13.90496 | 0.34787 | 0.00000 | 0.6000 |
| S2U15 | 13.75541 | 0.37052 | 0.00000 | 0.4000 |
| S2P15 | 13.75541 | 0.00000 | 0.37052 | 0.4000 |
| S2L15 | 13.75541 | -0.37052 | 0.00000 | 0.4000 |
| S2S15 | 13.75541 | 0.00000 | -0.37052 | 0.4000 |
| S2U16 | 13.60853 | 0.40855 | 0.00000 | 0.2000 |
| S2U17 | 13.53679 | 0.43444 | 0.00000 | 0.1000 |
| S2P17 | 13.53679 | 0.00000 | 0.43444 | 0.1000 |
| S2L17 | 13.53679 | -0.43444 | 0.00000 | 0.1000 |
| S2S17 | 13.53679 | 0.00000 | -0.43444 | 0.1000 |
| S2U18 | 13.50169 | 0.45046 | 0.00000 | 0.0500 |
| S2U19 | 13.48460 | 0.46018 | 0.00000 | 0.0250 |

Note: All dimensions are model scale in feet

# APPENDIX A

## LISTING OF COMPUTER CODE TO GENERATE AXISYMMETRIC HULL

Appendix A. Listing of computer code to generate axisymmetric hull

```
C
C ****************************************************************
C
C                  D A R P A 2 G E N . F O R
C
C ****************************************************************
C
C          THIS PROGRAM CONTAINS FOLLOWING EQUATIONS FOR
C          GENERATING OFFSETS IN FEET FOR DARPA2 MODEL
C          WITH (FULL/MODEL) SCALE RATIO = 24.
C
C      INCLUDED ARE:
C        BOW EQ.                 FOR        0.0 FT <= X <=  3.333333 FT,
C        PARALLEL MID-BODY EQ.   FOR   3.333333 FT <= X <= 10.645833 FT,
C        AFTERBODY EQ.           FOR  10.645833 FT <= X <= 13.979167 FT,
C        AFTERBODY CAP EQ.       FOR  13.979167 FT <= X <= 14.291667 FT.
C
C   AS SET UP HERE, OFFSETS ARE COMPUTED EVERY 0.1 FT.
C   (EXCEPT IN FIRST 0.5 FT, WHERE THEY ARE EVERY 0.01 FT)
C
C
      DIMENSION X(300), Y(300)
      REAL K0, K1
C
C ********************************
C
C        DEFINE CONSTANTS
C
C ********************************
C
      RMAX = 0.8333333
      XB =  3.333333
      XM = 10.645833
      XA = 13.979167
      XC = 14.291667
      CB1 = 1.126395101
      CB2 = 0.442874707
      CB3 = 1.0/2.1
      RH = 0.1175
      K0 = 10.0
      K1 = 44.6244
C
      XX = -0.01
      DX = 0.01
      DO 1000 I=1,300
      NP = I
      XX = XX + DX
      IF(XX.GE.0.5) DX = 0.1
      IF(XX.GE.XA) DX = 0.01
      IF(XX.GE.XB) GO TO 200
C
C ********************************
C
C         BOW EQUATION
C
C ********************************
C
      A = 0.3*XX - 1.0
      A3 = A**3
      A4 = A**4
```

```
      B = 1.2*XX + 1.0
      R = CB1*XX*A4 + CB2*XX*XX*A3 + 1.0 - A4*B
      R = RMAX*(R**CB3)
      X(I) = XX
      Y(I) = R
      GO TO 1000
C
  200 CONTINUE
      IF(XX.GE.XM) GO TO 400
C
C ******************************
C
C   PARALLEL MID-BODY EQUATION
C
C ******************************
C
      X(I) = XX
      Y(I) = RMAX
      GO TO 1000
C
  400 CONTINUE
      IF(XX.GE.XA) GO TO 600
C
C ******************************
C
C       AFTERBODY EQUATION
C
C ******************************
C
      XI = (13.979167 - XX)/3.333333
      C1 =                RH*RH
      C2 =                            RH*K0                   *XI*XI
      C3 = ( 20.0 - 20.0*RH*RH - 4.0*RH*K0 - 0.333333*K1)*XI**3
      C4 = (-45.0 + 45.0*RH*RH + 6.0*RH*K0 +          K1)*XI**4
      C5 = ( 36.0 - 36.0*RH*RH - 4.0*RH*K0 -          K1)*XI**5
      C6 = (-10.0 + 10.0*RH*RH +     RH*K0 + 0.333333*K1)*XI**6
      R = RMAX*(C1+C2+C3+C4+C5+C6)**0.5
      X(I) = XX
      Y(I) = R
      GO TO 1000
C
  600 CONTINUE
      IF(XX.GE.XC) GO TO 1100
C
C ******************************
C
C     AFTERBODY CAP EQUATION
C
C ******************************
C
      R = 1.0 - (3.2*XX - 44.733333)**2
      R = RH*RMAX*(R**0.5)
      X(I) = XX
      Y(I) = R
 1000 CONTINUE
 1100 CONTINUE
      X(NP) = XC
      Y(NP) = 0.0
C
C ******************************
```

```
C
C     WRITE OFFSETS TO TAPE 6
C     IN IPLOT FORMAT
C
C *******************************
C
      WRITE(6,1)
    1 FORMAT('DARPA2')
      WRITE(6,2)
    2 FORMAT('MODEL WITH (MODEL/FULL) = 24')
      WRITE(6,3) NP
    3 FORMAT(I5)
      WRITE(6,4) (X(I),Y(I),I=1,NP)
    4 FORMAT(2F10.5,3X,2F10.5,3X,2F10.5)
C
C  ALL DONE, PROGRAM ENDS
C
      STOP
      END
```

## APPENDIX B

## LISTING OF COMPUTER CODE TO GENERATE FAIRWATER

## Appendix B. Listing of computer code to generate fairwater

```
C
C  REVISED 11-JANUARY-1989
C
C*****************************************************************
C
C           D A R P A 2 G E N 2 . F O R
C
C*****************************************************************
C
C  THIS PROGRAM CONTAINS FOLLOWING EQUATIONS FOR
C  GENERATING OFFSETS IN FEET FOR THE SAIL OF
C  THE DARPA2 MODEL WITH (FULL/MODEL) SCALE
C  RATIO = 24.
C
C  INCLUDED ARE:
C  SAIL FOREBODY EQ.   FOR    3.032986 FT <= X <= 3.358507 FT
C                             0.833333 FT <= Z <= 1.507813 FT
C  SAIL MID-BODY EQ.   FOR    3.358507 FT <= X <= 3.559028 FT
C                             0.833333 FT <= Z <= 1.507813 FT
C  SAIL AFTERBODY EQ.  FOR    3.559028 FT <= X <= 4.241319 FT
C                             0.833333 FT <= Z <= 1.507813 FT
C  SAIL CAP EQ.        FOR    3.032986 FT <= X <= 4.241319 FT
C                             1.507813 FT <= Z <= 1.562501 FT
C
C  OFFSETS ARE COMPUTED EVERY .005 FT.
C
C
   DIMENSION
    .         NP(300),
    .         X(300,50,3)
C
C********************************
C
C  DEFINE CONSTANTS
C
C********************************
C
   A1     = 2.094759
   B1     = 0.207178
   A3     = 2.908891
   B3     = 1.234491
   C3     = 3.444817
   D3     = 3.850435
   E3     = 2.080019
   HMAX   = 0.109375
   DX     = 0.005
   DXO    = 0.005
   XXCST  = 3.032986
   XXAFN  = 4.241319
   XXFFN  = 3.358507
   XXMFN  = 3.559028
   XZST   = 1.507813
C
C********************************
C
C  CALCULATE
C
C********************************
C
           XX=XXCST-DX
   DO 1000 I = 1,300
   XZ=XZST
   X(I,1,3)=XZ
```

```
      J=1
      XX=XX+DX
      X(I,1,1)=XX
      IF (XX .GT. XXAFN) THEN
               NI=I-1
               GOTO 1014
      ENDIF
      IF (XX .GT. XXFFN) GOTO 1002
C
C********************************
C
C   SAIL FOREBODY EQUATION
C
C********************************
C
      D=3.072000*(XX-3.032986)
      DM1=D-1
      A=2*D*(DM1**4)
      B=D*D*(DM1**3)/3
      C=1-((DM1**4)*(4*D+1))
      X(I,1,2)=HMAX*(SQRT(A1*A+B1*B+C))
      GOTO 1004
C
C********************************
C
C   SAIL MID-BODY EQUATION
C
C********************************
C
 1002          CONTINUE
      IF (XX .GT. XXMFN) GOTO 1003
      X(I,1,2)=HMAX
      GOTO 1004
C
C********************************
C
C   SAIL AFTER BODY EQUATION
C
C********************************
C
 1003          CONTINUE
      E=(4.241319-XX)/.6822917
      F=E-1
      G=2.238361*E*F**4
      H=3.106529*(E**2)*(F**3)
      P=1-(F**4)*(4*E+1)
      X(I,1,2)=.1093750*(G+H+P)
C
C********************************
C
C   SAIL CAP EQUATION
C
C********************************
C
 1004          CONTINUE
      XZEND=(X(I,1,2)/2)+1.507813
      NP(I)=1
      DO 1008 J=2,50
      ICON1=0
 1005          XZ=XZ+DX
      X(I,J,3)=XZ
      IF (XZ .GT. XZEND) THEN
               ICON1=ICON1+1
```

```
            IF (ICON1 .EQ. 1) THEN
                             XZ=XZ-DX
                    DX=.0005
                    GOTO 1005
            ENDIF
            IF (ICON1 .EQ. 2) THEN
                    X(I,J,2)=0.0
                    X(I,J,3)=XZEND
                    NP(I)=J
                    ICON1=0
                    DX=DX0
                    GOTO 1000
            ENDIF
      ENDIF
      ADUM=(X(I,1,2)**2)-((2*(XZ-XZST))**2)
      X(I,J,2)=SQRT(ADUM)
 1008       CONTINUE
 1000       CONTINUE
C
C*******************************
C
C  WRITE OFFSETS TO TAPE6
C    IN IPLOT FORMAT
C
C*******************************
C
 1014       OPEN(6,STATUS='NEW',FORM='FORMATTED',FILE='TP6')
      WRITE(6,1015)
 1015       FORMAT('DARPA2 SAIL')
      WRITE(6,1016)
 1016       FORMAT('MODEL WITH (MODEL/FULL) = 24')
      WRITE(6,1017)NI
 1017       FORMAT(I5)
      WRITE(6,1018) (X(I,1,1),X(I,1,2),I=1,NI)
 1018       FORMAT(2F10.5,3X,2F10.5,3X,2F10.5)
      DO 1013 I=1,NI,8
      WRITE(6,1009)I
 1009       FORMAT(I3)
      WRITE(6,1010)X(I,1,1)
 1010       FORMAT(' X=' ,F7.3,' FEET')
      WRITE(6,1011) (NP(I)+1)
 1011       FORMAT(I5)
      WRITE(6,1012) X(I,1,2),1.5
      WRITE(6,1012) (X(I,J,2),X(I,J,3),J=1,NP(I))
 1012       FORMAT(2F10.5,3X,2F10.5,3X,2F10.5)
 1013       CONTINUE
  666       STOP
      END
```

# APPENDIX C

# LISTING OF COMPUTER CODE TO GENERATE STERN APPENDAGES

Appendix C. Listing of computer code to generate stern appendages

```
C
C ********************************************************************
C
C           D A R P A 2 S T E R N A P P . F O R
C
C ********************************************************************
C
C
C        THIS PROGRAM DEFINES THREE-DIMENSIONAL (X, Y, Z)
C        OFFSETS FOR DARPA2 STERN APPENDAGES WITH TRAILING
C        EDGE LOCATED AT THREE DIFFERENT VALUES OF AXIAL
C        LENGTH X.  FOR EACH AXIAL POSITION, FOUR IDENTICAL
C        STERN APPENDAGES ARE MOUNTED ON THE AXISYMMETRIC
C        HULL SURFACE AT TOP-DEAD-CENTER, 90 DEG, 180 DEG,
C        AND 270 DEG AZIMUTHALLY.
C
C
C     (X, RR, Z) = CARTESIAN COORDINATES IN FEET
C
C     H          = X COORDINATE OF STERN APPENDAGE TRAILING EDGE.
C                    H(1) = 12.729617
C                    H(2) = 13.146284 = BASELINE
C                    H(3) = 13.562950
C
C     CY         = CHORD LENGTH = -0.466338*RR + 0.88859
C
      DIMENSION XXI(19), H(3)
C
      PARAMETER RH = 0.1175, AK0 = 10.0, AK1 = 44.6244
      PARAMETER NP = 19, RMAX = 0.833333
C
      DATA XXI/0.0,    0.005, 0.0125, 0.025, 0.050, 0.075, 0.100,
     1          0.150, 0.200, 0.2500, 0.300, 0.400, 0.500, 0.600,
     2          0.700, 0.800, 0.9000, 0.950, 1.000/
C
      DATA H/12.729617, 13.146284, 13.562950/
C
C ********************************************
C
C     LOOP ON THE LOCATION OF STERN
C       APPENDAGE TRAILING EDGE
C
C ********************************************
C
      DO 900 K=1,3
      HH = H(K)
      WRITE(6,1) HH
    1 FORMAT(//2X,'STERN APPENDAGE TRAILING EDGE LOCATED AT X ='
     1          F10.5)
      DX = 0.05
      X = HH + DX
C
C ********************************************
C
C       LOOP ON THE AXIAL POSITION X.
C     BEGIN AT STERN APPENDAGE TRAILING
C        EDGE AND MOVE FORWARD IN X.
C
C ********************************************
C
```

```
      DO 800 J = 1,32
      X = X - DX
      IF(X.GT.RH) GO TO 800
C
C ********************************************
C
C     DEFINE HULL RADIUS AT VALUE OF X
C
C ********************************************
C
      XIB = (13.979167 - X)/3.333333
      A =            RH*RH +      RH*AK0                  *XIB*XIB
      B = ( 20.0 - 20.0*RH*RH - 4.0*RH*AK0 - 0.333333*AK1)*XIB**3
      C = (-45.0 + 45.0*RH*RH + 6.0*RH*AK0 +          AK1)*XIB**4
      D = ( 36.0 - 36.0*RH*RH - 4.0*RH*AK0 -          AK1)*XIB**5
      E = (-10.0 + 10.0*RH*RH +      RH*AK0 + 0.333333*AK1)*XIB**6
      RHA = A + B + C + D + E
      RHA = RMAX*SQRT(RHA)
      RHAS = RHA*RHA
      RR = 0.075
      DELR = 0.025
      ITR = 0
C
C ********************************************
C
C              LOOP ON RADIUS.
C            BEGIN WITH R = 0.1
C
C ********************************************
C
      DO 700 I=1,31
      RR = RR + DELR
  620 CONTINUE
      CY = -0.466308*RR + 0.88859
      XI = (X-RH)/CY + 1.0
      IF(XI.LT.0.0 .OR. XI.GT.1.0) GO TO 700
C
C ********************************************
C
C  DEFINE STERN APPENDAGE
C
C ********************************************
      Z = 0.29690*SQRT(XI) - 0.12600*XI - 0.35160*XI*XI
     1    + 0.28520*XI**3 - 0.10450*XI**4
      Z = CY * Z
      SRS = RR*RR + Z*Z
C
C ********************************************
C
C         IF STERN APPENDAGE LOCATED
C          INSIDE BODY, INCREASE R
C
C ********************************************
C
      IF(SRS.LT.RHAS. AND. ITR.EQ.0) GO TO 700
C
C ********************************************
C
C          IF STERN APPENDAGE LOCATED
C              ON BODY SURFACE,
```

```
C           GO TO 710 TO DEFINE
C          STERN APPENDAGE SECTION.
C
C ******************************************
C
      IF(ABS(SRS-RHAS).LE.0.00001) GO TO 710
C
C ******************************************
C
C         STERN APPENDAGE IS "CLOSE"
C         TO HULL RADIUS, GET CLOSER.
C
C ******************************************
C
      ITR = ITR + 1
      IF(ITR.GT.20) STOP1
      DELR = 0.5*DELR
      IF(SRS.GT.RHAS) RR = RR - DELR
      IF(SRS.LE.RHAS) RR = RR + DELR
      GO TO 620
  700 CONTINUE
      GO TO 800
  710 CONTINUE
C
C ******************************************
C
C     SOLVE FOR STERN APPENDAGE SECTION
C             AT GIVEN RADIUS
C
C ******************************************
C
      CY = -0.466308*RP + 0.68859
      I750 = 0
      XINIT = (X-HH)/CY + 1.0
C
C ******************************************
C
C                LOOP ON XI
C
C ******************************************
C
      DO 750 I=1,NP
      XI = XXI(I)
      IF(XI.LT.XINIT) GO TO 750
  740 CONTINUE
      XI = XXI(I)
      IF(I750.EQ.0) XI = XINIT
      XXX = (XI-1.0)*CY + HH
      IF(XI.LT.0.0 .OR. XI.GT.1.0) GO TO 750
      Z = 0.29690*SQRT(XI) - 0.12600*XI - 0.35160*XI*XI
     1    + 0.28520*XI**3 - 0.10450*XI**4
      Z = CY * Z
C
C ******************************************
C
C         PRINT X, Y, (+/-)Z VALUES
C            TO PRINTER FILE 6
C
C ******************************************
C
```

```
      IF(I750.EQ.0) WRITE(6,2)
    2 FORMAT(/6X,1HX,9X,1HY,6X,6H(+/-)Z)
      WRITE(6,3) XXX, RR, Z
    3 FORMAT(3F10.5)
      I750 = I750 + 1
      RBSMAX = RR
      IF(I750.EQ.1) GO TO 740
  750 CONTINUE
  800 CONTINUE
C
C ********************************************
C
C     COMPUTED ALL STERN APPENDAGE SECTIONS
C           WHICH INTERSECT HULL.
C         NOW COMPUTE STERN SECTIONS
C     WITH RADIUS LARGER THAN HULL RADIUS.
C
C ********************************************
C
      DELR = 0.05
      DO 850 I=1,NP
      RO = RR
      RR = RBSMAX + I*DELR
      IF(RR.GT.RMAX) RR = RMAX
      IF(RR.EQ.RO) GO TO 900
      CY = -0.466308*RR + 0.88859
      WRITE(6,2)
      DO 840 J=1,NP
      XI = XXI(J)
      XXX = (XI-1.0)*CY+HH
      Z = 0.23690*SQRT(XI) - 0.12600*XI - 0.35160*XI*XI
     1    + 0.28520*XI**3 - 0.10450*XI**4
      Z = CY * Z
C
C ********************************************
C
C         PRINT X, Y, (+/-)Z VALUES
C            TO PRINTER FILE 6
C
C ********************************************
C
      WRITE(6,3) XXX, RR, Z
  840 CONTINUE
  850 CONTINUE
  900 CONTINUE
      STOP
      END
```

# APPENDIX D

# LISTING OF COMPUTER CODE TO GENERATE RING WINGS

Appendix D. Listing of computer code to generate ring wings

```
C
C ******************************************************************
C
C      P R O G R A M      D A R P A 2 W I N G S
C
C ******************************************************************
C
C    THIS PROGRAM DEFINES THE DARPA2 RING WINGS
C
C    THE DARPA2 WINGS USE THE NACA66 (DTNSRDC MOD)
C              THICKNESS DISTRIBUTION
C                     AND
C              THE NACA A=0.4 MEANLINE
C
      DIMENSION XC(26), YC(26), YCP(26)
      DIMENSION B(17), YT(26)
      DIMENSION XU(26), YU(26), XL(26), YL(26)
      DIMENSION XDLE(2), YDLE(2), XDTE(2), YDTE(2)
C
C  XC ARRAY ARE THE X/C VALUES CURRENTLY USED TO DEFINE WING.
C
      DATA XC/0.0, 0.005, 0.0075, 0.0125, 0.025, 0.05, 0.075, 0.10,
     1        0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55,
     2        0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.0/
C
C  B ARRAY CONTAINS COEFFICIENTS FOR CALCULATION OF THICKNESS DISTR.
C
      DATA B/0.43756, -0.08136, -0.06496, -0.01926, -0.00185,
     1       0.00348,  0.00156, -0.00113, -0.00058,  0.00027,
     2       0.00080,  0.00006, -0.00027, -0.00033,  0.00005,
     3       0.00014,  0.00008/
C
C  XDLE, YDLE ARE LEADING EDGE X, R OF WING
C  XDTE, YDTE ARE TRAILING EDGE X, R OF WING
C
      DATA XDLE/13.46990, 13.46990/
      DATA YDLE/0.43004, 0.47681/
      DATA XDTE/14.21661,14.2074/
      DATA YDTE/0.35659- 0.33856/
C
C  THE ENTIRE PROGRAM IS EXERCISED TWO TIMES.
C    THE FIRST TIME, WING 1 IS DEFINED.
C       WING 1 HAS LEADING EDGE AT (X=13.46990, Y=0.43004)
C              AND TRAILING EDGE AT (X=14.23, Y=0.3558)
C    THE SECOND TIME, WING 2 IS DEFINED.
C       WING 2 HAS LEADING EDGE AT (X=13.46990, Y=0.3558)
C              AND TRAILING EDGE AT (X=14.23, Y=0.33628)
C
      NXC = 26
      DO 1000 KK = 1,2
      WRITE(6,2)
C
C  *******************
C
C   DEFINE MEAN LINE
C
```

```
C  ******************
C
      DO 100 I=1,NXC
      X = XC(I)
      D = 0.4 - X
      E = 1.0 - X
      IF(ABS(X-0.0).LE.1.0E-20) X = 1.0E-30
      IF(ABS(D).LE.1.0E-20) D = 1.0E-30
      IF(ABS(E).LE.1.0E-20) E = 1.0E-30
      YC(I) = -0.049921*(0.5*D*D*ALOG(ABS(D)) - 0.5*E*E*ALOG(E)
     1              + 0.25*E*E - 0.25*D*D)
      YC(I) = YC(I) +0.029953*(X*ALOG(X) + 0.227828 - 0.531076*X)
C
      YCP(I) =  -0.049921*(E*ALOG(E) - D*ALOG(ABS(D)))
     1           + 0.02995253*(ALOG(X) + 0.4689244)
C        WRITE(6,1) I, 100.*XC(I), 100.*YC(I), YCP(I)
    1   FORMAT(I5,2F10.3,F10.5)
  100 CONTINUE
C      WRITE(6,2)
    2 FORMAT(//)
C
C  ********************************
C
C    DEFINE THICKNESS DISTRIBUTION
C
C  ********************************
C
      NSER = 17
      DO 200 I=1,NXC
        X = XC(I)
        IF(I.GE.16) GO TO 150
        OM = ACOS(2.0*X-1.0)
        YY = 0.0
        DO 125 J=1,NSER
           YY = YY + B(J)*SIN(J*OM)
  125   CONTINUE
        YT(I) = YY
        GO TO 199
  150   CONTINUE
        XC1 = 1.0-XC(I)
        YT(I) =  0.033333 + 1.696969*XC1 - 1.441945*XC1*XC1
     1            -0.366363*XC1**3 + 0.333049*XC1**4
  199   CONTINUE
        YT(I) = 0.1*YT(I)
C        WRITE(6,3) I,X,YT(I)
    3   FORMAT(I5,F10.3,F10.5)
  200 CONTINUE
C      WRITE(6,2)
C
C *************************
C
C    DEFINE DARPA2 WING
C
C *************************
C
      XLINIT = 0.9425
      YLINIT = 0.0258
      CHORD = 0.0525
      XU(1) = 0.0
      YU(1) = 0.0
      XL(1) = 0.0
      YL(1) = 0.0
      I = 1
```

```
C      WRITE(6,6)
    6 FORMAT(2X,1HI,3X,4H XU ,5X,4H YU ,5X,4H XL ,5X,4H YL ,6X,3HX/C,
     1        7X,2HYT,7X,2HYC,4X,7HDYC/DXC/)
    5 FORMAT(I3, 4F9.5, F9.4,4F9.5)
C        WRITE(6,5) I,XU(I),YU(I),XL(I),YL(I),XC(I),YT(I),YC(I),YCP(I)
      DO 300 I=2,NXC
        TH = ATAN(YCP(I))
        SINTH = SIN(TH)
        COSTH = COS(TH)
        XU(I) = XC(I) - YT(I)*SINTH
        YU(I) = YC(I) + YT(I)*COSTH
        XL(I) = XC(I) + YT(I)*SINTH
        YL(I) = YC(I) - YT(I)*COSTH
C        WRITE(6,5) I,XU(I),YU(I),XL(I),YL(I),XC(I),YT(I),YC(I),YCP(I)
  300 CONTINUE
C
C ***********************************
C
C  DEFINE PHYSICAL WING DIMENSIONS
C
C ***********************************
C
      PHI = ATAN2((YDTE(KK)-YDLE(KK)),(XDTE(KK)-XDLE(KK)))
      CS = COS(PHI)
      SN = SIN(PHI)
      CHORD = SQRT((YDTE(KK)-YDLE(KK))**2 + (XDTE(KK)-XDLE(KK))**2)
C      WRITE(6,444) XDLE(KK),YDLE(KK), XDTE(KK),YDTE(KK)
  444 FORMAT(2X,'(XDLE,YDLE) = ',F10.5/2X,'(XDTE,YDTE) = ',F10.5)
      WRITE(6,6)
      DO 400 I=1,NXC
      XUU = XU(I)
      XU(I) = XDLE(KK) + CHORD*(XU(I)*CS - YU(I)*SN)
      YU(I) = YDLE(KK) + CHORD*(XUU*SN + YU(I)*CS)
      XLL = XL(I)
      XL(I) = XDLE(KK) + CHORD*(XL(I)*CS - YL(I)*SN)
      YL(I) = YDLE(KK) + CHORD*(XLL*SN + YL(I)*CS)
        WRITE(6,5) I,XU(I),YU(I),XL(I),YL(I),XC(I),YT(I),YC(I),YCP(I)
    4   FORMAT(I5,4F10.5)
  400 CONTINUE
C
C ********************************************
C
C   WRITE WING OFFSETS TO FILE 7 FOR IPLOT
C
C ********************************************
C
      IF(KK.EQ.1) WRITE(7.10)
   10 FORMAT('S1')
      IF(KK.EQ.2) WRITE(7,11)
   11 FORMAT('S2')
      IF(KK.EQ.1) WRITE(7,12)
   12 FORMAT('DARPA2 RING WING 1 ')
      IF(KK.EQ.2) WRITE(7,15)
   15 FORMAT('DARPA2 RING WING 2 ')
      NXC2 = 2*NXC
      WRITE(7,13) NXC2
   13 FORMAT(I5)
      DO 500 I=1,NXC2
        IF(I.GT.NXC) GO TO 450
        WRITE(7,14) XU(I),YU(I)
        GO TO 500
  450   CONTINUE
        J = NXC2-I+1
```

```
      GO TO 500
 450  CONTINUE
      J = NXC2-I+1
      WRITE(7,14) XL(J),YL(J)
 500 CONTINUE
  14 FORMAT(2F10.5)
C
C ********************************
C
C  PRINT OFFSETS IN AMI FORMAT
C        ONTO FILE 9.
C
C ********************************
C
     DO 600 I=1,NXC2
     IF(I.GT.NXC) GO TO 550
     J = NXC-I+1
     WRITE(9,14) XL(J), YL(J)
     GO TO 600
 550 CONTINUE
     K = I-NXC
     WRITE(9,14) XU(K), YU(K)
 600 CONTINUE
1000 CONTINUE
     STOP
     END
```

# APPENDIX E

# LISTING OF COMPUTER CODE TO GENERATE RING WING STRUTS

Appendix E. Listing of computer code to generate ring wing struts

```
C
C *********************************************
C
C     P R O G R A M     D A R P A 2 S T R U T
C
C *********************************************
C
C
C    THIS PROGRAM DEFINES THE STRUT WHICH ATTACHES THE
C     DARPA2 AXISYMMETRIC HULL TO THE DARPA2 RING WINGS.
C     THE SAME BASIC STRUT IS USED TO ATTACH BOTH
C     RING WING 1 AND RING WING 2.  THE UPPER PORTION OF
C     THE STRUT MUST BE MODIFIED TO FIT EACH WING.
C
C    THIS PROGRAM DEFINES A SINGLE STRUT WHICH WOULD
C     ATTACH TO THE DARPA2 AXISYMMETRIC HULL ALONG
C     THE UPPER SURFACE (I.E., THE SURFACE WITH THE
C     FAIRWATER).  FOUR IDENTICAL AXIMUTHALLY EQUALLY-
C     SPACED STRUTS WILL ATTACH THE RING WING AND THE HULL
C     AT A 45 DEGREE INCREMENT FROM THE SURFACE PRESSURE
C     TAP LOCATIONS.  THE STRUTS WILL BE PLACED
C     AT 90 DEGREE INCREMENTS.
C
C    THE BASIC STRUT SHAPE IS A NACA 0012 THICKNESS
C     DISTRIBUTION MODIFIED TO END AT A POINT.
C     THE CHORD LENGTH IS 0.25 FEET.
C
C   STRUT LEADING EDGE ATTACHES TO:
C        HULL         AT X=13.589,    R=0.14726
C        RING WING 1 AT X=13.63845, R=0.36886    (X/C=0.233)
C        RING WING 2 AT X=13.64487, R = 0.39755  (X/C=0.25)
C
C   STRUT TRAILING EDGE ATTACHES TO:
C        HULL         AT X=13.83582, R=0.10547
C        RING WING 1 AT X=13.88818, R=0.34002    (X/C=0.5651)
C        RING WING 2 AT X=13.89023, R=0.34932    (X/C=0.5804)
C
      DIMENSION XC(19), XUL(19), YUL(19), ZU(19), ZL(19)
C
      DATA XC/0., 0.005, 0.0125, 0.025, 0.05, 0.075, 0.1, 0.15,
     1        0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95, 1.0/
C
      NP = 19
      NR = 10
C
C   R1 = LE RADIUS OF STRUT AT HULL ATTACHMENT          = 0.14726
C   R2 = LE RADIUS OF STRUT AT RING WING 2 ATTACHMENT = 0.39755
C
      R1 = 0.14726
      R2 = 0.39755
      DELR = (R2-R1)/(NR-1)
      R = R1 - DELR
C
```

```
    2 FORMAT(/8X,'STRUT OFFSETS (IN FEET) AT RADIUS = ',F10.5/
     1    3X,'X PORT '3X,'Y PORT ',3X,'Z PORT ',5X,'X STBD ',3X,
     2    'Y STBD ',3X,'Z STBD '/)
      X0 = 0.223221*R + 13.556128
C
C  100 LOOP OVER STRUT CHORD
C
      DO 100 I=1,NP
      XI = XC(I)
      XUL(I) = X0 + 0.243995*XI
      YUL(I) = R  - 0.054465*XI
      ZT = 0.15*(0.29690*SQRT(XI) - 0.12600*XI - 0.35160*XI*XI
     1            + 0.28520*XI**3 - 0.10450*XI**4)
      ZU(I) = ZT
      ZL(I) = -ZT
      WRITE(6,3) XUL(I),YUL(I),ZU(I),XUL(I),YUL(I),ZL(I)
    3 FORMAT(3F10.5,2X,3F10.5)
  100 CONTINUE
  200 CONTINUE
      STOP
      END
```