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DTRC/SHD-1298-01 GEOMETRIC CHARACTERISTICS OF DARPA SUBOFF MODELS (DTRC MODEL NOS. 5470 and 5471)

David Taylor Research Center

Bethesda, MD 20084-5000

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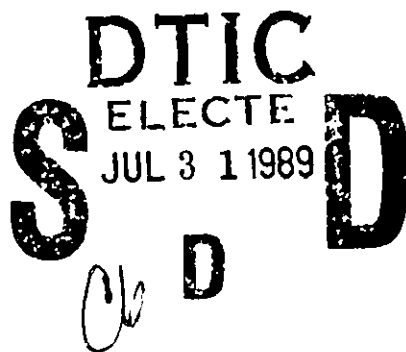
GEOMETRIC CHARACTERISTICS OF DARPA SUBOFF MODELS
(DTRC MODEL NOS. 5470 and 5471)

by

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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.

For more information, contact the author at the address given below.
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.

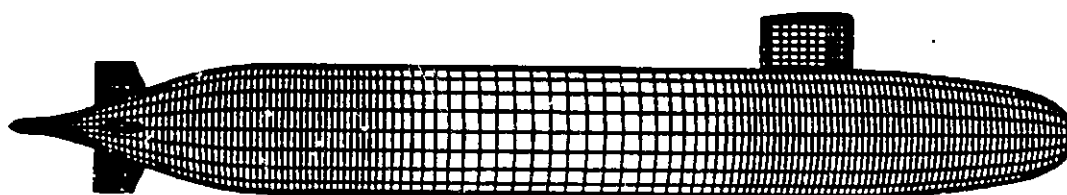


Figure 1. Sample grid representation of
MODEL Nos. 5470 and 5471

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)
 λ = (FULL/MODEL) SCALE RATIO = 24

BOW EQUATION

For $0 \text{ Ft} \leq x \leq 3.333333 \text{ Ft}$

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

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

PARALLEL MIDDLE BODY EQUATION

For $3.333333 \text{ Ft} \leq x \leq 10.645833 \text{ Ft}$

$$R = R_{\text{MAX}}$$

AFTERBODY EQUATION

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

For $10.645833 \text{ Ft} \leq x \leq 13.979167 \text{ Ft}$

$$R = R_{\text{MAX}} \left\{ r_h^2 + r_h K_o \xi^2 + (20 - 20r_h^2 - 4r_h K_o - \frac{1}{3} K_1) \xi^3 \right. \\
+ (-45 + 45r_h^2 + 6r_h K_o + K_1) \xi^4 + (36 - 36r_h^2 - 4r_h K_o - K_1) \xi^5 \\
\left. + (-10 + 10r_h^2 + r_h K_o + \frac{1}{3} K_1) \xi^6 \right\}^{1/2}$$

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

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

AFTERBODY CAP

For $13.979167 \text{ Ft} \leq x \leq 14.291667 \text{ Ft}$

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

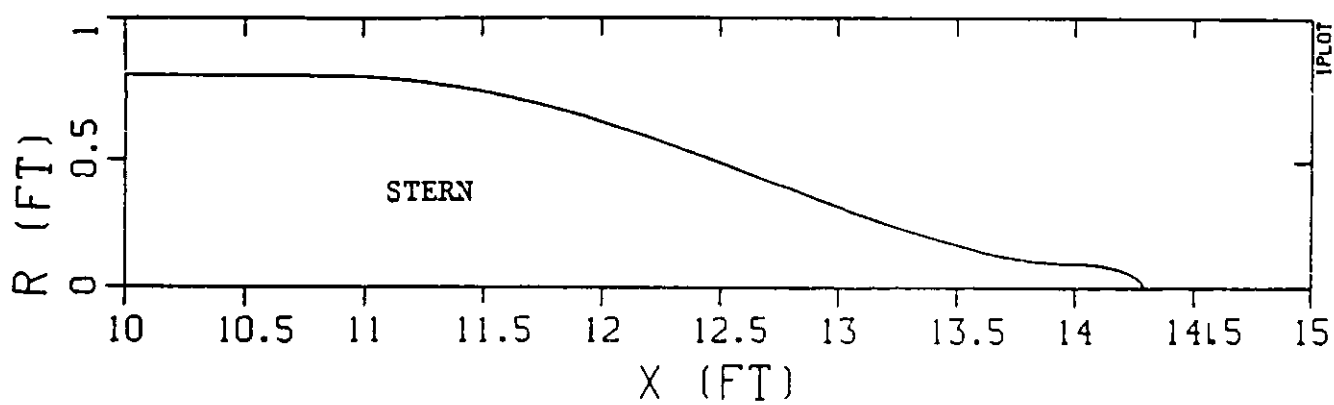
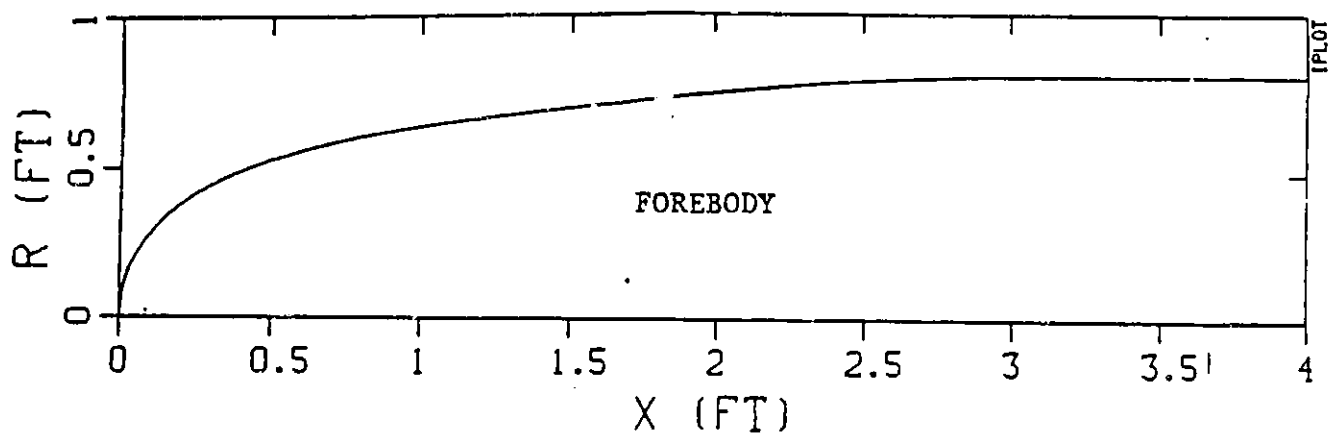
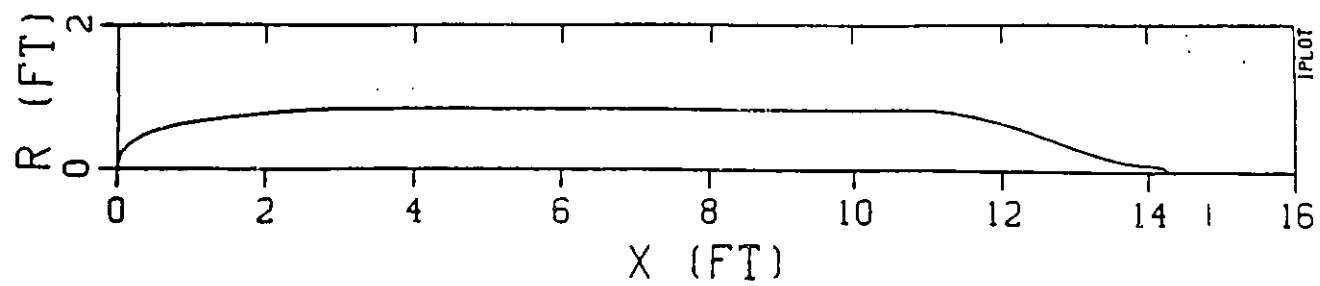


Figure 2. Hull profile

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.

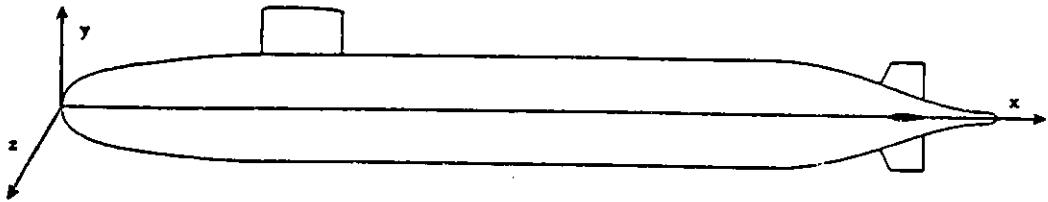
FAIRWATER

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

$y \leq 1.507813 \text{ Ft}$

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

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

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

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

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

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

$y \leq 1.507813 \text{ Ft}$

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

$E = (4.241319-x)/0.6822917$

SAIL CAP EQUATION

The sail is closed at top with an ellipsoid defined as

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

$1.507813 \text{ Ft} \leq y \leq (z_1/2) + 1.507813 \text{ Ft}$

$z_2 = [z_1^2 - (2(y-1.507813))^2]^{1/2}$

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)

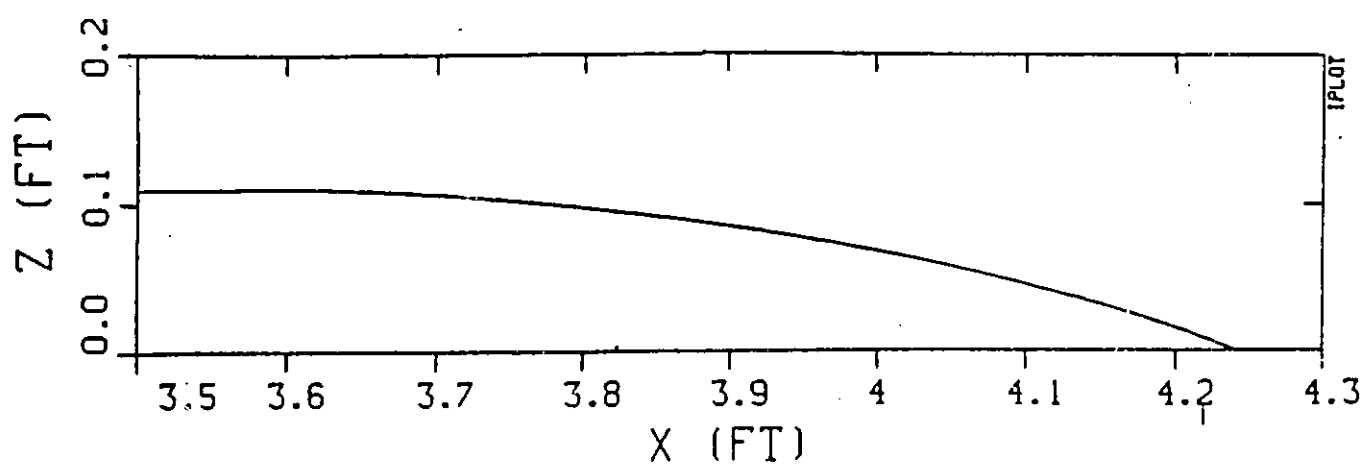
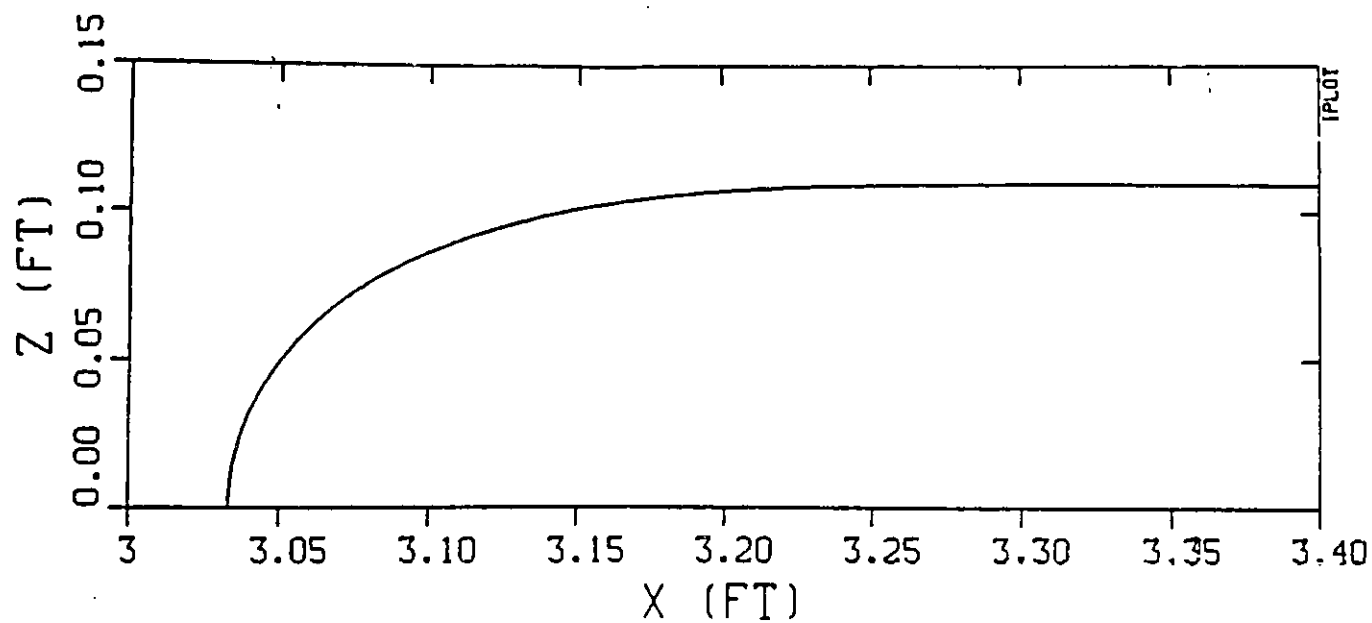
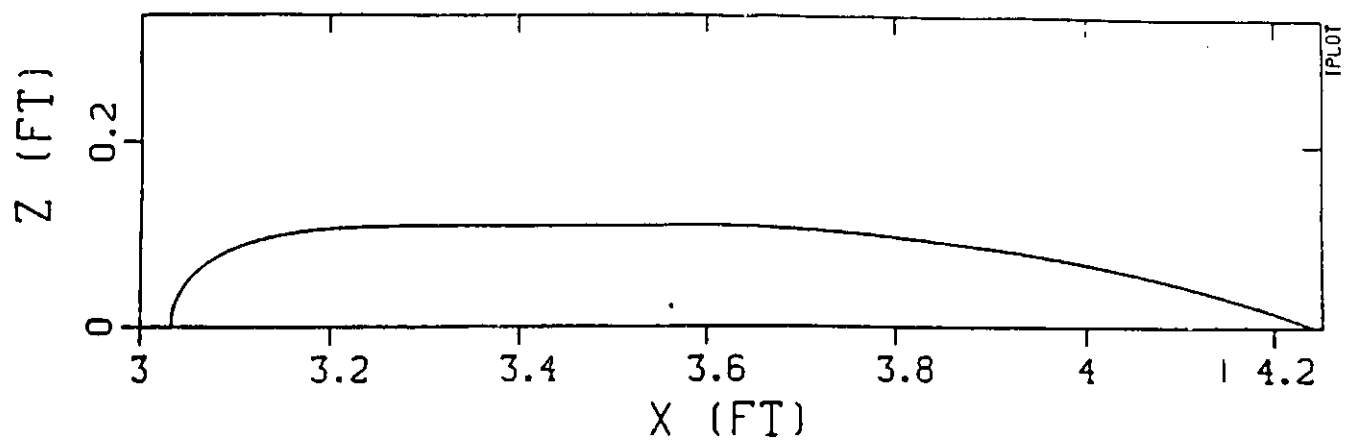


Figure 3. Fairwater section profile

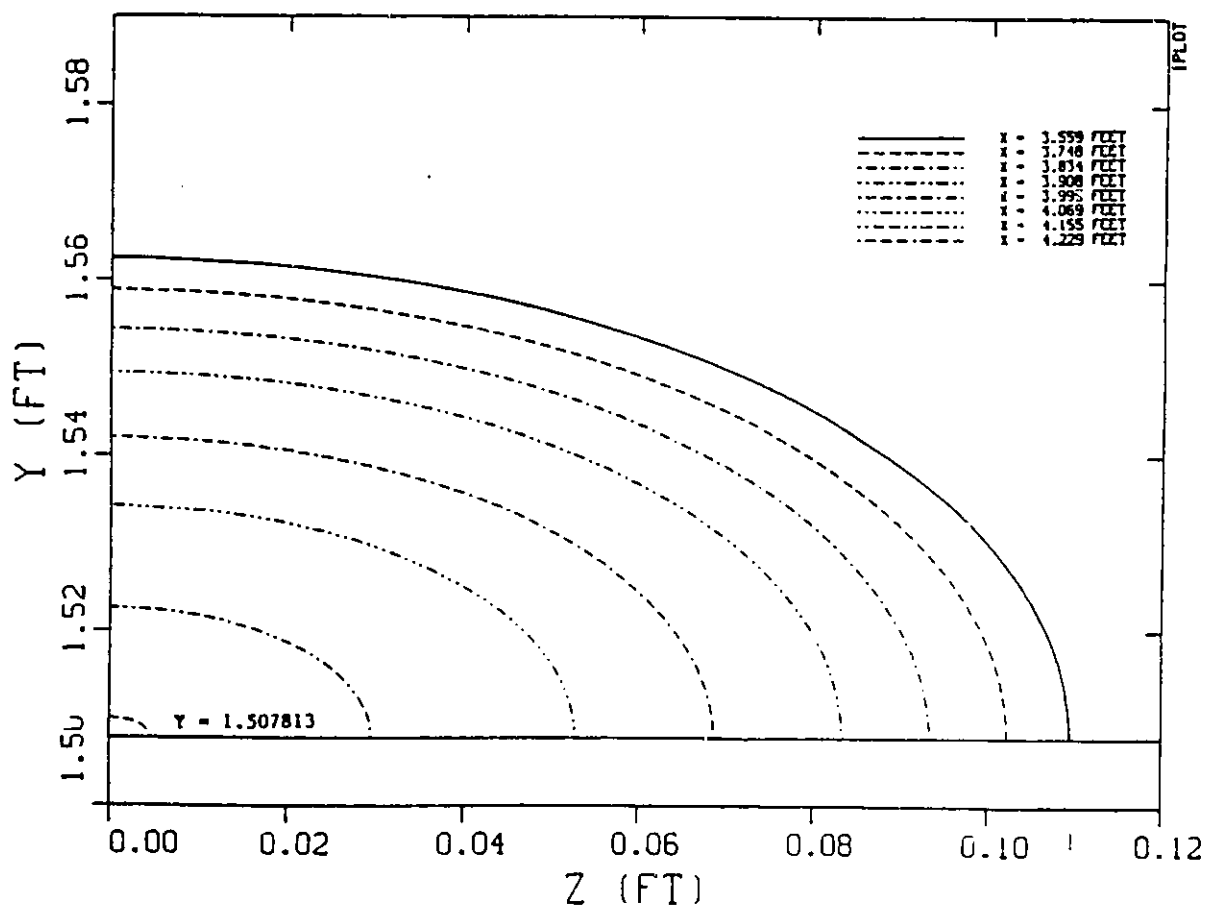
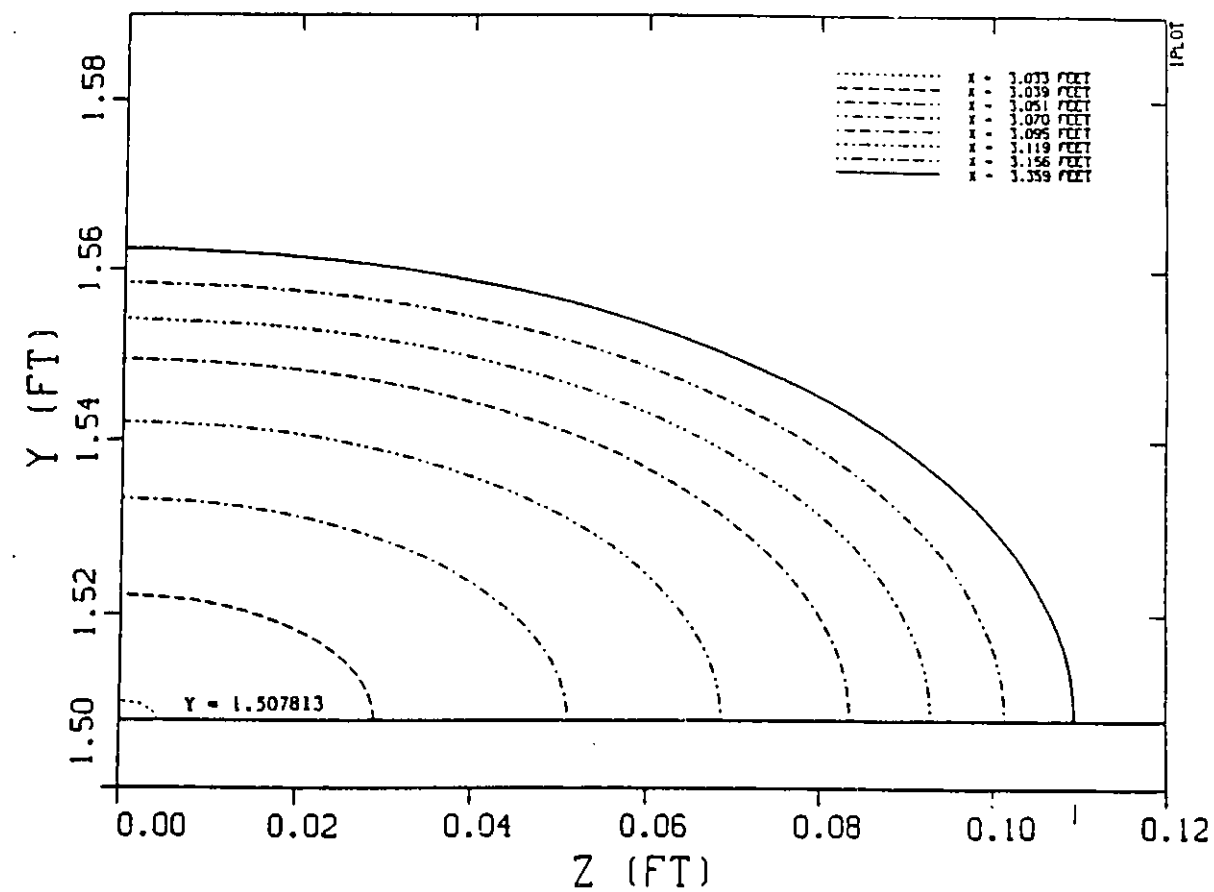


Figure 4. Cross sectional shape of fairwater cap

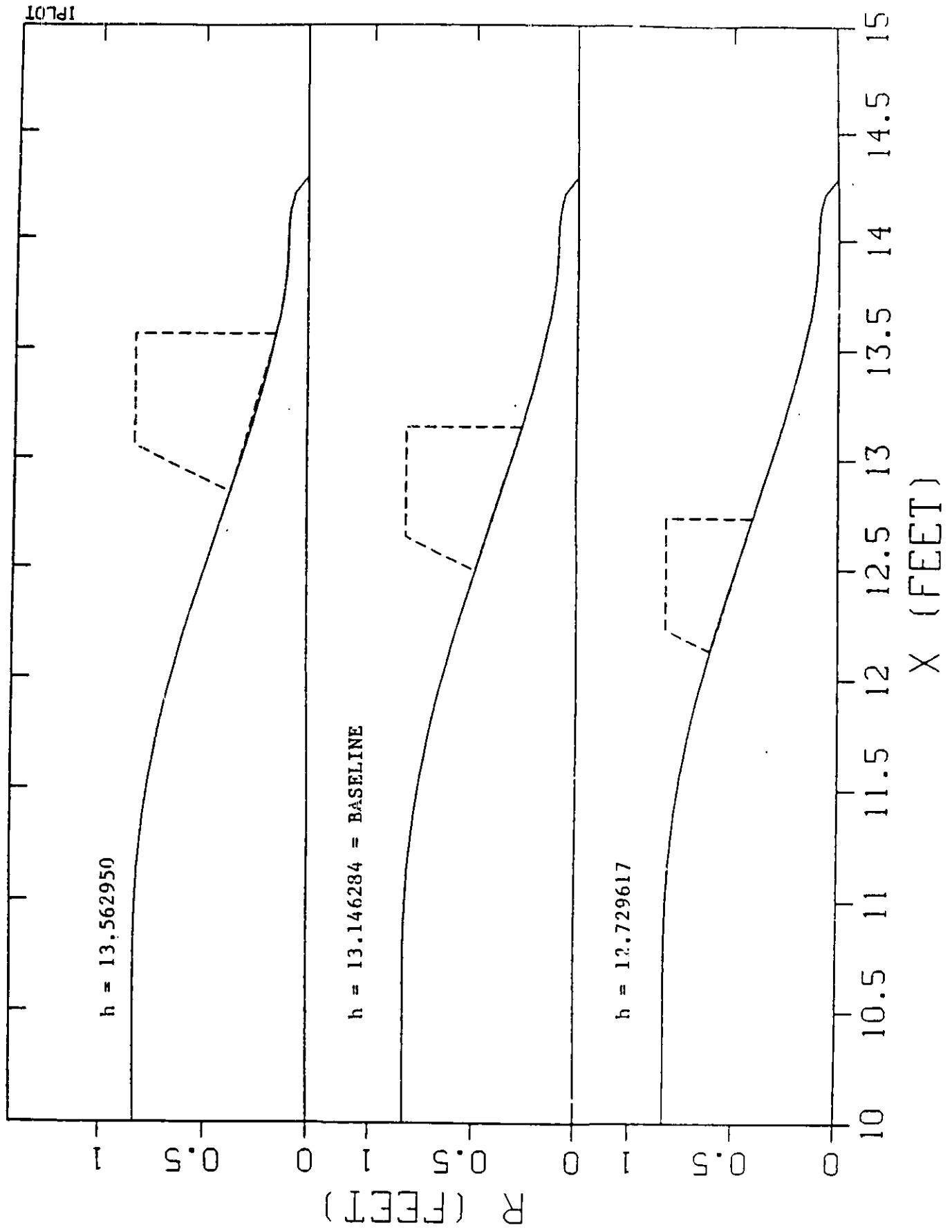


Figure 5. Stern appendage locations

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

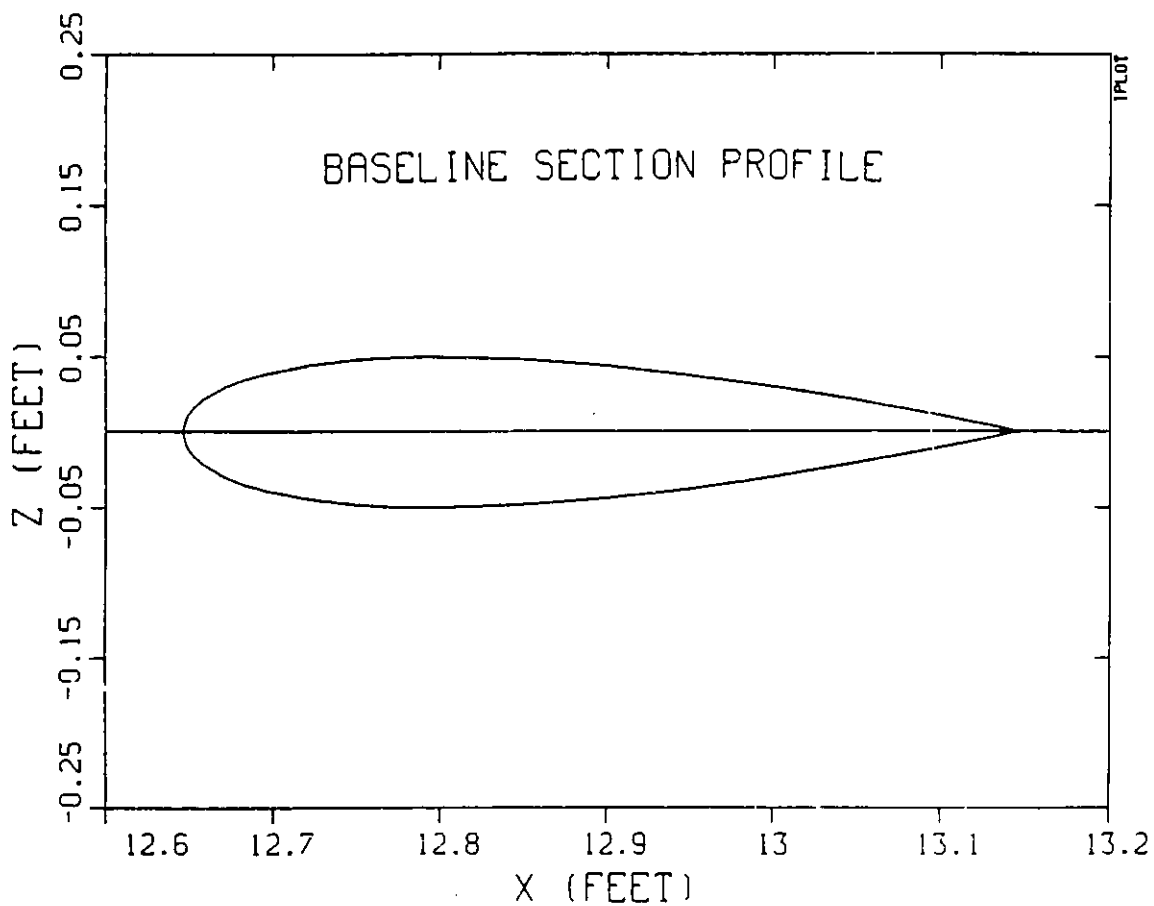
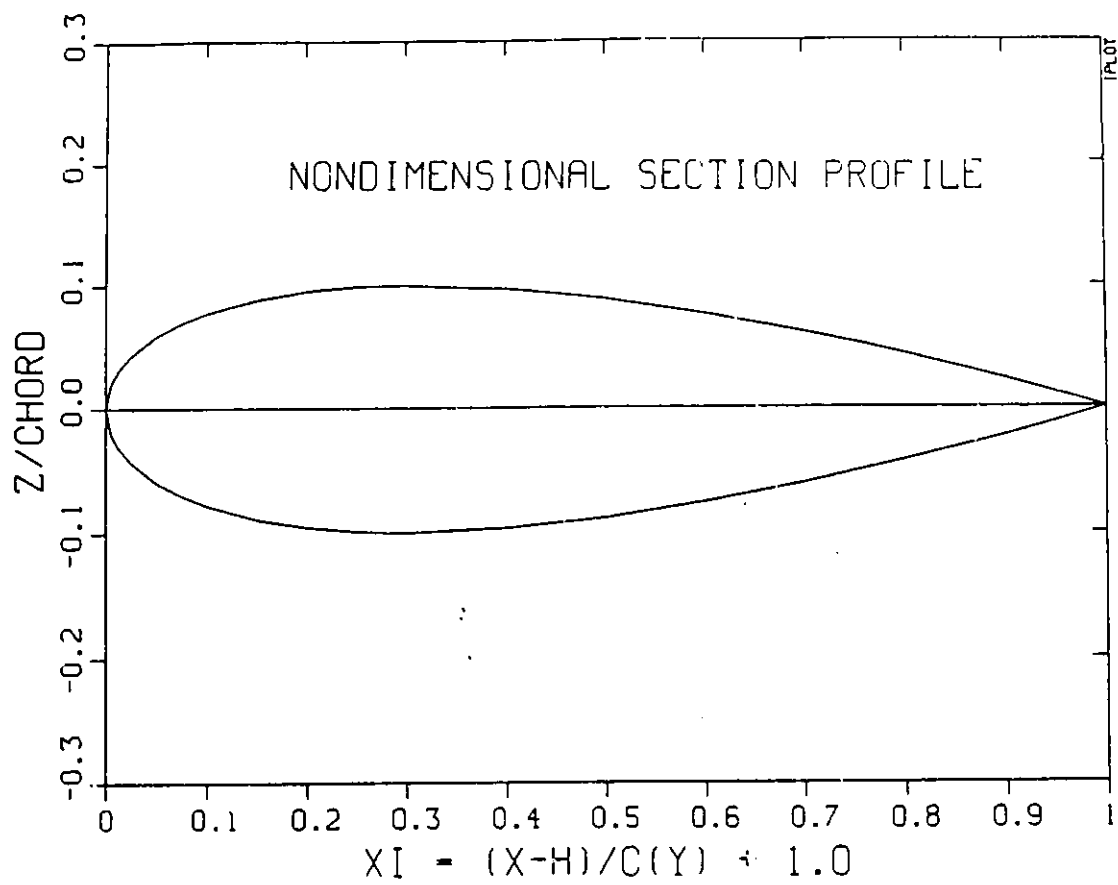
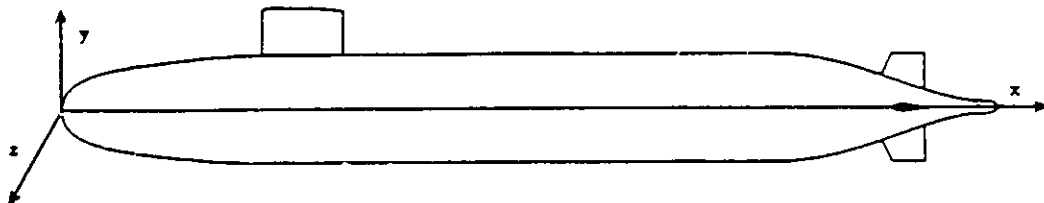


Figure 6. Stern appendage section profile

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.

STERN APPENDAGE EQUATION

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

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

where h = x coordinate of the stern appendage trailing edge

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

= chord length

Three values of h are considered:

$$h = 12.729617$$

$$h = 13.146284 = \text{BASELINE}$$

$$h = 13.562950$$

HULL/STERN APPENDAGE INTERSECTION

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

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:

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

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

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

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

BASIC GEOMETRY FOR RING WING

Camber:

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

$$\text{where } 0 \leq x \leq 1$$

$$D = 0.4 - x$$

$$E = 1.0 - x$$

Thickness:

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

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

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	-0.06496	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)

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

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

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

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

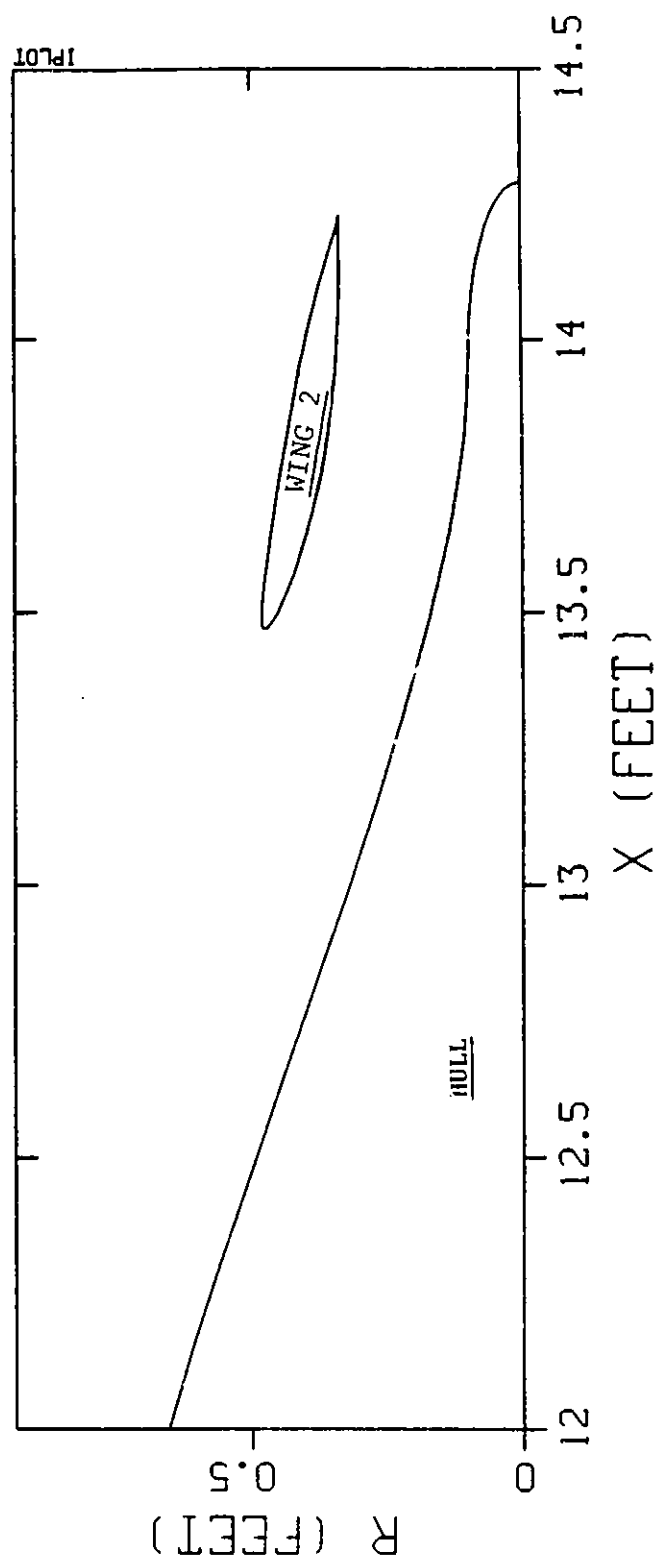
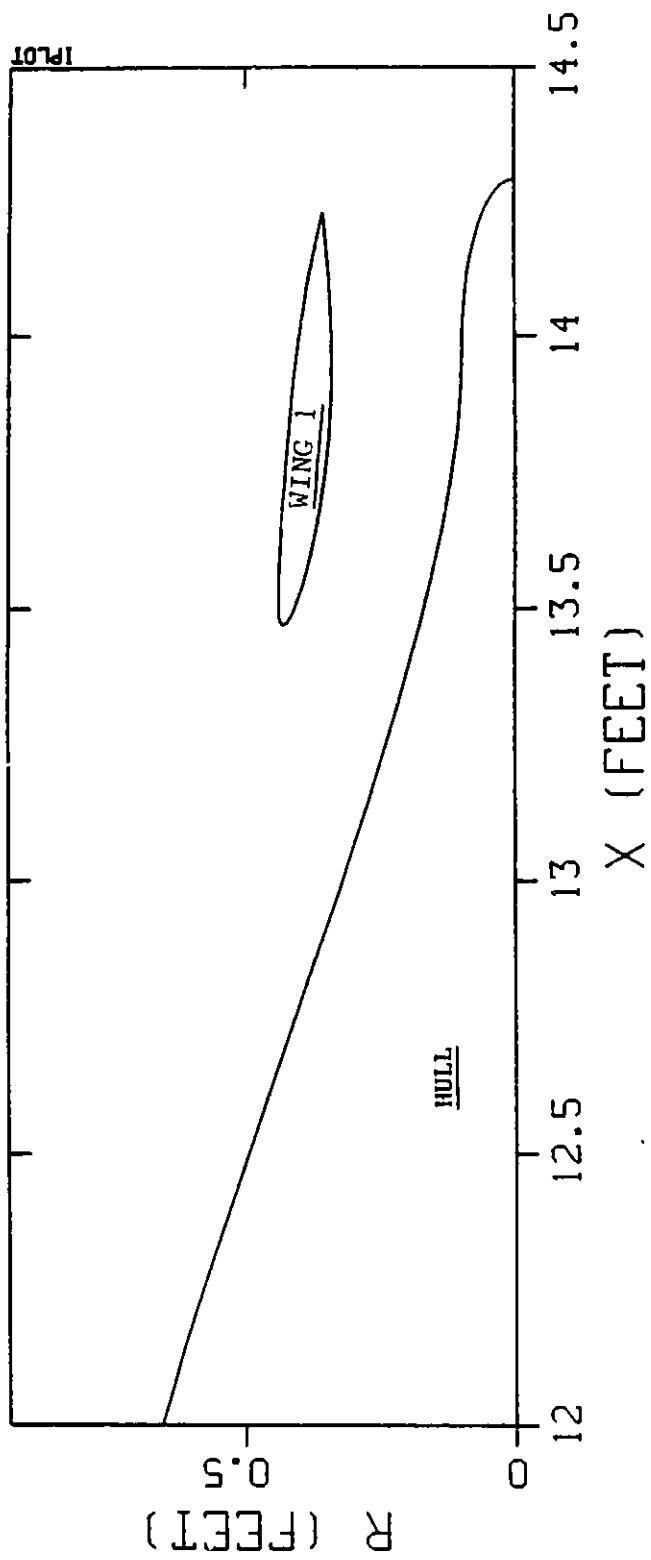


Figure 7. Ring wing section profile and placement

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 section 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.

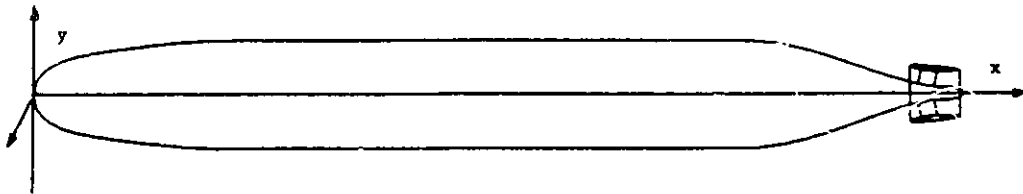
VELOCITY MEASUREMENT STATIONS

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 fair-water). Four identical, equally-spaced struts will attach the hull to the ring wing at a 45° increment from the wing surface pressure tap locations.

$$x = x_0 + 0.243995 \xi$$

$$y = y_0 - 0.054465 \xi$$

$$z = \pm 0.15 (0.29690 \sqrt{\xi} - 0.12600 \xi - 0.35160 \xi^2 + 0.28520 \xi^3 - 0.10450 \xi^4)$$

$$\text{where } x_0 = 0.223221 y_0 + 13.556128$$

$$R_1 \leq y_0 \leq R_2$$

$$\text{Ring Wing 1: } R_1 = 0.14726, \quad R_2 = 0.36886$$

$$\text{Ring Wing 2: } R_1 = 0.14726, \quad R_2 = 0.39755$$

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

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)

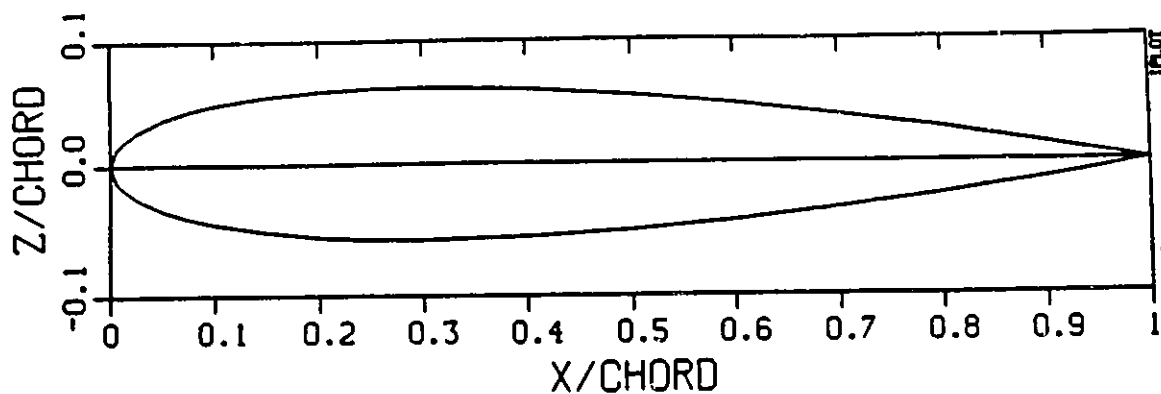


Figure 8a. Nondimensional section profile

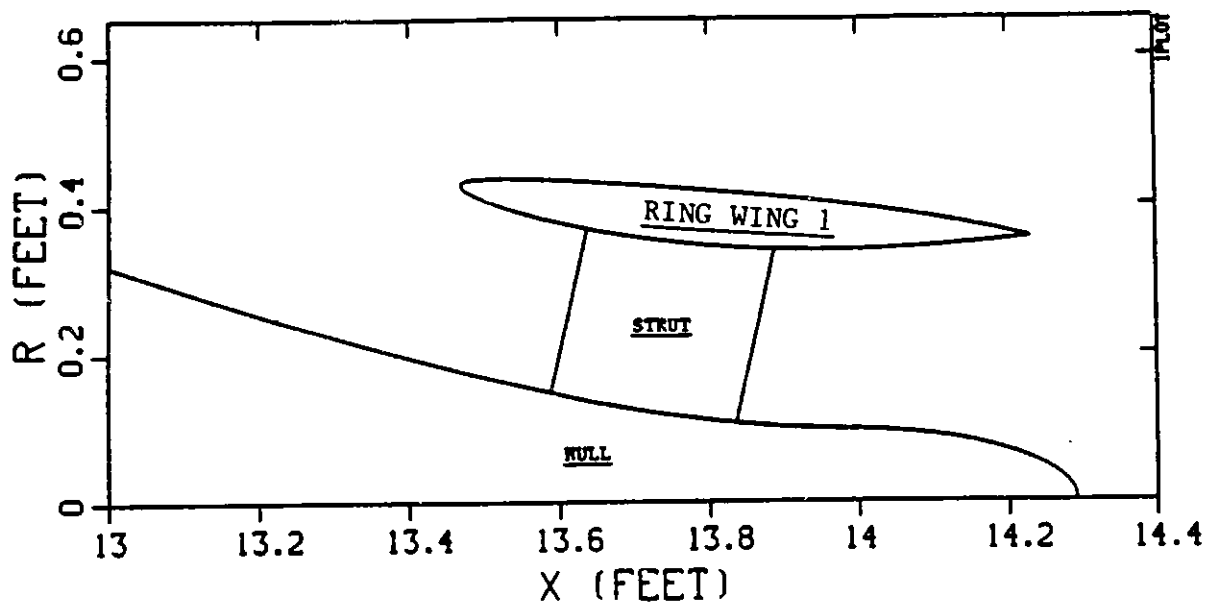


Figure 8b. Placement of strut on Ring Wing 1

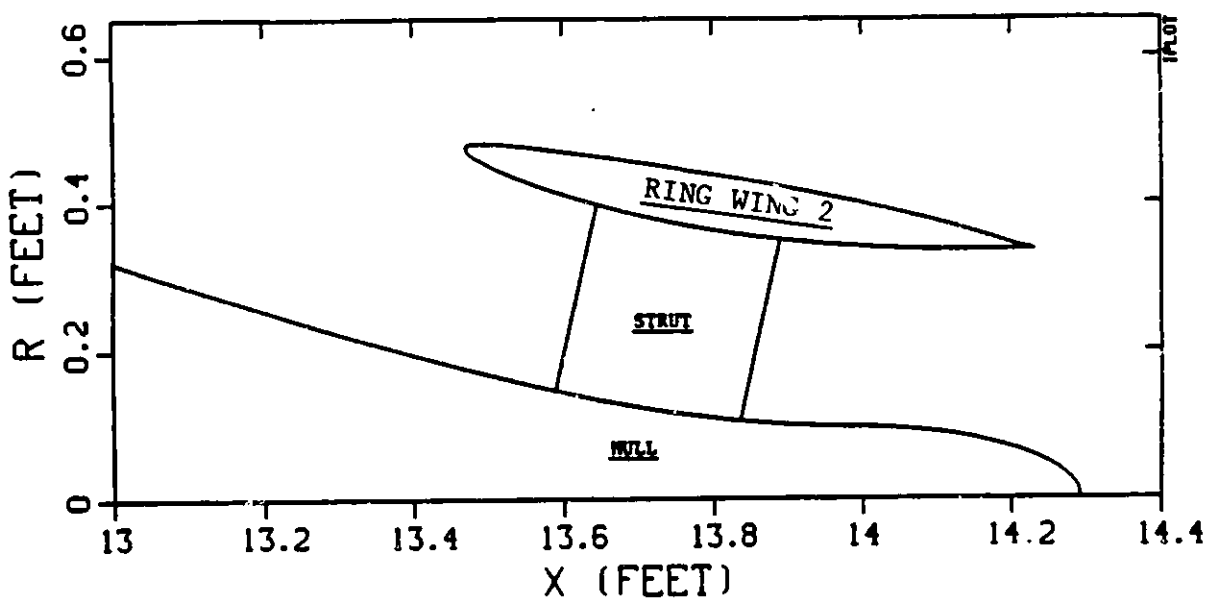


Figure 8c. Placement of strut on Ring Wing 2

Figure 8. Ring wing struts

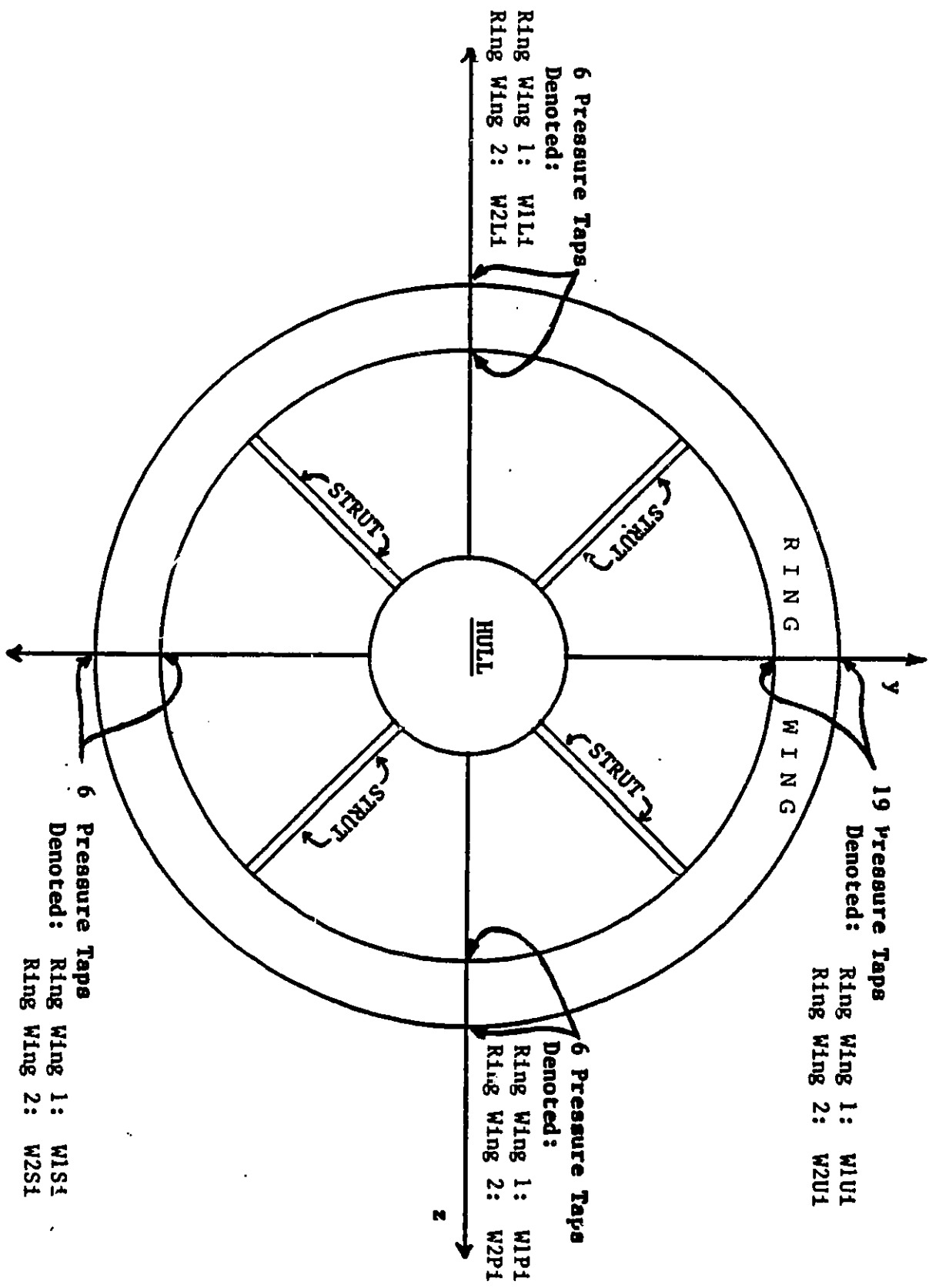


Figure 9. Typical cross section showing ring wing strut arrangement

VELOCITY MEASUREMENT STATIONS

X = 12.0 Ft
 12.91667 Ft
 13.97917 Ft
 15.66667 Ft
 18.58333 Ft

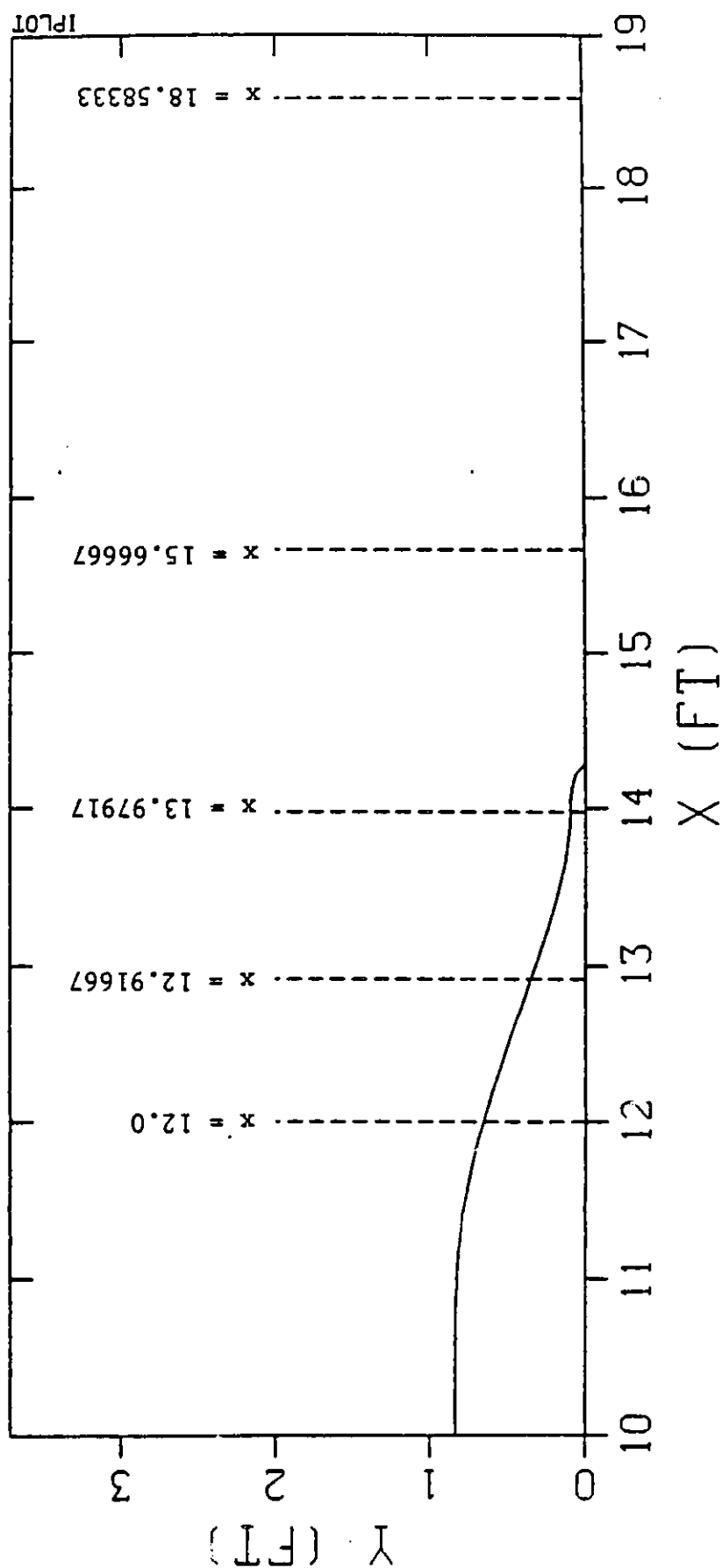


Figure 10. Velocity measurement planes

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

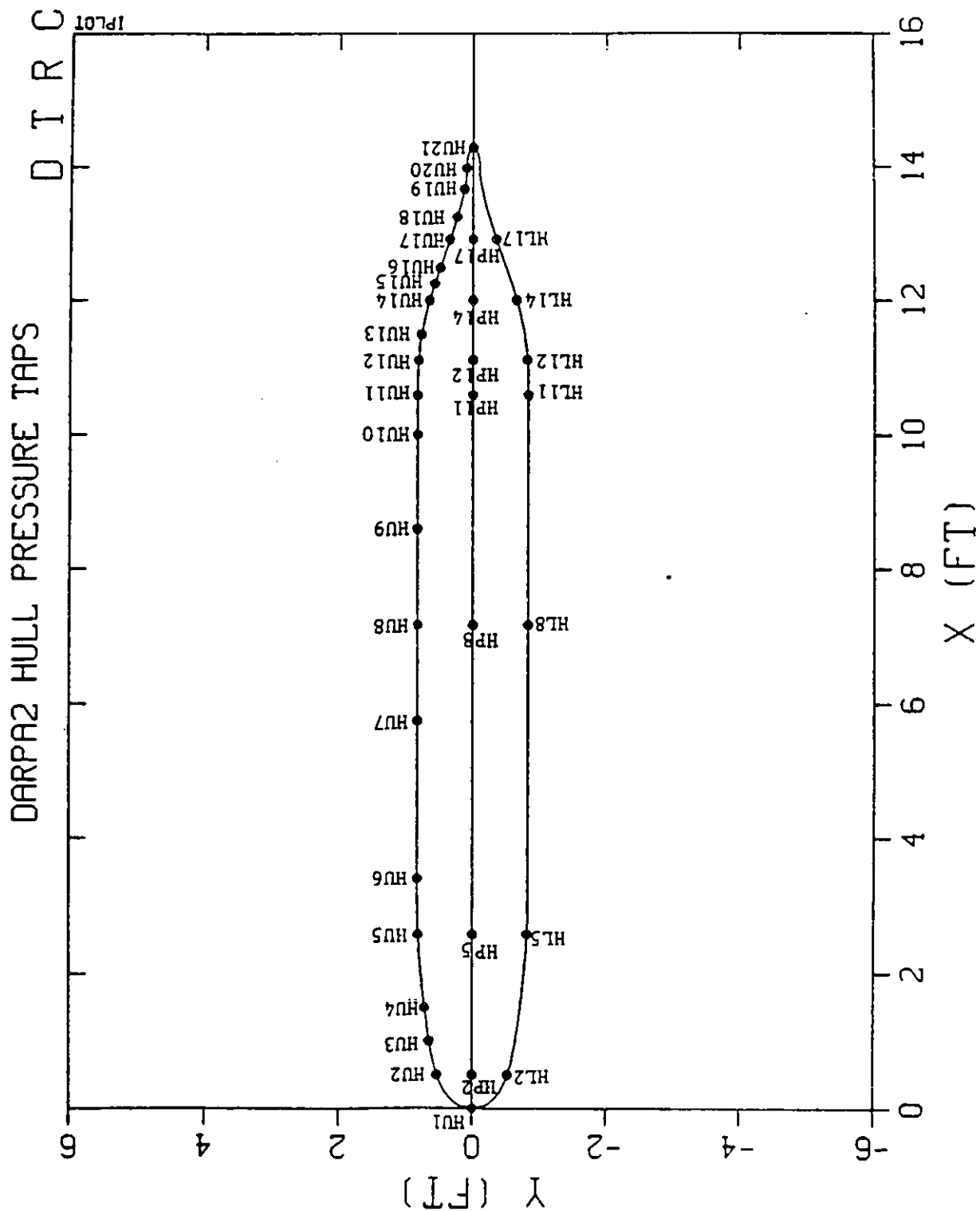


Figure 11. Axisymmetric hull pressure taps - MODEL No. 5471

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

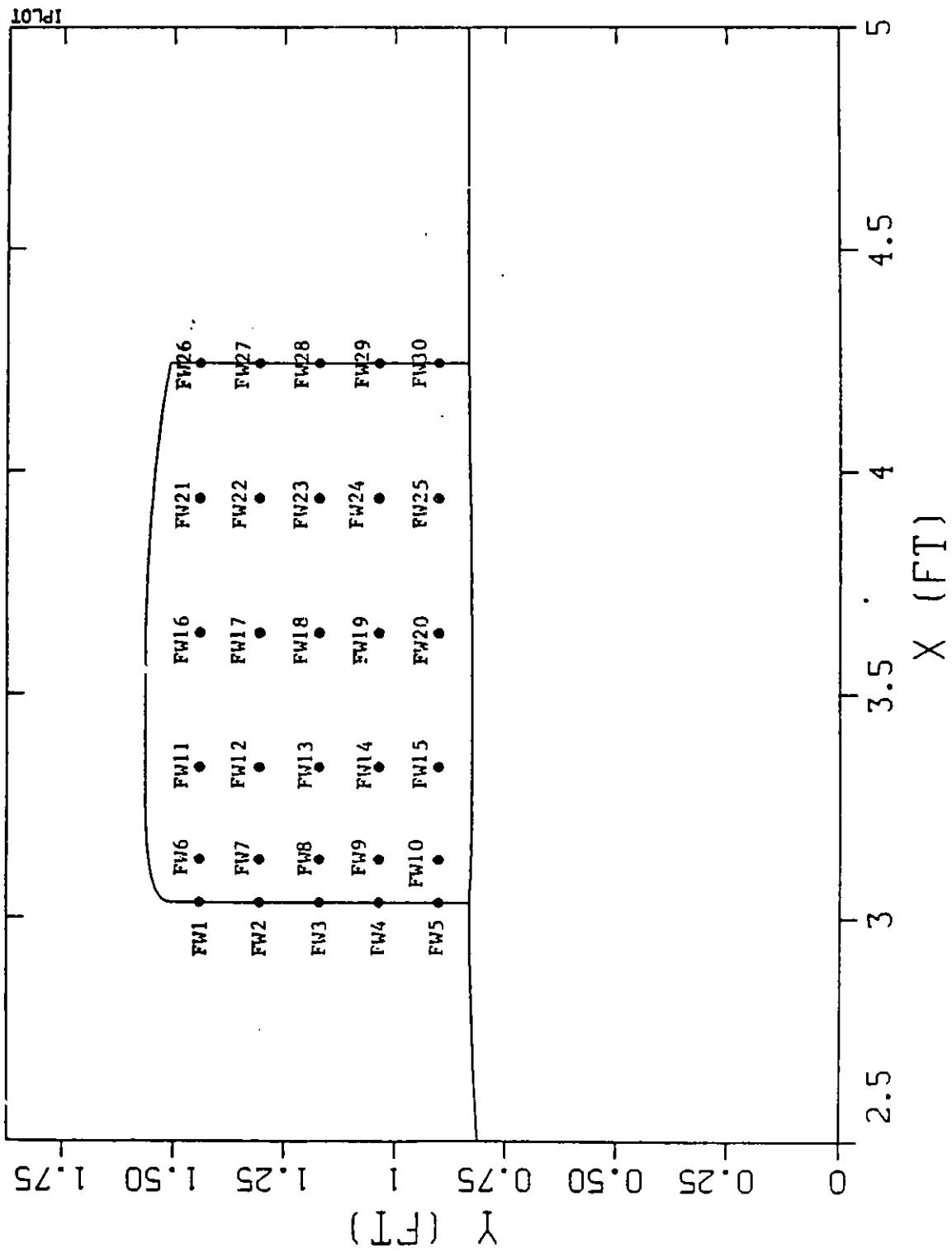


Figure 12. Pairwater pressure taps - MODEL No. 5471

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	3.09885	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

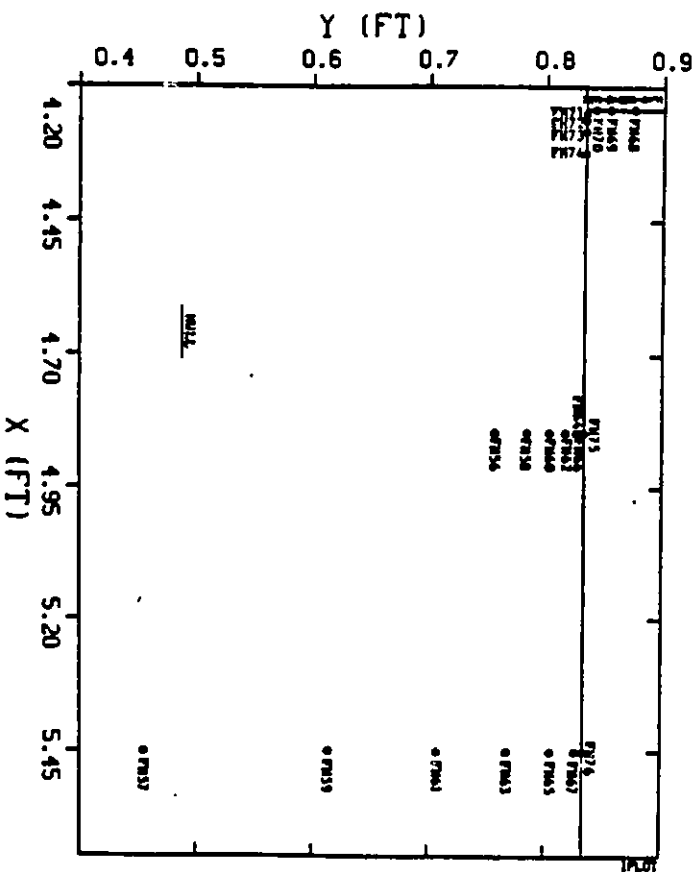
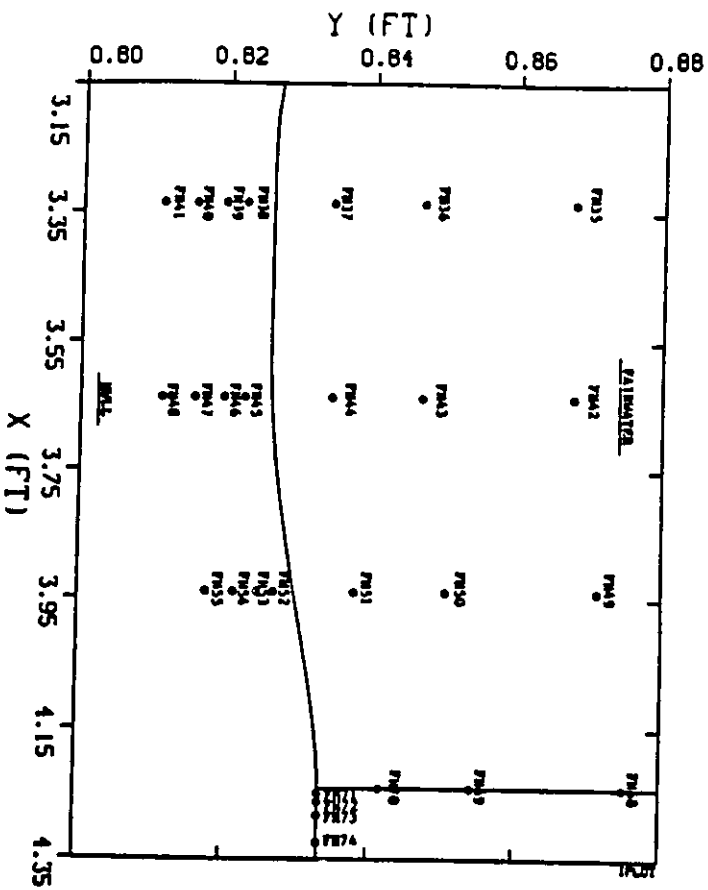
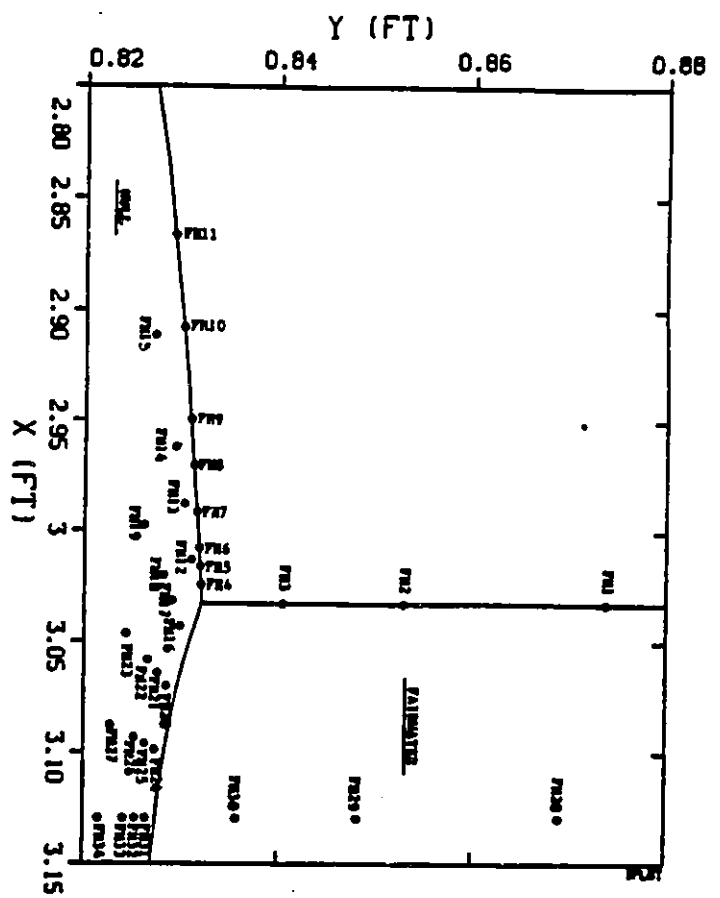


Figure 13. Hull/fairwater intersection region pressure taps - MODEL No. 5471

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

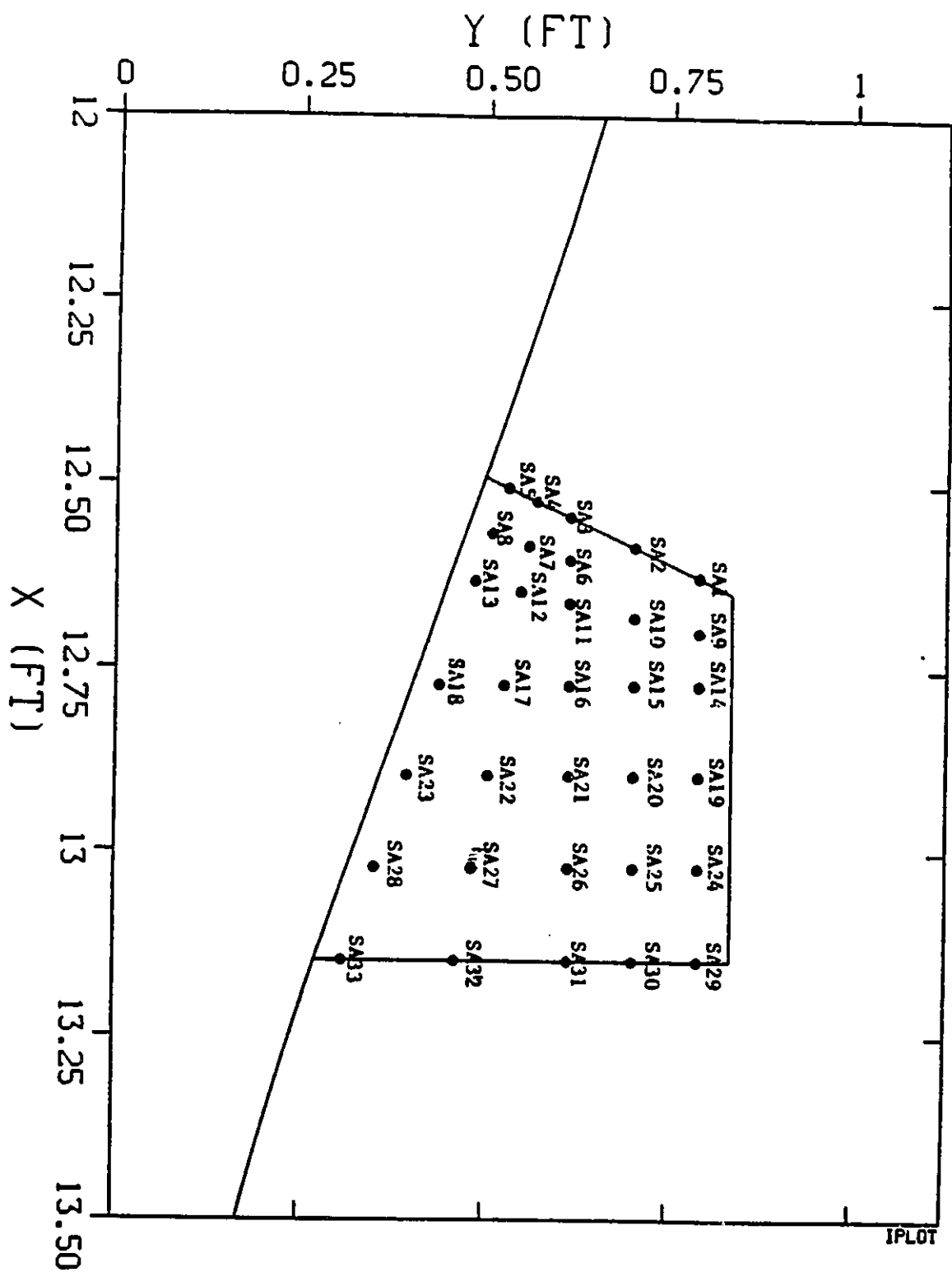


Figure 14. Baseline stern appendage pressure taps - MODEL No. 5471

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

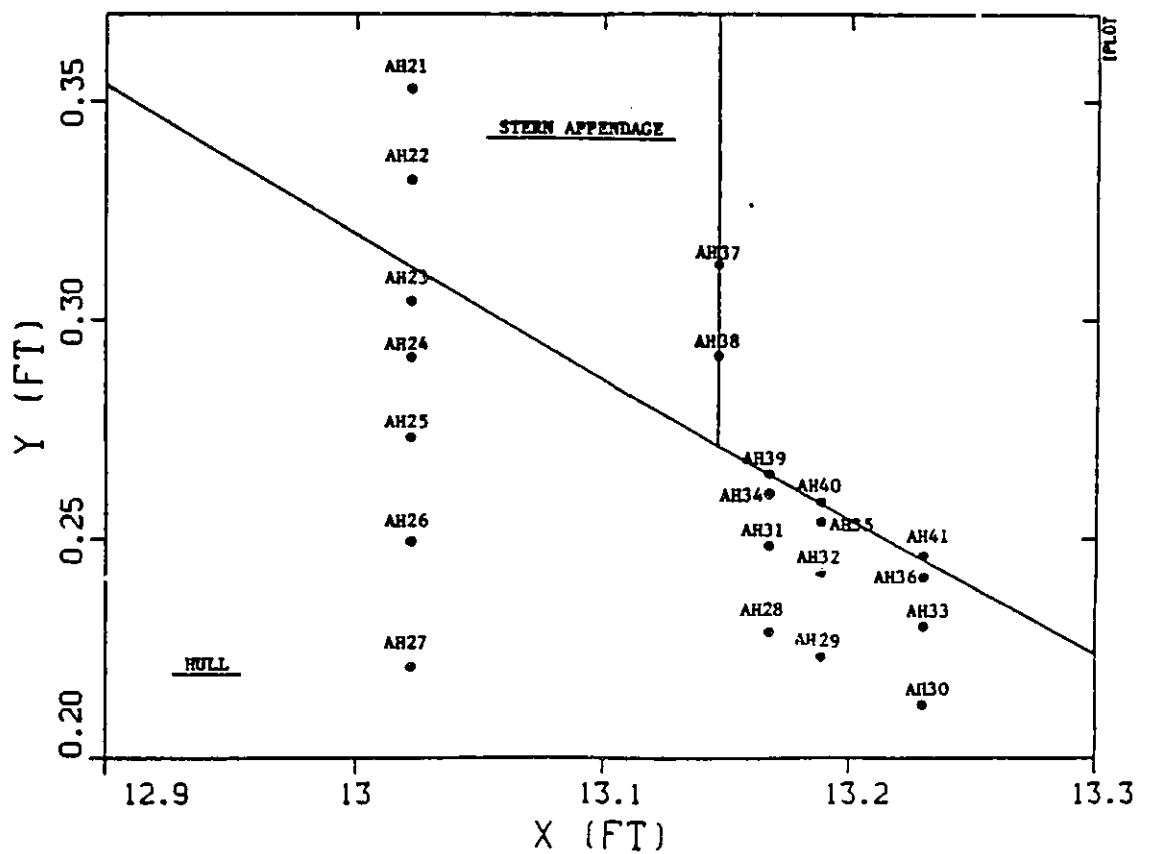
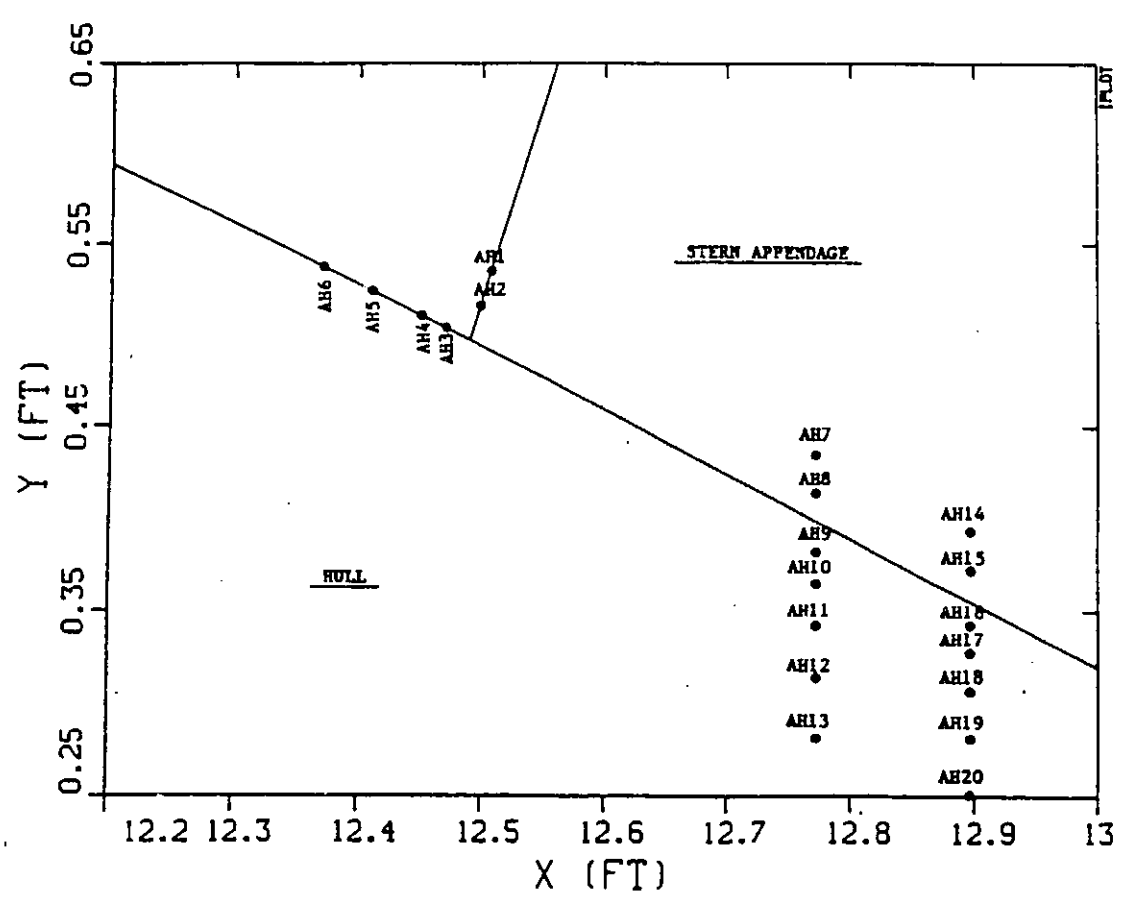


Figure 15. Baseline stern appendage/hull region pressure taps - MODEL No. 5471

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

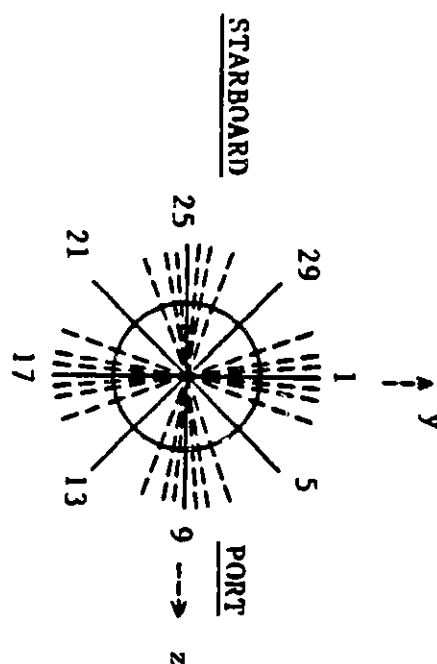
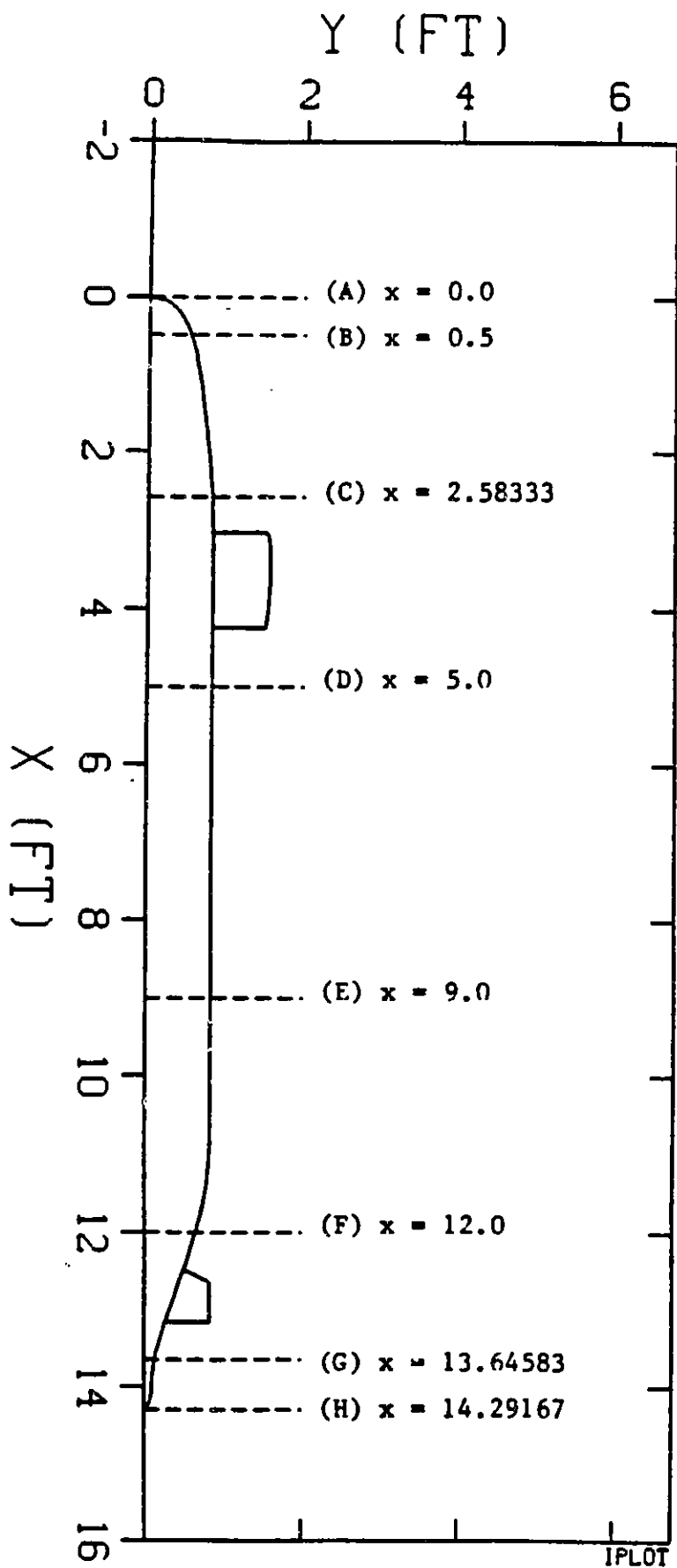


Figure 16. Surface pressure tap identification scheme on MODEL No. 5470 axisymmetric hull

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
TBFWP17	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
BFWS6	3.12965	1.44036	-0.09581
BFWS7	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
TBS P7	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 surface 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

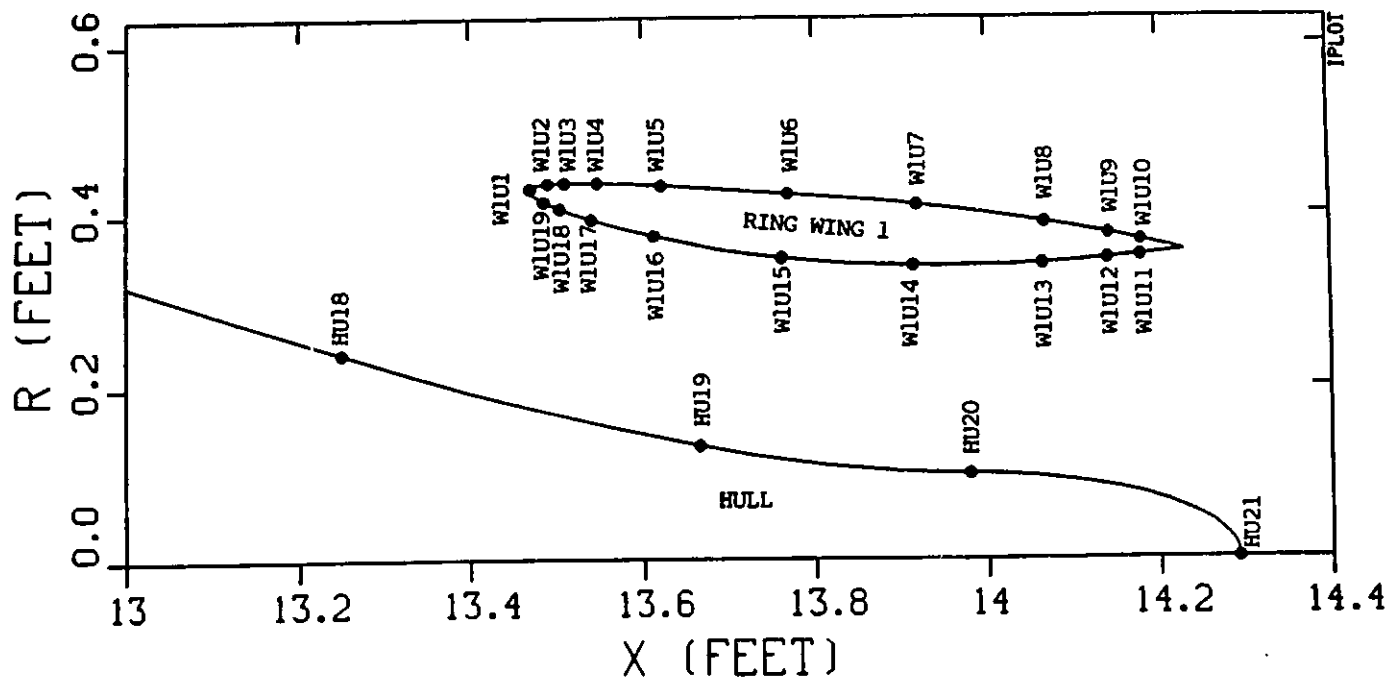


Figure 17. Ring Wing 1 pressure taps

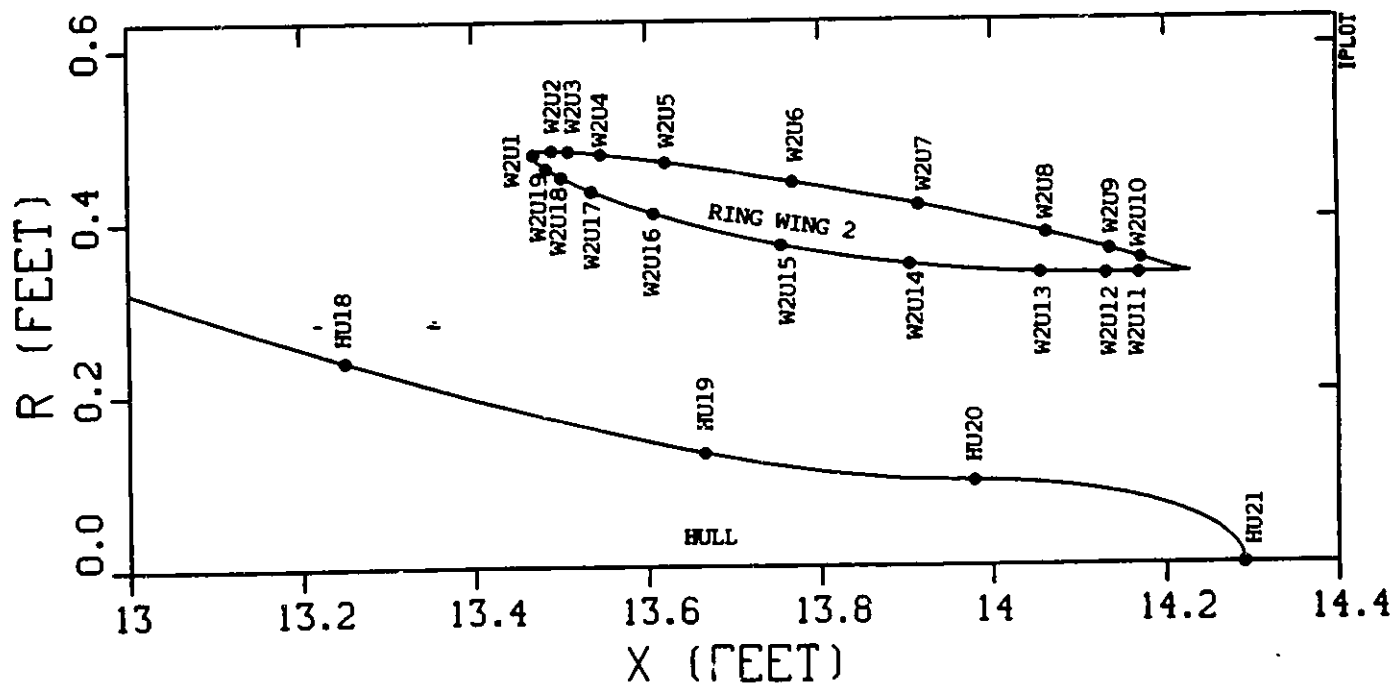


Figure 18. Ring Wing 2 pressure taps

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


```

      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
      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
      XI = (13.979167 - XX)/3.333333
      C1 = RH*RH
      C2 = RH*K0 *XI*X1
      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
      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
C      WRITE(6,1)
C      1 FORMAT('DARPA2')
C      WRITE(6,2)
C      2 FORMAT('MODEL WITH (MODEL/FULL) = 24')
C      WRITE(6,3) NP
C      3 FORMAT(I5)
C      WRITE(6,4) (X(I),Y(I),I=1,NP)
C      4 FORMAT(2F10.5,3X,2F10.5,3X,2F10.5)
C
C      ALL DONE, PROGRAM ENDS
C
C      STOP
C      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
C       .      NP(300),
C       .      X(300,50,3)
C
C*****
C
C   DEFINE CONSTANTS
C
C*****
C
C   A1      = 2.094759
C   B1      = 0.207178
C   A3      = 2.908891
C   B3      = 1.234491
C   C3      = 3.444817
C   D3      = 3.850435
C   E3      = 2.080019
C   HMAX    = 0.109375
C   DX      = 0.005
C   DXO     = 0.005
C   XXCST   = 3.032986
C   XXAFN   = 4.241319
C   XXFFN   = 3.358507
C   XXMFN   = 3.559028
C   XZST    = 1.507813
C
C*****
C
C   CALCULATE
C
C*****
C
C           XX=XXCST-DX
C   DO 1000 I = 1,300
C       XZ=XZST
C       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


```

DO 800 J = 1,32
X = X - DX
IF(X.GT.HH) GO TO 800
C
C *****
C
C     DE LINE 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-HH)/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 *****
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          STERN APPENDAGE IS "CLOSE"
C          TO HULL RADIUS, GET CLOSER.
C *****
C
C          ITR = ITR + 1
C          IF(ITR.GT.20) STOP1
C          DELR = 0.5*DELR
C          IF(SRS.GT.RHAS) RR = RR - DELR
C          IF(SRS.LE.RHAS) RR = RR + DELR
C          GO TO 620
700 CONTINUE
C          GO TO 800
710 CONTINUE
C
C *****
C          SOLVE FOR STERN APPENDAGE SECTION
C          AT GIVEN RADIUS
C *****
C          CY = -0.466308*RR + 0.88859
C          I750 = 0
C          XINIT = (X-HH)/CY + 1.0
C
C *****
C          LOOP ON XI
C *****
C          DO 750 I=1,NP
C          XI = XXI(I)
C          IF(XI.LT.XINIT) GO TO 750
740 CONTINUE
C          XI = XXI(I)
C          IF(I750.EQ.0) XI = XINIT
C          XXX = (XI-1.0)*CY + HH
C          IF(XI.LT.0.0 .OR. XI.GT.1.0) GO TO 750
C          Z = 0.29690*SQRT(XI) - 0.12600*XI - 0.35160*XI*XI
C          1 + 0.28520*XI**3 - 0.10450*XI**4
C          Z = CY * Z
C
C *****
C          PRINT X, Y, (+/-)Z VALUES
C          TO PRINTER FILE 6
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
      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 = 0.29690*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
      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
C      DIMENSION XC(26), YC(26), YCP(26)
C      DIMENSION B(17), YT(26)
C      DIMENSION XU(26), YU(26), XL(26), YL(26)
C      DIMENSION XDLE(2), YDLE(2), XDTE(2), YDTE(2)
C
C      XC ARRAY ARE THE X/C VALUES CURRENTLY USED TO DEFINE WING.
C
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
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
C      DATA XDLE/13.46990, 13.46990/
C      DATA YDLE/0.43004, 0.47681/
C      DATA XDTE/14.21661, 14.2074/
C      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
C      NXC = 26
C      DO 1000 KK = 1,2
C      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
      WRITE(6,5) I,XU(I),YU(I),XL(I),YL(I),XC(I),YT(I),YC(I),YCP(I)
C    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    444 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
        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
        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   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
C   DIMENSION XC(19), XUL(19), YUL(19), ZU(19), ZL(19)
C
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
C   NP = 19
C   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
C   R1 = 0.14726
C   R2 = 0.39755
C   DELR = (R2-R1)/(NR-1)
C   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

```