

SPLASH

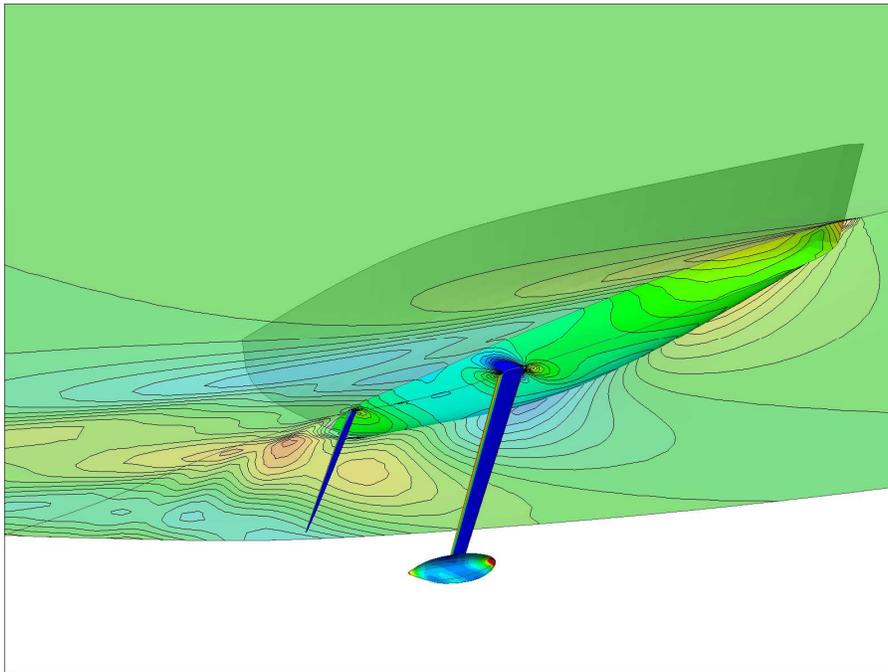
Free-Surface Panel Code

Computer Program

Aerodynamic and Hydrodynamic Flow Analysis
for Steady Flow with Free-Surface Waves

Version 5.1.0.04
Reference Manual

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South Bay Simulations, Inc. • 44 Sumpwams Ave. • Babylon, NY 11702
(631) 587-3770 www.panix.com/~brosen brosen@panix.com

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SPLASH Version 5.1.0.04 Reference Manual

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Overview

SPLASH stands for Small Perturbation Linearized Analysis of Free-Surface Hydrodynamics. It is a computer program for calculating aerodynamic and hydrodynamic steady flow fields about arbitrary configurations. It is a panel code, and as such is capable of computing inviscid potential flows about relatively complex shapes. It features a unique boundary condition for treatment of free-surface waves in calm water due to steady forward motion.

The free-surface boundary condition allows the hydrodynamic effects of waves generated at the air/water interface to be included in flows about shapes which are aerodynamically complex in their own right, even without a free-surface. For yachts and simple ship hull forms, supporting automated panelization packages are used to facilitate modeling. These same packages can be used to iteratively and convergently drive SPLASH to steady nonlinear free-surface solutions.

Steady Flow Theory and Numerical Procedure

The flow equation is that for steady, inviscid, incompressible potential flow, i.e., Laplace's equation for the velocity potential Φ :

$$\nabla^2 \Phi = 0$$

The vector velocity \bar{V} is given by the spatial gradient of the velocity potential (unless noted otherwise, velocities are nondimensionalized by the boat's steady forward velocity, U_{boat}):

$$\bar{V} = \nabla \Phi = \Phi_x \hat{i} + \Phi_y \hat{j} + \Phi_z \hat{k}$$

The problem thus becomes one of determining the velocity potential such that appropriate panel model boundary conditions are satisfied (as well as the flow equation).

Constant strength source and doublet singularity panels are distributed over the configuration surface, over a finite portion of the wakes shed by the configuration, and over a finite portion of the free-surface. These singularities individually satisfy the flow equation by construction, and the problem is further reduced to determining the unknown source and doublet strengths which satisfy the specified panel boundary conditions.

At any point in the flow the potential, and flow velocity, can be expressed (via influence coefficients) as a linear superposition of terms, each term proportional to one unknown source or doublet strength. Specifying an independent potential or velocity boundary condition for each unknown singularity strength results in a linear matrix system of equations to be solved, e.g., $\mathbf{Ax}=\mathbf{B}$, where \mathbf{x} is the vector of unknown singularity strengths.

Two boundary conditions are used at each configuration panel center and each free-surface panel center, so there are implicitly as many boundary conditions as there are unknown source and doublet strengths. Doublet-only wake panels do not introduce any additional singularity strengths, since wake doublet strength is determined as the difference between the lifting surface upper and lower trailing edge panel doublet strengths, and it is merely convected downstream at constant strength thereafter.

A typical panel model is shown in Figure 1, as is the global coordinate system (x,y,z) . This is a right-handed Cartesian coordinate system moving with respect to the earth at the same steady forward velocity as the configuration. For SPLASH free-surface cases, the y coordinate is directed vertically downwards. This is a carryover from aircraft applications, where the y coordinate is usually in the spanwise direction, over to yacht applications, where the spanwise direction is downward along the keel. The undisturbed free-surface is located at $y=0.0$.

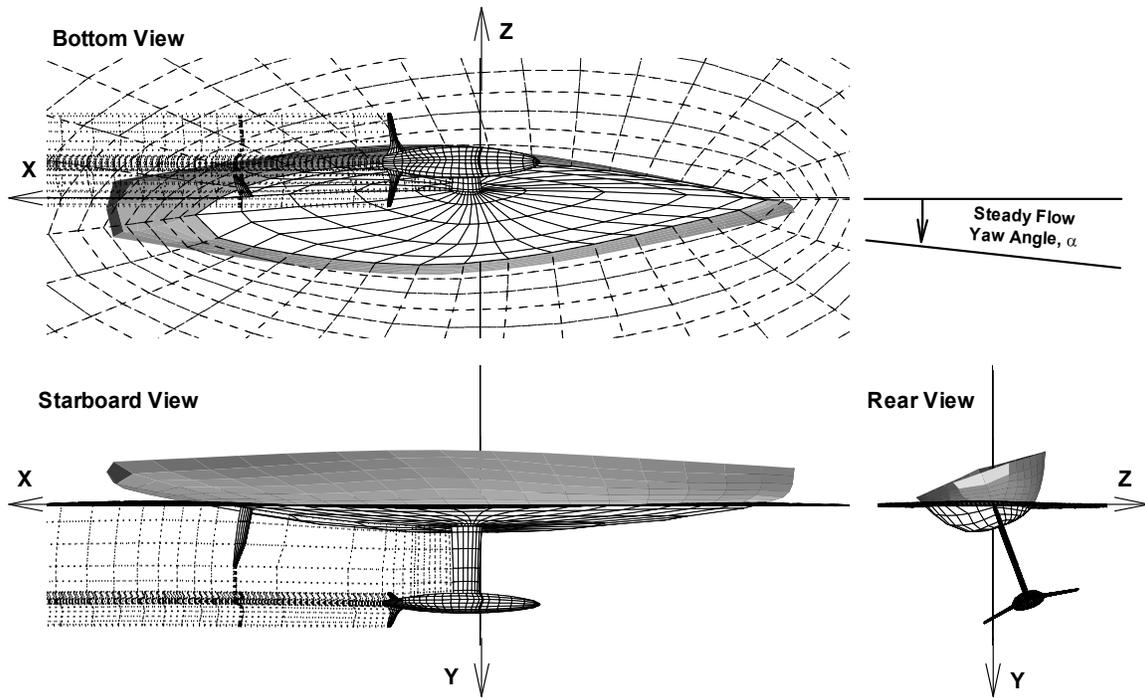


Figure 1 SPLASH Free-Surface Panel Model for IACC Yacht in Global Coordinate System

The surfaces are divided into networks, each network being a collection of panels defined by a single rectangular (in I and J) array of points. The model in Figure 1 consists of 17 surface and wake networks. Each network has an upper surface and a lower surface, depending on the order of input of the points, and a resulting number assigned to each of its four edges. These network conventions are illustrated in Figure 2. Several types of networks are available to model the various surfaces, each type of network having different source/doublet singularity and boundary condition treatment options. The types of networks and their usages are discussed later.

Each panel is flat, being formed by the projection of its corner points on the mean plane through them. Each panel is assigned upper and lower surfaces and edge numbers, in accordance with the network to which the panel belongs. Boundary condition control points are placed at the center of each panel. Associated with each panel is a local curvilinear coordinate system (ξ, ζ, n) . The ξ and ζ coordinates are formed by joining a panel's control point with those of its neighboring panels, so in general ξ and ζ are not orthogonal. The n coordinate points outward and is normal to the plane of the panel. These panel conventions and the local panel coordinate system are illustrated in Figure 3.

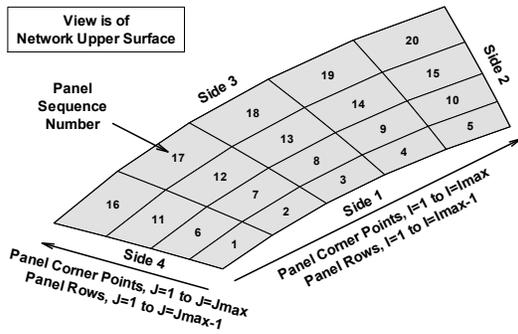


Figure 2 SPLASH Network Conventions

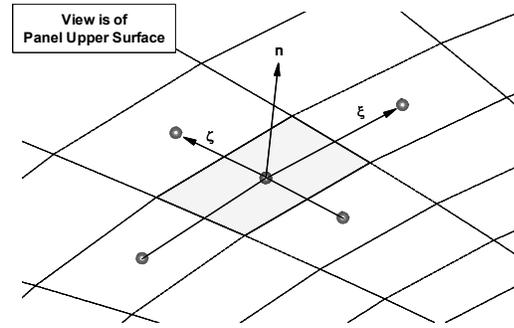


Figure 3 SPLASH Panel Conventions and Local Panel Coordinate System

Surface Velocities, and the Zero-Internal-Perturbation Boundary Condition

Appropriate boundary conditions are applied at each panel control point (except, as previously mentioned, for wake panels). The simplest such boundary condition is that the external flow velocity at the surface must be tangent to the panel, or, in other words, that the component of the external flow velocity normal to the panel is zero ($\bar{\mathbf{V}} \cdot \bar{\mathbf{n}} = 0$). Even after one such external boundary condition has been applied at each panel center, there are still an infinite number of combinations of panel source and doublet strengths that will satisfy them ... each such combination results in a different internal flow field, in the regions internal to the configuration. Although the internal flow field in the regions inside the configuration is not of any interest to the end-user, they can have a major impact on the numerical calculations and on the reliability and accuracy of the external flow field, which of course is of paramount interest to the end-user.

The source and doublet strengths are therefore rendered unique by appropriate specification of panel boundary conditions relating to the internal flow. The internal boundary condition used in SPLASH is that the flow perturbation (the difference in flow velocity relative to the freestream) is zero. This approach simplifies the external surface velocity calculations, and boundary conditions, and significantly reduces the number of machine operations required to obtain the final flow calculation. This approach is also very numerically robust, as specifying the internal flow disturbance to be zero helps to avoid any internal flow field disturbances that might adversely impact the external flow field of interest (this can occur due to the discretized nature of the panel model flow solution). This approach is not unique to SPLASH, as a large number of existing panel codes make similar use of surface distributions of sources and doublets along with internal-zero-perturbation boundary conditions.

The zero-internal-perturbation approach requires that the panel model forms one or more closed or watertight enclosures making up the configuration, so that specifying zero perturbation potential at panel interior (lower) surface control points indeed corresponds to zero perturbation potential everywhere inside the configuration. For example, trailing edges and tips of lifting surfaces should be closed to zero thickness, or they should be paneled (the former is usually sufficient and much easier to model). The upward-facing side of free-surface panels are also considered to enclose the interior region of the panel model, and the zero-internal-perturbation boundary condition is also imposed on the interior side of free-surface panels. Leakage may

occur between interior and exterior flow regions, at the outer edge of the paneled portion of the free-surface, but is assumed to be negligible.

The zero-internal-perturbation approach simplifies calculation of external surface flow velocities at the panel centers. The final result is that the external flow velocity at the surface depends only on the freestream velocity, the local panel source strength σ , and the local panel-to-panel gradient of doublet strength μ :

$$\begin{aligned}\bar{\mathbf{V}} &= \bar{\mathbf{V}}_\infty \\ &+ 4\pi \sigma (n_x \hat{\mathbf{i}} + n_y \hat{\mathbf{j}} + n_z \hat{\mathbf{k}}) \\ &+ 4\pi \mu_\xi (\xi_x \hat{\mathbf{i}} + \xi_y \hat{\mathbf{j}} + \xi_z \hat{\mathbf{k}}) \\ &+ 4\pi \mu_\zeta (\zeta_x \hat{\mathbf{i}} + \zeta_y \hat{\mathbf{j}} + \zeta_z \hat{\mathbf{k}})\end{aligned}$$

Here, the term involving the source strength directly determines the velocity normal to the panel, and the terms involving the gradients of the doublet strengths directly determine the velocities tangent to (in the plane of) the panel. The derivatives of n , ξ and ζ , with respect to x , y and z ($n_x, n_y, n_z, \xi_x, \xi_y, \xi_z, \zeta_x, \zeta_y, \zeta_z$) are the geometric grid metrics relating derivatives in curvilinear coordinates (ξ, ζ, n) to those in Cartesian coordinates (x, y, z) .

The grid metrics, as well as the derivatives of doublet strength with respect to ξ and ζ , (μ_ξ and μ_ζ), are evaluated using local panel geometry and corresponding panel-to-panel numerical finite difference formulae. The 3-point centered difference stencils for the ξ and ζ directions, and the panel centroids involved, are illustrated in Figure 3. If the required panels are not available, a one-sided 3-point or 2-point stencil will be attempted.

The zero-internal-perturbation approach thus simplifies the external surface boundary conditions, and also significantly reduces the number of machine operations required to obtain the final flow calculation. For example, consider the basic zero-normal-velocity external panel boundary condition mentioned previously. With the panel normal perpendicular to ξ and ζ , this boundary condition reduces to:

$$\sigma = -\bar{\mathbf{V}}_\infty \cdot \bar{\mathbf{n}} / 4\pi$$

So the panel source strengths may be determined in advance, and the total number of unknowns is cut in half, and only the unknown doublet strengths need to be determined. These are found via solution of a linear matrix system of N equations, this resulting from the internal-zero-perturbation boundary conditions imposed at the center of each panel i :

$$\phi_{i, \text{internal}} = \sum_{j=1}^N A_{i,j} \mu_j + \sum_{j=1}^N B_{i,j} \sigma_j = 0 \quad (\text{for } i = 1 \text{ to } N)$$

Here ϕ is the perturbation potential at the interior of panel center i , and $A_{i,j}$ and $B_{i,j}$ are the influence coefficients indicating the contribution to that potential due to unit doublet and source strength, respectively, on panel j . Since the source strengths are determined in advance, this may be recast in terms of just the unknown doublet strengths:

$$\sum_{j=1}^N A_{i,j} \mu_j = -B_i = -\sum_{j=1}^N B_{i,j} \sigma_j \quad (\text{for } i = 1 \text{ to } N)$$

This linear matrix system of N equations is solved using direct or, preferably, iterative matrix solution techniques. Only the scalar potential influence coefficients are required, and the more complex and numerically intensive vector velocity influence coefficients are avoided. Once all the source and doublet strengths are known, final velocities and aerodynamic/hydrodynamic pressures can be determined:

$$U = \Phi_x = U_\infty + 4\pi (\sigma n_x + \mu_\xi \xi_x + \mu_\zeta \zeta_x)$$

$$V = \Phi_y = V_\infty + 4\pi (\sigma n_y + \mu_\xi \xi_y + \mu_\zeta \zeta_y)$$

$$W = \Phi_z = W_\infty + 4\pi (\sigma n_z + \mu_\xi \xi_z + \mu_\zeta \zeta_z)$$

$$C_p = \frac{p - p_\infty}{\frac{1}{2} \rho U_{boat}^2} = 1 - \nabla \Phi \cdot \nabla \Phi = 1 - (U^2 + V^2 + W^2)$$

Here, p is the fluid pressure, ρ is the fluid density, and U, V and W are the Cartesian components of the velocity.

Knowledge of each panel's neighbors is required to compute the panel-to-panel gradients of doublet strength. Automated search algorithms within SPLASH attempt to determine the correct "neighbor" relationships. The user can also specify the correct relationships through optional inputs which override any relationships determined by the automated search algorithms. It is good practice for the user to specify the correct relationships for all panel edges lying along network edges, in the event that the automated search algorithms do not identify the correct relationships.

Types of Surface Networks and External Boundary Conditions

Solid Surface (NTYPE=2) Networks

The majority of the surface of the configuration is paneled using solid-surface networks. These must be properly oriented, with upper surfaces facing the external flow, and lower surfaces facing the inside of the configuration. Constant strength source and doublet singularities are distributed across each of the panels.

The simplest external boundary condition is that the external flow velocity at the surface must be tangent to the panel, i.e., that the component of the external flow velocity normal to the panel is zero. This is the same zero-normal-velocity boundary condition mentioned previously.

This boundary condition can be extended to cases where the velocity normal to the panel is non-zero but can still be determined and specified in advance. Such cases include thin-airfoil type surface deflections, and attached boundary layer displacement thickness effects. For such cases, the user specifies the non-zero normal velocities to be applied, and the local source strengths may still be determined in advance of the matrix solution:

$$\sigma = (\mathbf{V}_{norm,specified} - \bar{\mathbf{V}}_\infty \cdot \bar{\mathbf{n}}) / 4\pi$$

For example, for a thin-airfoil type surface deflection of magnitude δ , the specified normal velocities on the airfoil's deflected upper and lower surfaces are $-\delta$ and $+\delta$. For a boundary layer displacement thickness δ^* , the specified normal velocity is $\partial\delta^*/\partial x$.

A more accurate deflected thick airfoil surface type of boundary condition is also available in SPLASH. Here, the velocity normal to the would-be deflected surface is set to zero:

$$\bar{\mathbf{V}} \cdot \bar{\mathbf{n}}_{rotated} = 0$$

The vector components of the rotated normal are calculated based on user inputs defining the angle of rotation and the hinge line axis about which the rotation occurs. Note that the velocity normal to the panel itself, which does not actually rotate, is no longer zero, and so the source strength cannot be determined in advance. However it is still possible, using the relationships already presented, to relate the local source strength to the local gradient of doublet strength:

$$\sigma = - \frac{\left[\bar{\mathbf{V}}_\infty + 4\pi \mu_\xi (\xi_x \hat{\mathbf{i}} + \xi_y \hat{\mathbf{j}} + \xi_z \hat{\mathbf{k}}) + 4\pi \mu_\zeta (\zeta_x \hat{\mathbf{i}} + \zeta_y \hat{\mathbf{j}} + \zeta_z \hat{\mathbf{k}}) \right] \cdot \bar{\mathbf{n}}_{rotated}}{4\pi (\bar{\mathbf{n}} \cdot \bar{\mathbf{n}}_{rotated})}$$

This can be expressed in the alternate form:

$$\sigma_j = \sum_k a_{j,k} \mu_k + b_j \quad (\text{for some panels } j, \text{ those with rotated normals})$$

Substituting such relationships into the matrix system of equations, and moving those terms involving unknown doublet strengths from the right-hand side to the left-hand side, results in a modified system of equations, but still involving only the unknown doublet strengths:

$$\sum_{j=1}^N A_{i,j} \mu_j + \sum_{\text{some } j} B_{i,j} \sum_k a_{j,k} \mu_k = - \sum_{\text{remaining } j} B_{i,j} \sigma_j - \sum_{\text{some } j} B_{i,j} b_j \quad (\text{for } i = 1 \text{ to } N)$$

Lifting-Type Wake (NTYPE=11) Networks

Lifting-type wakes are shed from the trailing edges of lifting-type solid-surface networks (NTYPE=2) used to model wings, keels, rudders, etc. The wakes must be explicitly modeled in order for the surfaces to generate circulation or lift. Only a finite portion of the wakes are paneled. Wake networks should extend sufficiently far downstream so that their truncation does not significantly influence the flow upstream in the vicinity of the configuration.

A wake network may also terminate along the leading edge of a second, more downstream lifting surface. This approach is used to model coplanar lifting surfaces, such as a wing and a tail, or a keel and a rudder. The terminated wake's doublet strength is implicitly captured by the downstream surface's singularity strengths, as well as in the wakes shed by the downstream surface itself. More details are described in the separate section covering coplanar wakes.

Wake networks should be paneled with network edge 4 running along the trailing edge of the lifting surface from which it is shed. The streamwise panel edges (i.e., the trailing vortices) ideally lie along flow streamlines. In practice this is difficult if not impossible to accomplish, as exact flow streamlines are not known in advance. But approximations to exact streamlines usually suffice. For example, an isolated wing wake may be paneled using straight trailing vortices, i.e., a flat wake with no contraction or rollup. More complicated situations may arise, for example for fully appended yachts, where slender body theory can be applied to the hull and bulb to provide approximate streamlines for generating wake networks shed from the keel, rudder, winglets, etc.

Doublet-only networks (no sources) are used for the wakes. Boundary conditions for wakes require that there be no discontinuity in pressure or normal velocity across the wake. To satisfy these requirements exactly requires solution of a nonlinear set of equations. In SPLASH, as in many other panel codes, simplifying assumptions are made to linearize the wake boundary condition. The result is that for any streamwise column of wake panels, the doublet strength is assumed to be constant, and to be given by the difference in doublet strength between configuration trailing edge upper and lower wake shedding panels. Wakes therefore do not introduce any additional unknown singularity strengths:

$$\mu_{wake} = \mu_{te,upper} - \mu_{te,lower}$$

Upper and lower orientation of the wake network is critical, as it determines which lifting surface trailing edge panel is the upper wake shedding panel and which surface panel is the lower wake shedding panel. For a wake network with its upper surface oriented in the same direction as the upper surface of the lifting surface, the lifting surface upper trailing edge panel is the upper wake shedding panel, and the lifting surface lower trailing edge panel is the lower wake shedding panel. Conversely, for a wake network with its upper surface oriented in the same direction as the lower surface of the lifting surface, the lifting surface lower trailing edge panel is the upper wake shedding panel, and the lifting surface upper trailing edge panel is the lower wake shedding panel.

An automated search algorithm within SPLASH can be called upon to determine wake shedding information. The automated search algorithm, however, is not fool proof and may not always produce the correct results. The correct wake shedding information can, and normally should, be specified through optional user inputs which will override information determined by the automated search algorithm.

For the purpose of non-lifting calculations (for force and moment corrections, which are discussed later), lifting wake networks (NTYPE=11) are ignored.

Free-Surface (NTYPE=1) Networks

Only a finite portion of the free-surface, in the vicinity of the configuration and its free-surface wake, is paneled. How large a portion depends on the application. For typical yacht or ship applications, one or two boat lengths usually suffices. A typical free-surface panelization is shown in Figure 4.

**Wave Far Field Radiation Boundary Conditions (KDMP=0)
Applied to Outer Boundary (Shaded) Free-Surface Panels Only**

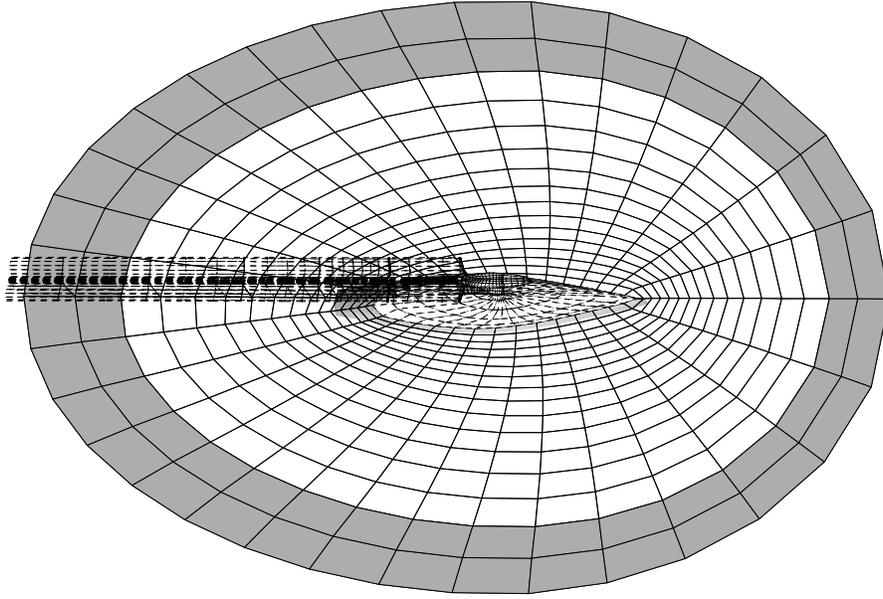


Figure 4 SPLASH Free-Surface Panelization for IACC Yacht

The exact nonlinear free-surface boundary condition can be written as:

$$\frac{U_{boat}^2}{2g} \frac{\partial C_p}{\partial s} + \frac{V}{(U^2 + V^2 + W^2)^{1/2}} = 0$$

Here, g is the acceleration due to gravity constant, and $\partial/\partial s$ denotes a derivative along a streamline. This boundary condition is exact only if applied on the actual free-surface. SPLASH uses a linearized approximation to the exact nonlinear free-surface boundary condition, and applies it on panels which may only approximate the actual free-surface. The linearization is about a basis flow, this being the flow which is obtained when all free-surface panels are treated as solid and fixed. The linearized free-surface boundary condition is:

$$\frac{U_{boat}^2}{2g} \frac{\partial C_p}{\partial s_o} + \frac{V}{(U_o^2 + V_o^2 + W_o^2)^{1/2}} = 0$$

where

$$C_p = 1 + (U_o^2 + V_o^2 + W_o^2) - 2(U_o U + V_o V + W_o W)$$

The basis flow quantities are those denoted by $()_o$. The free-surface boundary condition in this form is very useful. For flat free-surface panelizations, it yields the classical zero-Froude-number or double-body-flow linearized free-surface boundary condition. If, however, the user can arrange that free-surface panels are located at their computed elevations (or nearly so), then full nonlinear results are recovered (or nearly so). This can be accomplished using SPLASH and

its companion panelization package ACCPAN together, in an iterative solution and model update process.

For free-surface flow solutions, the above linearized form of the pressure coefficient C_p is used on the solid model surface panels as well as on the free-surface panels. This is critical to calculating the final forces and moments acting on the configuration which are found by integrating the pressures acting on the solid model surface panels.

The free-surface pressure gradient term $\partial C_p / \partial s_o$ is computed using streamwise upwind (one-sided) panel-to-panel finite difference formulae which can account for arbitrary free-surface panel orientation (and which assume the basis flow is tangent to the panel):

$$\frac{\partial C_p}{\partial s_o} = \frac{\bar{U}_o \frac{\partial}{\partial \xi} + \bar{W}_o \frac{\partial}{\partial \zeta}}{(U_o^2 + V_o^2 + W_o^2)^{1/2}} C_p$$

The contravariant velocities are given by:

$$\begin{aligned}\bar{U}_o &= U_o \xi_x + V_o \xi_y + W_o \xi_z \\ \bar{W}_o &= U_o \zeta_x + V_o \zeta_y + W_o \zeta_z\end{aligned}$$

The free-surface boundary condition in this form is applied to the external (upper) side of free-surface panels (which face downward). The internal zero-perturbation potential boundary condition is applied to the internal (lower) side of free-surface panels (which face upward). The interior of surface piercing portions of the configuration along with the region on the other side of the free-surface (where air and the dry portion of the configuration would otherwise be located) thus form a single combined region of zero internal perturbation. Any flow around the outer edge of the finite free-surface model is neglected. To minimize any edge flow, and its effect on the configuration, it is important to locate the free-surface outer boundary a sufficient distance away from the configuration.

Due to the formulation of the basis flow solution and the linearization of the free-surface boundary conditions, the free-surface pressure coefficient gradient, $\partial C_p / \partial s_o$, depends on panel doublet strengths only, and not on panel source strengths. On the other hand, the vertical velocity V in the free-surface boundary conditions depends mostly on the local panel source strength (at least, as long as free-surface panels retain some horizontal aspect and do not become too wall-sided).

The free-surface boundary condition can therefore be reduced to a form where the local panel source strength can be expressed as a linear combination of the local doublet strengths (those involved in the finite difference formula for the pressures and free-surface pressure gradients), similar in form to that previously presented for the more accurate deflected thick airfoil surface boundary condition. As with the previous deflected airfoil boundary condition, the free-surface boundary condition thus allows the unknown free-surface panel source strengths in the solution matrix to be replaced by a linear combination of unknown doublet strengths, and the final doublet-only solution matrix structure is retained.

In the event, however, that a free-surface panel does become too wall-sided (if the vertical component of the panel normal is less than a specified value), then the size of the solution matrix is increased to include that panel's source strength as an additional unknown (in addition to its unknown doublet strength), and to explicitly include that panel's free-surface boundary condition as the corresponding additional equation (in addition to the standard zero-internal-perturbation boundary condition).

There are some instances where the desired basis flow velocity may not be completely tangent to a free-surface panel. This may occur in the vicinity of an immersed transom, where the predicted free-surface shape may not drop completely to the bottom edge of the transom. In such cases the user may specify that the basis flow is tangent to the predicted free-surface shape, rather than tangent to the actual free-surface panels (which may have been adjusted during panel model generation so as to directly connect to the bottom edge of the transom). As a result, the basis flow is no longer completely tangent to the free-surface panel, and the pressure on the panel will thus depend on panel source strength and not just on surface gradients of doublet strength. However the source dependencies should remain rather small and are not accounted for in the SPLASH free-surface boundary conditions.

Panel-to-panel neighbor relationships for computing free-surface pressure gradients are initially the same as velocity neighbor relationships for computing doublet strength gradients. Situations may arise where this may be inappropriate. Through optional user input, changes may be made to just the pressure gradient neighbor relationships without affecting the velocity neighbor relationships.

Wave far field boundary conditions are applied to panels at or near the outer boundary of the finite free-surface model. Two approaches are available. The preferred approach is to use wave radiation. On inflow panels (panels where the basis flow enters the modeled portion of the free-surface), no waves are permitted. On outflow panels (panels where the basis flow leaves the modeled portion of the free-surface), the standard free-surface boundary conditions are applied. An older approach, which is now mostly obsolete, is to use wave damping. Here, the number of points used to upwind the free-surface pressure gradient is reduced as the outer boundary is approached, regardless of inflow or outflow considerations. For both the wave radiation and the wave damping approaches, panels at or near the outer boundary of the free-surface model must be identified as such by the user.

Separated Base Flow (NTYPE=3) Networks

One use of separated base flow surface networks is to cover the base region of a bulb with a pointed but truncated trailing edge, where a flow singularity would arise if the pointed trailing edge was retained. The singularity is avoided, and a more realistic boundary layer displacement thickness or separation effect is modeled, by truncating the bulb (typically at about 95% of its length) or otherwise opening up and paneling the base. This is highly recommended.

Other possible uses of separated base flow surface networks might include over a completely wet transom stern, or as an approximate model for exhaust flow due to an aft facing jet.

For inviscid potential flow it is not possible to calculate all flow properties, e.g., total pressure, within the separation region and its wake. For this reason, hydrodynamic pressure forces acting on these surfaces are not included in overall total configuration forces and moments.

The default boundary condition applied to separated base flow panels is an external zero perturbation potential boundary condition. In terms of total potential, this is:

$$\Phi = \Phi_{\infty} = \bar{V}_{\infty} \cdot \bar{x}$$

Other specified values for the total potential may be appropriate for certain situations. Optional user input is available to specify other values of total potential on these types of networks.

As usual, the internal zero-perturbation potential boundary condition is applied, together with the external boundary condition. The doublet strengths for these panels may then be determined in advance:

$$\mu = (\Phi_{\text{specified}} - \Phi_{\infty}) / 4\pi$$

With the doublet strength determined, the source strength instead becomes the unknown quantity for these panels in the resulting linear matrix system of equations to be solved.

Separated Base Flow Wake (NTYPE=12) Networks

The wake region downstream of separated base flow surface panels must be enclosed by separated base flow wake networks (and/or by adjacent solid-surface or free-surface networks).

Separated base flow wake networks are shed from separated base flow panels, often at panel edges at trailing edge junctures where solid-surface panels meet separated base flow panels. They are otherwise similar in operation to lifting-type wake networks.

For the purpose of non-lifting calculations (for force and moment corrections, which are discussed later), the influence of separated wake networks (NTYPE=12) are still included.

Wake Jumps

Using the zero-internal-perturbation boundary condition, panel in-plane surface velocities are directly related to the local panel-to-panel gradients of doublet strength. The latter are represented and calculated using panel-to-panel finite difference stencils.

In some stencils, adjacent panels may be separated by wake panels that have been shed from a more upstream surface. For example, this typically occurs on the hull and free-surface, downstream of a keel, if the root of the keel wake is modeled as remaining attached to and following the contour of the downstream hull and free-surface centerline. In this instance the panel-to-panel finite difference formulae for the doublet gradients and velocities on the hull and free-surface must take into account the jump in doublet strength that occurs across the keel wake panels which separate otherwise adjacent hull or free-surface panels. This example is illustrated in Figure 5.

doublet gradient between free-surface panels includes jump across keel/rudder wake

$$(\partial\mu/\partial\xi)_i = [\mu_{i+1} - (\mu_{i-1} + \Gamma_{\text{wake}})] / (2\Delta\xi)$$

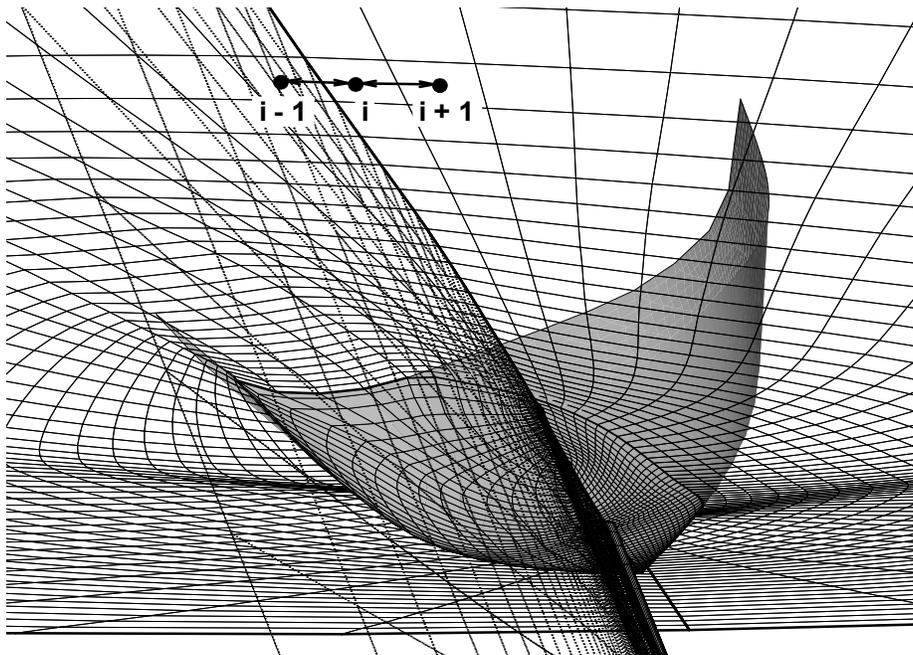


Figure 5 Wake Jumps

An automated search algorithm within SPLASH can be activated to determine wake jump information. The user can also specify wake jump information through optional inputs which override information determined by the automated search algorithm. It is good practice for the user to specify the all wake jump information, as the automated search algorithm may not always identify the correct information.

Coplanar Lifting Surface and Wake Systems

Consider two or more lifting surfaces that are coplanar, and one surface is upstream of the other (for example, a keel and rudder). Assuming a flat wake panelization, the wake shed from the upstream surface (keel) trailing edge will impinge upon the downstream surface (rudder) leading edge. One way to deal with this would be to deflect the wake from the upstream surface a small amount, ϵ , away from (above or below) the downstream surface and its wake. This approach is illustrated in the top portion of Figure 6. In the limit as ϵ goes to zero, it is possible to treat the upstream wake panels as coincident with the downstream surface (upper or lower) and its wake. This approach is illustrated in the bottom portion of Figure 6.

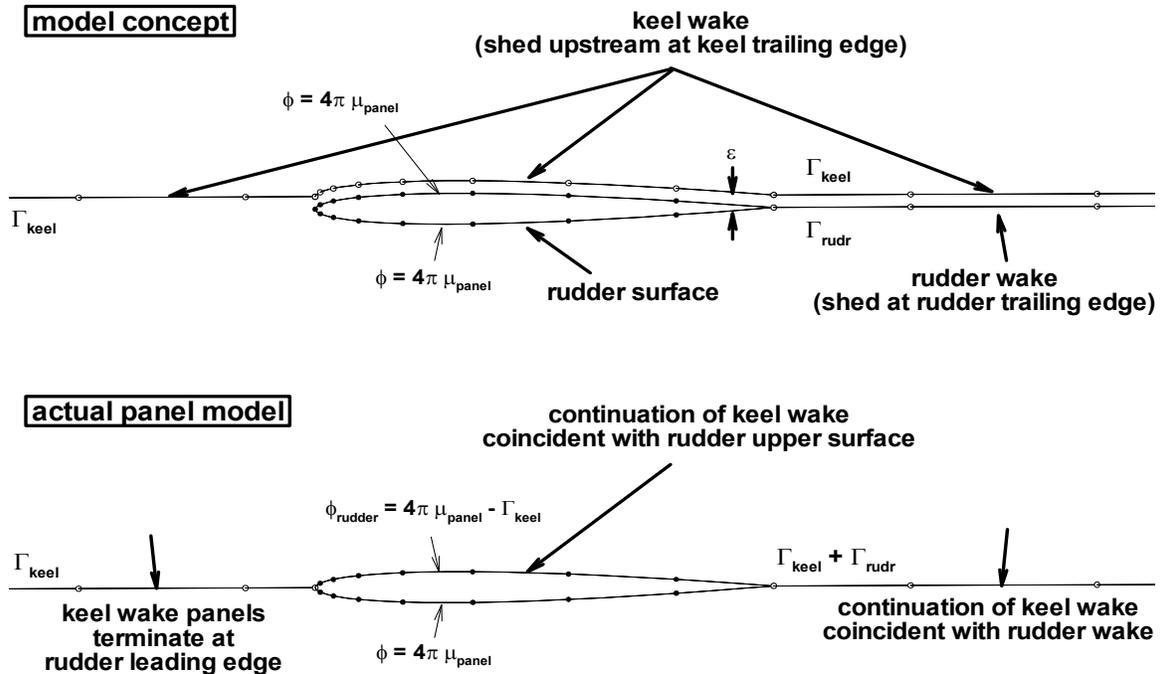


Figure 6 Coplanar Lifting Surface and Wake System (2-D View)

The latter approach, which gives rise to a coplanar lifting surface and wake system, is easy to implement and numerically robust. The upstream wake panelization is merely terminated at the downstream surface leading edge.

The inputs must also identify the panels on the upper or lower side of the downstream lifting surface with which the continuation of the upstream wake is coplanar. On these panels, the surface potentials will be corrected for the jump in potential across the wake ($-\Gamma_{keel}$ in Figure 6b). This directly impacts potentials and flow velocities on the downstream surface.

Conveniently, any wake shed from the downstream surface's own trailing edge implicitly captures the full coplanar wake doublet strength (due to both the upstream and downstream lifting surface wakes), by way of the impact of the coplanar wake model on the doublet strengths on the downstream surface wake's upper and lower wake shedding (trailing edge) panels.

Free-Surface Waterline Boundary Conditions

In the free-surface boundary conditions, the upwind pressure gradients are calculated using panel-to-panel finite difference formulae. As the finite difference stencils proceed upstream, some may encounter and cross over waterline edges (panel edges shared between free-surface panels and adjacent, neighboring, solid configuration panels, such as hull panels). The crossing of the waterline, and the subsequent appearance of solid configuration surface panels in the free-surface pressure gradient stencils, require special treatment.

Three primary options are available for the waterline boundary conditions, depending on configuration surface topology and local flow details at the waterline. The three options are:

default, dry chine; wet chine; and dry or partially-wet, immersed transom. Whenever the free-surface stencil crosses the waterline, the waterline edge is checked for the type of waterline boundary condition to be used.

In general, free-surface waterline boundary conditions require that the hull (or other solid) and free-surface panels share a common edge along the waterline, and that they are “naboring panels” for the purposes of computing velocities and pressures (i.e., doublet gradients), and the upwind gradients thereof.

The free-surface waterline boundary condition may be prorated by the user amongst the three different options. For example, with some panelization schemes, the waterline may at first move downstream, along the side of the hull, and then abruptly turn downward upon reaching the edge of an immersed transom. If no effort is made to redistribute the waterline panel corner points so as to exactly capture the point where the waterline intersects the transom, then one of the waterline panel edges will be partially along the side of the hull and partially along the transom. For that edge the corresponding waterline boundary condition would be appropriately prorated between the dry chine and dry transom options.

Default Dry Chine Waterline Boundary Condition

The dry chine free-surface waterline boundary condition should be applied wherever the waterline is produced by the otherwise smooth flow of water at the free-surface. The free-surface attaches or detaches smoothly from the solid surface of its own accord, and not due to the sudden presence of a sharp edge such as a chine or transom. The dry chine option is the default and applies if no other type of waterline boundary condition is specified for the edge in question.

For displacement hull sailing yachts, this is the option typically applied along the entire hull waterline, except along any immersed transom. For planing flat plates, this option is recommended for use along the leading edge.

When a free-surface pressure gradient stencil crosses a waterline edge subject to the dry chine boundary condition, the stencil includes the pressure on the adjacent solid configuration surface panel, and then terminates (even if the order of the corresponding finite difference formula is reduced). The flow is smooth and regular, and without any edge effects, and no special accounting is needed to balance the elevation versus the hydrostatic and hydrodynamic pressures at the waterline itself.

Dry or Partially Wet Immersed Transom Waterline Boundary Condition

The dry or partially wet immersed transom option is used wherever the flow of water at the free-surface has departed from the solid surface in a more or less smooth fashion, but due to an abrupt termination of the solid surface. Free-surface panels should be arranged as if they were shedding from the edge of the immersed transom. This may require a trough or depression of free-surface panels in the region downstream of the transom.

For displacement hull sailing yachts, this is the option applied along any dry or partially wet immersed transom. For planing flat plates, this option is recommended for use along the trailing edge.

When a free-surface stencil crosses a waterline edge subject to the dry or partially wet transom boundary condition, the stencil will include the hydrodynamic pressure required at “the elevation at which the free-surface leaves the edge”. The stencil, if not then completely filled, will also include the solid surface panel pressure. The stencil will then terminate. This treatment weakly satisfies at the transom edge both the atmospheric free-surface pressure condition and the hull flow tangency boundary condition.

Due to the weak satisfaction of the transom boundary conditions, and due to the discretization of the panel model problem, the calculated free-surface elevation may not drop completely down to the bottom edge of the transom, especially at lower speeds. Depending on additional user input options, “the elevation at which the free-surface leaves the edge” may be the actual transom edge elevation, or it may be based on a computed value (this from the previous step in a series of iterative calculations). It may also be a special, Froude-scaling-dependent blending of these two options, a capability exploited by the nonlinear, iterative calculations using SPLASH and its companion panelization package ACCPAN.

Wet Chine Waterline Boundary Condition

The wet chine option is used wherever the flow of water at the free-surface has departed from the solid surface in a possibly non-smooth fashion due to the presence of a sharp edge, such as along the side edges of a planing flat plate or ski.

Appropriate to its name, this option might also be used for a wet chine hull at semi-planing or planing conditions. This type of application has yet to be investigated using SPLASH.

When a free-surface stencil crosses a waterline edge subject to the wet chine boundary condition, the stencil will include the pressure required at “the elevation at which the free-surface leaves the edge”, and then terminate. The solid surface panel pressure is not included in the stencil. This allows the flow velocity and direction on the free-surface and on the solid surface to be quite different, even if separated only by a small region of extreme velocity and pressure gradient at the edge itself.

Fully Wetted Immersed Transom Models

Not much has been developed regarding SPLASH panel models with fully wetted immersed transoms. One approach would be to panel the wetted transom using separated base flow panels, and to enclose the fluid (the water) downstream of the transom between the downstream free-surface and a separated-flow wake surface (this being shed underwater from the immersed transom edge). The downstream free-surface would connect to the top of the transom at the undisturbed surface elevation. Waterline boundary conditions would be applied along the edges where the top row of transom panels meets the first row of downstream free-surface panels.

Transverse Boundary Conditions for Adjacent Surfaces with Mismatched Panels

In general, best results are obtained when all panel edges are shared entirely between two, and only two, neighboring panels. For complex configurations, it may be quite difficult to generate models meeting this condition everywhere. This is particularly true at junctures where keel or rudder appendages meet a hull or free-surface. If appendages are more or less randomly inserted along the centerline of hull and free-surface panelizations that were otherwise generated without taking the appendages into account, then the ability to correctly prorate the hull and free-surface

panel edge conditions can be critical for reliable nonlinear sink and trim and free-surface calculations. The transverse boundary conditions were developed to treat such situations.

The transverse boundary conditions were developed to treat adjacent surfaces that are more or less perpendicular to each other. The adjacent surfaces need not be completely perpendicular, but the more so, the better. Use of transverse boundary conditions for adjacent surfaces which are more or less tangent to each other was not anticipated, has not been investigated, and is not recommended at this time.

The basic concept behind the transverse boundary condition is illustrated in Figure 7. This shows a portion of a model for a fully appended hull. This was generated for SPLASH by its companion panelization package ACCPAN. Some hull panels along the centerline that would otherwise neighbor to each other edgewise are instead separated, in whole or partially, by the rudder surface. Centroids of affected hull panels are indicated by the green circles in the figure. The transverse boundary condition inputs are used to construct flow values at the hull panel edge midpoints, the blue circles in the figure, which can then be used for alternate stencil construction. The edge midpoint flow values are determined according to user-specified linear functions representing the interpolation and extrapolation, and averaging along the edge, of corresponding flow values from the adjacent rudder panel centroids, the red circles in the figure.

The transverse boundary conditions are therefore simply a means to inform SPLASH that the standard panel-to-panel finite difference stencils should be interrupted, and should instead include an edge midpoint value, this being a user-specified linear combination of corresponding values on some other, usually adjacent, group of panels.

Stencils for one of the hull panels adjacent to the rudder are shown as dashed lines in Figure 7. Due to the presence of the rudder, the stencil is interrupted and cannot communicate as usual with the hull panel on the other side of the rudder. The dashed lines through the rudder panel centroids show the stencils that were selected to construct the user-specified function expressing the required hull edge midpoint value as a linear combination of values at rudder panel centroids.

In some cases, the user-specified linear combination may also include any jumps across wakes which separate the panels in question from the adjacent surface (except for coplanar wakes, which are automatically accounted for). If, for example, a keel and its wake are present but not coplanar with the rudder, then the jump across the keel wake between the hull panel and the rudder panels must be accounted for in the user-specified linear combination. This can be accomplished by directly including contributions from the keel root upper and lower trailing edge wake shedding panels in the user-specified linear combination function.

Using bilinear interpolation and extrapolation, and an edge-averaged approach, the sum of the coefficients of the user-specified linear combination should add up to the fractional part of the panel edge that is overlapped by, and/or otherwise separated from its neighboring panel by, the adjacent surface. Based on this fraction of panel edge that is overlapped and/or separated from its neighboring panel, final stencils for the panel will be appropriately prorated combinations of the original (uninterrupted) and modified (interrupted) stencils.

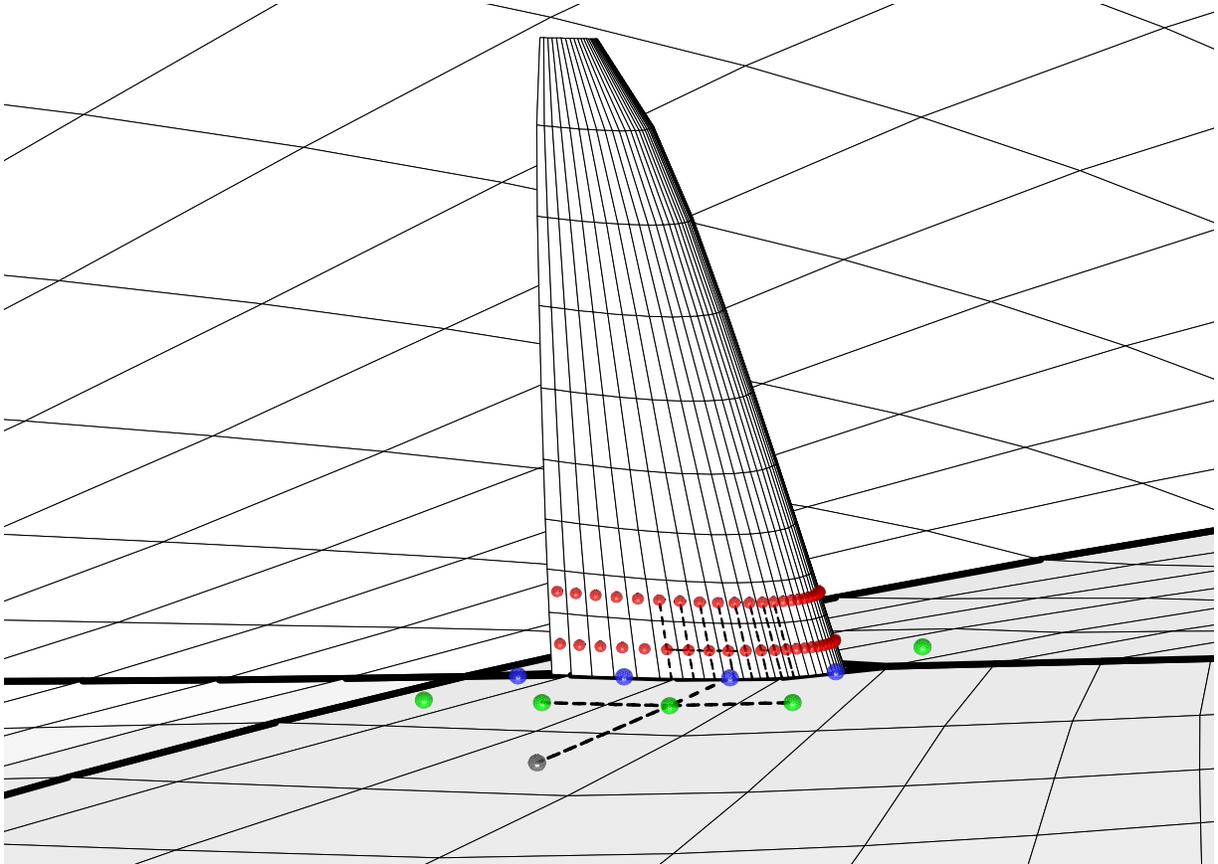


Figure 7 Transverse Boundary Condition Description: Green = Hull Panels Affected by Transverse Surface; Blue = Imaginary Hull Panel Edge Midpoint Values of Potential, Velocity, Pressure, Etc.; Red = Rudder Transverse Surface Panel Centroid Values Used to Construct the Extrapolations to the Imaginary Panel Midpoints

This prorating capability can be critical for reliable nonlinear sink and trim and free-surface results, if appendages are more or less randomly inserted along the centerline of hull and free-surface panelizations that were otherwise generated without taking the appendages into account.

Standard wake jumps, i.e., those between otherwise neighboring panels, must be specified for any uninterrupted portions of stencils, as though no surface were intervening. For example, in Figure 7, for the hull panel extending forward of the rudder leading edge, a full jump across the keel wake would be specified (assuming here a coplanar keel and rudder). Likewise, for the hull panel extending aft of the rudder trailing edge, a full jump across the rudder wake would be specified. If these were in fact the same panel (for example, using a much shorter rudder chord), then the jump would be prorated between the keel and rudder wakes, according to the ratio of hull panel length upstream of the leading edge or downstream of the rudder trailing edge, respectively, to the total hull panel length both upstream of the leading edge and downstream of the trailing edge.

The user must input transverse boundary condition data on a panel-by-panel basis. This input includes: the panel and side on which stencil is interrupted; the panels on the adjacent surface which are involved in the interpolation and extrapolation and edge-averaging to obtain the

midpoint value along the interrupted panel edge; the corresponding coefficients of the linear combination made up of flow values at the adjacent surface panel centroids, and possibly including any wake jumps between them and the panel in question (but excluding coplanar wakes, which are automatically accounted for); and, if the adjacent surface has not completely intervened, the panel's normal one-to-one neighbor, and any wake jumps between it and the panel in question.

Specifying all the transverse boundary condition data can be tedious. The companion panelization package ACCPAN produces all of the required data, automatically, for any hull or free-surface panel stencils interrupted by keel or rudder surfaces.

On the other hand, ACCPAN does not specify any transverse boundary conditions for keel or rudder panels adjacent to the hull or free-surface. With no one-to-one neighboring panels available, and if no transverse boundary conditions are specified, then one-sided difference stencils will be constructed on the foil root panels. But foil panelizations are usually well organized, and not highly skewed, and free-surface boundary conditions are usually not involved, so the resulting one-sided stencils at the foil roots are deemed sufficient.

Forces and Moments

Final forces and moment are computed by simple panel pressure integration. Total forces and moments acting on the configuration do not include any contributions from free-surface panels. For separated base flow panels, only the contributions due to hydrostatic pressure are included in the totals, whereas the contributions due to hydrodynamic pressure are not. The calculations assume flat and constant-pressure panels.

For cases with free-surface panels at non-zero forward speed, the linearized form of the pressure coefficient is used for the force and moment calculations. If the user can arrange that free-surface panels are located at their computed elevations (or nearly so), then full nonlinear results are recovered (or nearly so). This can be accomplished using SPLASH and its companion panelization package ACCPAN together, in an iterative solution and model update process.

SPLASH computes the forces and moments due to hydrostatic pressures acting over all the configuration panels. They are printed in the standard output file, as Fr^2 times the usual force and moment coefficients. However they are not written to the force and moment iteration history file, as it is assumed that more accurate hydrostatic calculations are available elsewhere. This is indeed the case when using the companion panelization package ACCPAN, which itself computes the hydrostatic forces and moments acting over the wetted portion of the configuration database. Because the database typically has higher resolution than the panel model, ACCPAN is expected to yield more accurate hydrostatic calculations.

Because fully or partially wetted immersed transoms are not paneled, the forces and moments acting on immersed transoms cannot be included in the forces and moments calculated by panel pressure integration. At zero Froude number, the hydrostatic forces and moments acting on an immersed transom may be included in the hydrostatic forces and moments which are being computed by other means. At non-zero Froude number, those forces and moments may be included in the SPLASH hydrodynamic totals via the transom waterline integrals (as described in the following section). ACCPAN adopts these same conventions.

Standard and Transom Waterline Integrals

Waterline integrals may also be included in the total configuration hydrodynamic forces and moments. These account for any mismatch between the final panel edge geometric elevation at the panel model waterline and the final calculated free-surface wave height at the waterline.

In a standard (a.k.a. dry chine) waterline integral, the hull (or other solid surface) waterline panel edge is imagined to move up or down in the plane of the panel and parallel to itself, so as to extend or reduce the wetted area of the panel, from the geometric panel waterline to the final calculated waterline wave height.

In a transom waterline integral, the mismatch between panel elevation and calculated wave height at the transom edge is imagined to be indicative of a partially wetted transom. The wetted transom area is estimated as the area extending vertically upward from the transom panel edge to the calculated free-surface wave height.

In either case, the final waterline integrals are the total contributions of the incremental forces and moments associated with the average pressures operating over the resulting, albeit imaginary, changes in area. The concept is illustrated in Figure 8.

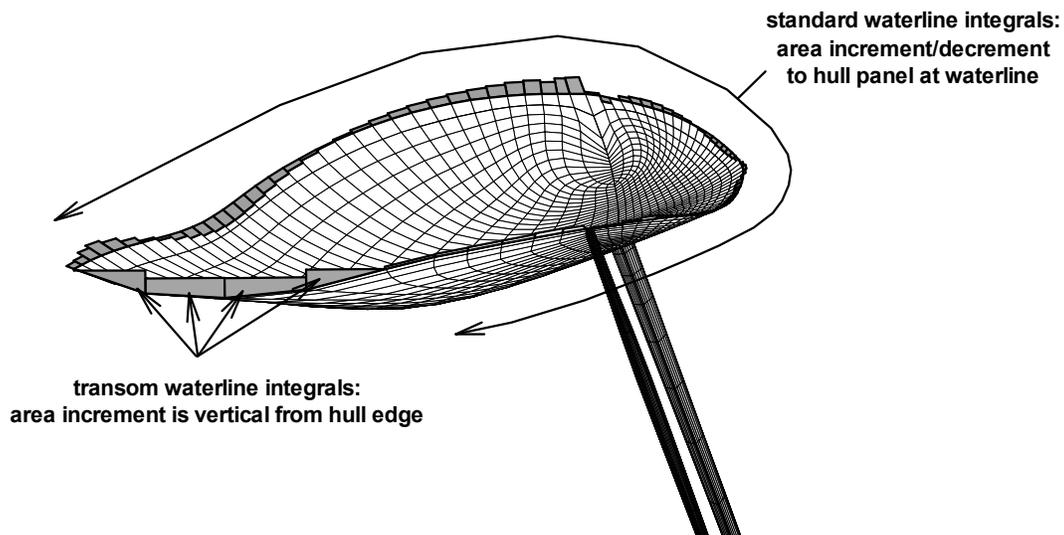


Figure 8 Waterline Integral Conceptualization

For exact nonlinear free-surface solutions, the waterline integral contributions will by definition be zero. The contributions may be significant for fully linearized (flat free-surface panel) results. For partially nonlinear free-surface results, such as those generated using the companion panelization package ACCPAN's option to smooth calculated free-surface elevations prior to updating panel models, the standard waterline integral contributions are expected to be small but non-zero, and to improve force and moment predictions. The transom waterline integrals will also be significant, if partially wetted transoms are treated using fully dry transom panel models, as is the case if using ACCPAN.

Waterline integrals are not computed for zero Froude number cases. Thus, when running a dry transom type of panel model at zero Froude number, there is no accounting by SPLASH for the hydrostatic pressure acting on the transom, even though it may be wet. These hydrostatic pressure forces must therefore be accounted for by other means. For example, using the companion panelization package ACCPAN, the transom forces and moments are included in the ACCPAN-computed hydrostatic totals only for cases at zero Froude number.

Forces by Wake Integration

Forces due to aerodynamic lift and associated lift-induced drag are computed by wake integration in the Treftz plane at downstream infinity. The locations of the downstream edges of trailing wake networks are assumed to represent the locations of the trailing vortices in the Treftz plane.

Lift vectors in the Treftz plane are computed from trailing wake sheet circulation strength, and are directed perpendicular to the trailing vortex sheet. Lift-induced drag is accounted for by assuming that the induced downwash at the bound lifting lines due to the trailing wake vortices is one half of the downwash computed in the Treftz plane. The rotation of the lift vectors relative to the freestream direction due to the downwash at the bound lifting lines produces the lift-induced drag.

The wake integration algorithm relies on a double-body image of the wake vortex system, that is, the actual wake system and its image on the “other side” of an undisturbed (flat) free-surface. This flat free-surface approximation may render the wake integration algorithm invalid except for zero Froude number cases.

Steady Force and Moment Post-Processing Corrections

Hydrodynamic Leakage Corrections:

A consequence of inviscid, incompressible potential flow theory is that a closed, non-lifting body in an unbounded steady flow experiences zero hydrodynamic drag. This includes cases with a free-surface at zero Froude number. Due to panel discretization errors, calculations under such conditions can still yield small non-zero hydrodynamic drag or side force. Experience has shown that the small but non-zero force coefficients calculated under such conditions may be used as “hydrodynamic leakage corrections”. Computed at zero Froude number and at non-lifting conditions, the corrections provide an estimate of the panel discretization errors that, when subtracted from standard calculation results, may enhance prediction accuracy.

Hydrodynamic leakage corrections are computed at zero Froude number. In certain situations, an upright leakage correction alone might suffice. In practice, it is often computed as a function of heel angle. The corrections are simply the SPLASH-computed hydrodynamic axial force and side force coefficients for zero boat speed cases at non-lifting conditions (at zero yaw, tab and rudder, and with all lifting-surface type wakes removed) at the desired heel angles.

Special care must be taken for cases with dry immersed transoms. If the transom is immersed for any of the zero Froude number cases used to calculate the hydrodynamic leakage corrections, then the model body is not closed, and the assumption of zero hydrodynamic drag is no longer correct. Hydrodynamic leakage corrections are not appropriate under such circumstances, and

should not be applied to any of the test point results (or to results for other models to be involved in boat-to-boat comparisons).

At-Rest Hydrostatic Corrections:

The total dynamic forces and moments reflect not only the calculated hydrodynamic contributions but also changes in the hydrostatic forces and moments due to nonlinear sink, trim and free-surface shape. It is often convenient to subtract the at-rest hydrostatic contributions at zero Froude number from the hydrostatic contributions at forward speeds.

Such “at-rest hydrostatic corrections” serve an additional purpose. At zero Froude number, the hydrostatic axial force and side force should be zero. However, due to panel or database discretization errors, calculations under such conditions can yield small non-zero values. Experience has shown that the small but non-zero forces may be used as at-rest hydrostatic corrections. Computed at zero Froude number, the corrections provide an estimate of the panel or database discretization errors that, when subtracted from standard calculation results, enhance prediction accuracy.

At-rest hydrostatic corrections are computed at zero Froude number, at each heel (and, optionally, each yaw, tab and rudder combination) of interest. As noted previously, the forces and moments due to hydrostatic pressure acting on the paneled portion of the database are often supplied by means other than SPLASH, such as ACCPAN. For zero Froude number cases, the hydrostatic pressure acting on an immersed but unpanelled transom must also be included in the hydrostatic forces and moments (as is the case when using ACCPAN).

Surfing Rudder Corrections:

For many yacht models of interest, it may not be possible to maintain hull and free-surface panel density in the vicinity of the rudder to the degree required to fully capture the rudder/free-surface interaction. This results in a poor prediction of wave drag due to rudder thickness. Experience has shown that “surfing rudder corrections” computed for special cases can be used to subtract from the regular calculations the incorrectly predicted wave drag due to rudder thickness.

Surfing rudder corrections are obtained as a function of boat speed. In certain situations upright surfing rudder corrections alone might suffice. In practice, surfing rudder corrections are often computed as a function of heel angle as well as boat speed. The corrections are computed as the difference in hydrodynamic forces between a rudder-on case and a rudder-off case, both at non-lifting conditions (zero yaw, tab and rudder, and with all lifting-type wakes removed). Both cases are run at the boat speed and heel angle for which a correction is desired.

Unit Dimensions

SPLASH assumes that all inputs are specified using a self-consistent set of unit dimensions. The following are examples of self-consistent unit dimensions:

Physical Quantity	English Units	Metric Units
length	foot (ft)	meter (m)
mass	slug	kilogram (kgm)
time	second (sec)	second (sec)
velocity	ft/sec	m/sec
acceleration	ft/sec ²	m/sec ²
force, weight, displacement	pound (lbf) = slug-ft/sec ²	Newton (N) = kgm-m/sec ²
density	slug/ft ³	kgm/m ³
viscosity	lbf-sec/ft ² = slug/(ft-sec)	N-sec/m ² = kgm/(m-sec)

All angles are input, and the vast majority are output, in degrees.

SPLASH Input/Output Files

Figure 9 shows SPLASH input and output file dependencies. The corresponding ACCPAN filename conventions are also indicated.

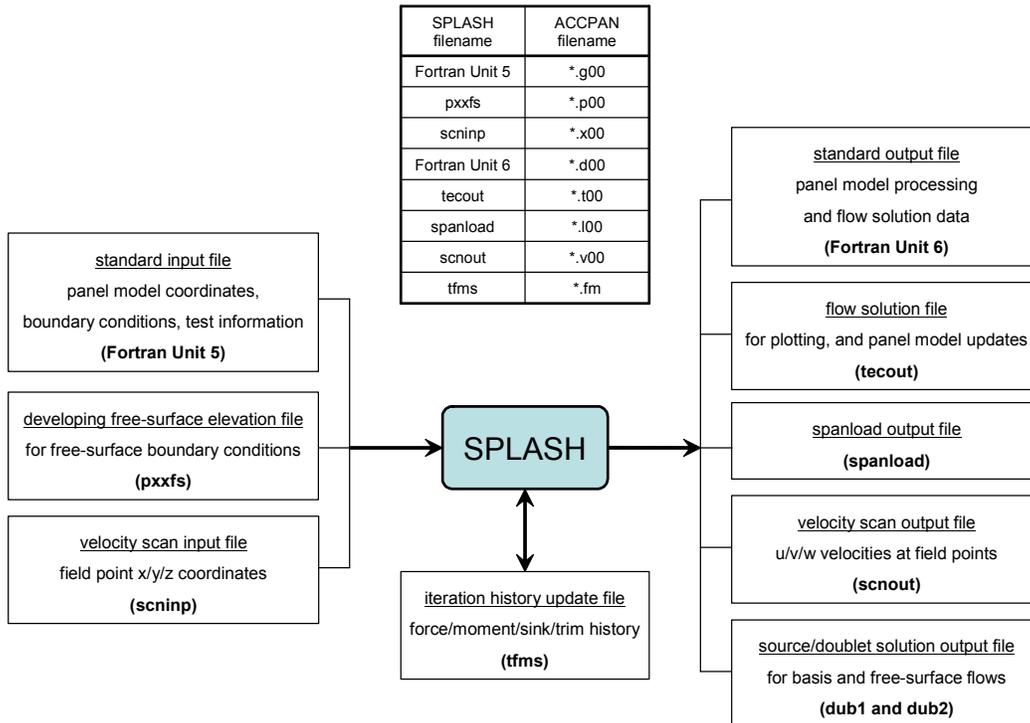


Figure 9 SPLASH Input/Output Files

SPLASH Standard-Input File Format

A slightly abbreviated, sample SPLASH standard-input file is included below, followed by a detailed description of the input format and parameters:

```

mx12-5.1.0.00-5.1.0.00
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  uboat     xlboat     grav      alp      bet      rnf      rff
  6.17329   17.2000   9.80665   4.00000   0.00000   0.00000   0.00000
  heel      sink      trim      xdatum   ydatum   zdatum   dkeel      drudr
  20.00000   0.0676   -0.07686  -0.00001  0.06907  -0.00342  5.00000   4.00000
  density   viscosity
  0.102500E+04  0.121800E-02
  iupvwl    iradbc     iupvbc     ilagbc     xautowl
  1          1          0          0          1.00000
  inrmzero  inrmfrsq   cnorm      iedgzero   iedgfrsq   cedge     inotopp
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  1 1 1 0 0 0 0 0 0 0 0 surf port
  2 2 1 0 0 0 0 0 0 0 0 hull port
  2 2 1 0 0 0 0 0 0 0 0 hull star
  2 3 2 0 0 0 0 0 0 1 0 keel
  2 4 3 0 0 0 0 0 0 1 0 rudr
  2 5 4 0 0 0 0 0 0 0 0 bulb star top
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  3 5 5 0 0 0 0 0 0 0 0 base port top
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  2 7 7 0 0 0 0 0 0 1 0 wing star
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  5 45 45 1 1 1.14166 1
  5 1 3 1 1 5.00000 1
  5 46 48 1 1 5.00000 1

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5	4	4	10	10	1.15619	1								
5	45	45	10	10	1.15619	1								
5	1	3	10	10	5.00000	1								
5	46	48	10	10	5.00000	1								
5	4	4	11	11	1.15914	1								
5	45	45	11	11	1.15914	1								
5	1	3	11	11	5.00000	1								
5	46	48	11	11	5.00000	1								
5	4	4	12	12	1.16409	1								
5	45	45	12	12	1.16409	1								
5	1	3	12	12	5.00000	1								
5	46	48	12	12	5.00000	1								
5	4	4	13	13	1.17197	1								
5	45	45	13	13	1.17197	1								
5	1	3	13	13	5.00000	1								
5	46	48	13	13	5.00000	1								
5	4	4	14	14	1.18325	1								
5	45	45	14	14	1.18325	1								
5	1	3	14	14	5.00000	1								
5	46	48	14	14	5.00000	1								
5	4	4	15	15	1.19747	1								
5	45	45	15	15	1.19747	1								
5	1	3	15	15	5.00000	1								
5	46	48	15	15	5.00000	1								
6	1	24	1	11	4.00000	2								
6	25	48	1	11	4.00000	2								
0														
xhnge1	yhnge1	zhnge1	xhnge2	yhnge2	zhnge2	ihtype								
0.7000	0.0681	-0.0034	0.7050	3.8269	1.3647	1								
8.6500	0.0575	-0.0034	8.9033	2.5285	0.8961	1								
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0								
nptot	i1	i2	j1	j2	ptot									
0														
nab1	i1	i2	j1	j2	ns1	nab2	i1	i2	j1	j2	ns2	nw	jw1	jw2
1	1	45	30	30	3	0	0	0	0	0	0			
2	1	45	30	30	3	0	0	0	0	0	0			
1	1	1	1	30	4	2	45	45	1	30	2			
2	45	45	1	30	2	1	1	1	1	30	4			
1	45	45	1	30	2	2	1	1	1	30	4			
2	1	1	1	30	4	1	45	45	1	30	2			

1	1	45	1	1	1	4	45	1	1	1	1
2	1	45	1	1	1	3	45	1	1	1	1
3	1	45	1	1	1	2	45	1	1	1	1
4	1	45	1	1	1	1	45	1	1	1	1
3	45	45	1	15	2	4	1	1	1	15	4
4	1	1	1	15	4	3	45	45	1	15	2
3	1	1	1	15	4	4	45	45	1	15	2
4	45	45	1	15	2	3	1	1	1	15	4
3	1	45	15	15	3	4	45	1	15	15	3
4	1	45	15	15	3	3	45	1	15	15	3
5	1	48	1	1	1	0	0	0	0	0	0
5	1	1	1	15	4	5	48	48	1	15	2
5	48	48	1	15	2	5	1	1	1	15	4
5	1	48	15	15	3	0	0	0	0	0	0
6	1	48	1	1	1	0	0	0	0	0	0
6	1	1	1	11	4	6	48	48	1	11	2
6	48	48	1	11	2	6	1	1	1	11	4
6	1	48	11	11	3	0	0	0	0	0	0
7	1	18	1	1	1	10	1	18	7	7	3
7	19	33	1	1	1	0	0	0	0	0	0
7	34	51	1	1	1	10	34	51	7	7	3
7	1	39	7	7	3	8	1	39	1	1	1
7	40	46	7	7	3	0	0	0	0	0	0
7	47	51	7	7	3	8	47	51	1	1	1
7	1	1	1	7	4	0	0	0	0	0	0
7	51	51	1	7	2	11	1	1	1	7	4
8	1	39	1	1	1	7	1	39	7	7	3
8	40	46	1	1	1	0	0	0	0	0	0
8	47	51	1	1	1	7	47	51	7	7	3
8	1	51	7	7	3	9	1	51	1	1	1
8	1	1	1	7	4	0	0	0	0	0	0
8	51	51	1	7	2	12	1	1	1	7	4
9	1	51	1	1	1	8	1	51	7	7	3
9	1	39	7	7	3	10	1	39	1	1	1
9	40	46	7	7	3	0	0	0	0	0	0
9	47	51	7	7	3	10	47	51	1	1	1
9	1	1	1	7	4	0	0	0	0	0	0
9	51	51	1	7	2	13	1	1	1	7	4
10	1	39	1	1	1	9	1	39	7	7	3
10	40	46	1	1	1	0	0	0	0	0	0
10	47	51	1	1	1	9	47	51	7	7	3
10	1	18	7	7	3	7	1	18	1	1	1
10	19	33	7	7	3	0	0	0	0	0	0
10	34	51	7	7	3	7	34	51	1	1	1
10	1	1	1	7	4	0	0	0	0	0	0
10	51	51	1	7	2	14	1	1	1	7	4
11	1	2	1	1	1	14	1	2	7	7	3
11	1	2	7	7	3	12	1	2	1	1	1
11	1	1	1	7	4	7	51	51	1	7	2
11	2	2	1	7	2	0	0	0	0	0	0
12	1	2	1	1	1	11	1	2	7	7	3
12	1	2	7	7	3	13	1	2	1	1	1
12	1	1	1	7	4	8	51	51	1	7	2
12	2	2	1	7	2	0	0	0	0	0	0
13	1	2	1	1	1	12	1	2	7	7	3
13	1	2	7	7	3	14	1	2	1	1	1
13	1	1	1	7	4	9	51	51	1	7	2
13	2	2	1	7	2	0	0	0	0	0	0
14	1	2	1	1	1	13	1	2	7	7	3
14	1	2	7	7	3	11	1	2	1	1	1
14	1	1	1	7	4	10	51	51	1	7	2
14	2	2	1	7	2	0	0	0	0	0	0
15	1	40	1	1	1	0	0	0	0	0	0
15	1	40	10	10	3	0	0	0	0	0	0
15	1	1	1	10	4	15	40	40	1	10	2
15	40	40	1	10	2	15	1	1	1	10	4
16	1	40	1	1	1	0	0	0	0	0	0
16	1	40	10	10	3	0	0	0	0	0	0
16	1	1	1	10	4	16	40	40	1	10	2
16	40	40	1	10	2	16	1	1	1	10	4
0											
ngp1	i1	i2	j1	j2	ns1	ngp2	i1	i2	j1	j2	ns2

```

0
nwak  j1  j2  nwku  i1  i2  j1  j2  nsu  nwkl  i1  i2  j1  j2  nsl
17  1  11  5  48  48  1  11  2  5  1  1  1  11  4
18  1  4  5  48  48  12  15  2  5  1  1  12  15  4
19  1  11  6  48  48  1  11  2  6  1  1  1  11  4
20  1  7  7  51  51  1  7  2  0  0  0  0  0  0
21  1  7  8  51  51  1  7  2  0  0  0  0  0  0
22  1  7  9  51  51  1  7  2  0  0  0  0  0  0
23  1  7  10  51  51  1  7  2  0  0  0  0  0  0
24  1  7  11  1  1  1  7  4  0  0  0  0  0  0
25  1  7  12  1  1  1  7  4  0  0  0  0  0  0
26  1  7  13  1  1  1  7  4  0  0  0  0  0  0
27  1  7  14  1  1  1  7  4  0  0  0  0  0  0
28  1  10  15  40  40  1  10  2  15  1  1  1  10  4
29  1  10  16  40  40  1  10  2  16  1  1  1  10  4
0
nnwj  i1  i2  j1  j2  ns  nw  jw1  jw2  rnwj
3  16  1  15  15  3  -17  1  1  1.00000
4  30  45  15  15  3  17  1  1  1.00000
3  1  1  15  3  4  -17  1  1  1.00000
4  45  45  15  3  2  17  1  1  1.00000
1  1  1  3  30  4  19  1  1  1.00000
2  45  45  3  30  2  -19  1  1  1.00000
7  34  51  1  1  1  18  4  4  1.00000
10 34  51  7  7  3  -18  4  4  1.00000
7  47  51  7  7  3  29  1  1  1.00000
8  47  51  1  1  1  -29  1  1  1.00000
9  47  51  7  7  3  -28  10 10  1.00000
10 47  51  1  1  1  28  10 10  1.00000
0
nncw  i1  i2  j1  j2  nwcw  j1  j2  rncw
6  25  48  1  11  17  1  11  1.00000
0
nwl n  i1  i1  j1  j2  ns  rwlnt  nwltyp
3  1  45  1  1  1  1.00000  1
4  1  45  1  1  1  1.00000  1
0
ntbc  i1  i1  j1  j2  ns  rwetch  rdrytr
0
iedgpts  iedgcps  iedgcpv
0  0  0
nabc ipbc jpbc nsbc
nnab inab jnab nsnb (if nabc != 0)
nabc iabc jabc rabc (if nabc != 0)
nwbc jwbc rwbc (if nabc != 0)
3  23  15  3
4  23  15  3
5  15  1  0.003493
5  16  1  0.063545
5  17  1  0.140158
5  18  1  0.138609
5  19  1  0.112770
5  20  1  0.090995
5  21  1  0.072337
5  22  1  0.055087
5  23  1  0.037575
5  24  1  0.019845
5  25  1  0.004564
5  15  2  -0.001066
5  16  2  -0.019390
5  17  2  -0.042754
5  18  2  -0.042268
5  19  2  -0.034376
5  20  2  -0.027728
5  21  2  -0.022033
5  22  2  -0.016770
5  23  2  -0.011430
5  24  2  -0.006031
5  25  2  -0.001387
0  0  0  0.000000
0  0  0.00000
3  22  15  3

```

0	0	0	0
5	10	1	0.000130
5	11	1	0.100749
5	12	1	0.287586
5	13	1	0.345841
5	14	1	0.293202
5	15	1	0.242379
5	16	1	0.141011
5	17	1	0.028924
5	10	2	-0.000040
5	11	2	-0.030835
5	12	2	-0.087913
5	13	2	-0.105660
5	14	2	-0.089537
5	15	2	-0.073986
5	16	2	-0.043028
5	17	2	-0.008823
0	0	0	0.000000
0	0	0.00000	
3	21	15	3
0	0	0	0
5	8	1	0.092543
5	9	1	0.357697
5	10	1	0.516117
.			
.			
.			
5	46	2	-0.176512
5	47	2	-0.072665
5	48	2	-0.001599
0	0	0	0.000000
0	0	0.00000	
4	29	15	3
3	17	15	3
5	46	1	0.106460
5	47	1	0.262741
5	48	1	0.757527
5	46	2	-0.033016
5	47	2	-0.081595
5	48	2	-0.235656
0	0	0	0.000000
17	1	1.00000	
0	0	0.00000	
3	1	2	4
4	45	2	2
6	9	1	0.000635
6	10	1	0.008443
6	11	1	0.017469
6	12	1	0.017478
6	13	1	0.015014
6	14	1	0.012738
6	15	1	0.010689
6	16	1	0.008889
6	17	1	0.007332
6	18	1	0.006006
6	19	1	0.004883
6	20	1	0.003935
6	21	1	0.003144
6	22	1	0.002405
6	23	1	0.001527
6	24	1	0.000572
6	25	1	0.000062
6	9	2	-0.000241
6	10	2	-0.003204
6	11	2	-0.006625
6	12	2	-0.006626
6	13	2	-0.005690
6	14	2	-0.004826
6	15	2	-0.004049
6	16	2	-0.003367

6	17	2	-0.002777
6	18	2	-0.002275
6	19	2	-0.001850
6	20	2	-0.001490
6	21	2	-0.001191
6	22	2	-0.000911
6	23	2	-0.000578
6	24	2	-0.000217
6	25	2	-0.000023
0	0	0	0.000000
-17	1		0.63686
-19	1		0.36314
0	0		0.00000
3	1	1	4
4	45	1	2
6	4	1	0.000556
6	5	1	0.012797
6	6	1	0.028781
6	7	1	0.032329
6	8	1	0.030354
6	9	1	0.027167
6	10	1	0.015750
6	11	1	0.002877
6	4	2	-0.000213
6	5	2	-0.004889
6	6	2	-0.010976
6	7	2	-0.012309
6	8	2	-0.011542
6	9	2	-0.010320
6	10	2	-0.005978
6	11	2	-0.001091
0	0	0	0.000000
-17	1		0.24685
-19	1		0.75315
0	0		0.00000
2	45	1	2
1	1	1	4
6	1	1	0.010136
6	2	1	0.026713
6	3	1	0.034735
.			
.			
6	43	2	-0.005744
6	44	2	-0.000375
0	0	0	0.000000
17	1		0.24685
19	1		0.75315
0	0		0.00000
1	1	1	4
2	45	1	2
6	42	1	0.003493
6	43	1	0.017717
6	44	1	0.029166
6	45	1	0.029713
6	46	1	0.028726
6	47	1	0.019828
6	48	1	0.005781
6	42	2	-0.001330
6	43	2	-0.006756
6	44	2	-0.011138
6	45	2	-0.011367
6	46	2	-0.011012
6	47	2	-0.007619
6	48	2	-0.002228
0	0	0	0.000000
17	1		0.09062
19	1		0.90938
0	0		0.00000
1	1	2	4

2	45	2	2
6	46	1	0.000064
6	47	1	0.001241
6	48	1	0.022704
6	46	2	-0.000024
6	47	2	-0.000477
6	48	2	-0.008749
0	0	0	0.000000
17	1	0.00057	
19	1	0.99943	
0	0	0.00000	
0	0	0	0
network x,y,z coordinates			
46	31	free-surface star	
8.8428		-0.0173	-0.0081
8.5212		0.0042	0.0822
8.1724		0.0252	0.1802
.			
.			
-23.0230		-0.0015	7.8237
-24.5579		-0.0018	4.1355
-25.1293		-0.0021	-0.0423
46	31	free-surface port	
-10.0616		-0.1751	-0.0972
-9.7286		-0.1861	-0.2454
-9.3199		-0.2027	-0.4194
.			
.			
30.7383		0.0764	-0.8924
30.7628		0.0675	-0.4315
30.7707		0.0597	0.0299
46	16	hull port	
8.8846		-0.0102	-0.0477
9.2200		-0.0294	-0.1606
9.5470		-0.0410	-0.2983
.			
.			
-6.5863		0.2947	0.0755
-6.8225		0.2683	0.0658
-7.0328		0.2441	0.0569
46	16	hull star	
-10.0616		-0.1751	-0.0972
-9.7229		-0.1680	-0.0317
-9.3305		-0.1633	0.0471
.			
.			
5.4380		0.4395	0.1341
5.6834		0.4147	0.1251
5.8947		0.3913	0.1168
49	16	keel	
1.0008		0.6754	0.2178
0.9152		0.6792	0.2099
0.8224		0.6828	0.2011
.			
.			
0.8266		3.1995	1.1555
0.9190		3.2132	1.1506
1.0042		3.2265	1.1463
49	12	rudr	
9.0859		-0.0442	-0.0402
9.0479		-0.0388	-0.0422
9.0069		-0.0317	-0.0438
.			
.			
9.1413		2.4881	0.8815
9.1681		2.4880	0.8815
9.1929		2.4878	0.8814

52	8		bulb star top
-1.6554	3.4964	1.2432	
-1.6495	3.4724	1.2345	
-1.6327	3.4453	1.2246	
.			
2.3533	3.4734	1.3019	
2.4268	3.4750	1.2894	
2.4951	3.4781	1.2782	
52	8		bulb star bot
-1.6554	3.4964	1.2432	
-1.6505	3.4876	1.2676	
-1.6342	3.4773	1.2957	
.			
2.3669	3.5466	1.2634	
2.4333	3.5358	1.2596	
2.4952	3.5259	1.2560	
52	8		bulb port bot
-1.6554	3.4964	1.2432	
-1.6507	3.5206	1.2520	
-1.6345	3.5485	1.2622	
.			
2.3534	3.5152	1.1869	
2.4268	3.5084	1.1976	
2.4951	3.5036	1.2082	
52	8		bulb port top
-1.6554	3.4964	1.2432	
-1.6505	3.5053	1.2188	
-1.6342	3.5155	1.1908	
.			
2.3663	3.4355	1.2230	
2.4330	3.4460	1.2269	
2.4951	3.4559	1.2305	
3	8		bulb base star top
2.4951	3.4559	1.2305	
2.4951	3.4734	1.2369	
2.4951	3.4909	1.2432	
2.4951	3.4544	1.2359	
2.4951	3.4726	1.2395	
2.4951	3.4909	1.2432	
2.4951	3.4537	1.2438	
2.4951	3.4723	1.2435	
2.4951	3.4909	1.2432	
2.4951	3.4553	1.2538	
2.4951	3.4731	1.2485	
2.4951	3.4909	1.2432	
2.4951	3.4599	1.2637	
2.4951	3.4754	1.2535	
2.4951	3.4909	1.2432	
2.4951	3.4666	1.2713	
2.4951	3.4787	1.2573	
2.4951	3.4909	1.2432	
2.4951	3.4731	1.2759	
2.4951	3.4820	1.2596	
2.4951	3.4909	1.2432	
2.4951	3.4781	1.2782	
2.4951	3.4845	1.2607	
2.4951	3.4909	1.2432	
3	8		bulb base star bot
2.4951	3.4781	1.2782	
2.4951	3.4845	1.2607	
2.4951	3.4909	1.2432	
2.4951	3.4835	1.2797	
2.4951	3.4872	1.2615	
2.4951	3.4909	1.2432	
2.4951	3.4914	1.2804	

2.4951	3.4912	1.2618
2.4951	3.4909	1.2432
2.4951	3.5014	1.2788
2.4951	3.4961	1.2610
2.4951	3.4909	1.2432
2.4952	3.5114	1.2742
2.4951	3.5011	1.2587
2.4951	3.4909	1.2432
2.4952	3.5190	1.2676
2.4951	3.5049	1.2554
2.4951	3.4909	1.2432
2.4952	3.5235	1.2610
2.4951	3.5072	1.2521
2.4951	3.4909	1.2432
2.4952	3.5259	1.2560
2.4952	3.5084	1.2496
2.4951	3.4909	1.2432
3	8	bulb base port bot
2.4952	3.5259	1.2560
2.4952	3.5084	1.2496
2.4951	3.4909	1.2432
2.4952	3.5273	1.2506
2.4952	3.5091	1.2469
2.4951	3.4909	1.2432
2.4952	3.5280	1.2427
2.4952	3.5095	1.2429
2.4951	3.4909	1.2432
2.4952	3.5265	1.2327
2.4952	3.5087	1.2380
2.4951	3.4909	1.2432
2.4952	3.5218	1.2227
2.4951	3.5064	1.2330
2.4951	3.4909	1.2432
2.4952	3.5152	1.2151
2.4951	3.5030	1.2292
2.4951	3.4909	1.2432
2.4952	3.5087	1.2106
2.4951	3.4998	1.2269
2.4951	3.4909	1.2432
2.4951	3.5036	1.2082
2.4951	3.4972	1.2257
2.4951	3.4909	1.2432
3	8	bulb base port top
2.4951	3.5036	1.2082
2.4951	3.4972	1.2257
2.4951	3.4909	1.2432
2.4951	3.4982	1.2068
2.4951	3.4946	1.2250
2.4951	3.4909	1.2432
2.4951	3.4903	1.2061
2.4951	3.4906	1.2247
2.4951	3.4909	1.2432
2.4951	3.4803	1.2076
2.4951	3.4856	1.2254
2.4951	3.4909	1.2432
2.4951	3.4704	1.2123
2.4951	3.4806	1.2278
2.4951	3.4909	1.2432
2.4951	3.4628	1.2189
2.4951	3.4768	1.2311
2.4951	3.4909	1.2432
2.4951	3.4582	1.2254
2.4951	3.4745	1.2343
2.4951	3.4909	1.2432
2.4951	3.4559	1.2305
2.4951	3.4734	1.2369
2.4951	3.4909	1.2432
41	11	wing port
2.0876	4.3141	-0.1080
2.0810	4.3142	-0.1079
2.0738	4.3143	-0.1078

.			
2.0124	3.5482	1.1380	
2.0604	3.5463	1.1462	
2.1040	3.5443	1.1539	
41 11		wing star	
2.1039	3.4745	1.3457	
2.0604	3.4774	1.3537	
2.0125	3.4805	1.3622	
.			
2.0723	3.2533	2.8072	
2.0796	3.2532	2.8071	
2.0862	3.2531	2.8071	
50 12		keel wake - to rudr leading edge	
1.0008	0.6754	0.2178	
1.0479	0.6747	0.2175	
1.0740	0.6744	0.2174	
.			
8.6015	2.4825	0.8792	
8.7958	2.4751	0.8766	
8.8158	2.4743	0.8763	
103 5		keel wake - outboard of rudr	
1.0034	2.6452	0.9347	
1.0524	2.6468	0.9353	
1.0796	2.6477	0.9356	
.			
27.1795	3.3268	1.2137	
28.8994	3.3225	1.2147	
30.7701	3.3152	1.2148	
30 12		rudr wake	
9.0859	-0.0442	-0.0402	
9.2339	-0.0628	-0.0467	
9.4258	-0.0842	-0.0543	
.			
27.1797	2.5476	0.9300	
28.8996	2.5431	0.9309	
30.7702	2.5355	0.9309	
79 8		bulb wake star top	
2.4951	3.4559	1.2305	
2.5324	3.4558	1.2305	
2.9259	3.4545	1.2302	
.			
27.1795	3.3491	1.2615	
28.8994	3.3448	1.2624	
30.7701	3.3375	1.2625	
79 8		bulb wake star bot	
2.4951	3.4781	1.2782	
2.5325	3.4780	1.2782	
2.9259	3.4768	1.2779	
.			
27.1795	3.3968	1.2392	
28.8994	3.3925	1.2402	
30.7701	3.3852	1.2402	
79 8		bulb wake port bot	
2.4952	3.5259	1.2560	
2.5325	3.5258	1.2560	
2.9260	3.5245	1.2557	
.			
27.1795	3.3746	1.1914	
28.8994	3.3703	1.1924	

30.7701	3.3629	1.1925	
79 8			bulb wake port top
2.4951	3.5036	1.2082	
2.5325	3.5035	1.2082	
2.9259	3.5022	1.2079	
.			
27.1795	3.3268	1.2137	
28.8994	3.3225	1.2147	
30.7701	3.3152	1.2148	
79 8			bulb base wake star top
2.4951	3.4559	1.2305	
2.5324	3.4558	1.2305	
2.9259	3.4545	1.2302	
.			
27.1795	3.3491	1.2615	
28.8994	3.3448	1.2624	
30.7701	3.3375	1.2625	
79 8			bulb base wake star bot
2.4951	3.4781	1.2782	
2.5325	3.4780	1.2782	
2.9259	3.4768	1.2779	
.			
27.1795	3.3968	1.2392	
28.8994	3.3925	1.2402	
30.7701	3.3852	1.2402	
79 8			bulb base wake port bot
2.4952	3.5259	1.2560	
2.5325	3.5258	1.2560	
2.9260	3.5245	1.2557	
.			
27.1795	3.3746	1.1914	
28.8994	3.3703	1.1924	
30.7701	3.3629	1.1925	
79 8			bulb base wake port top
2.4951	3.5036	1.2082	
2.5325	3.5035	1.2082	
2.9259	3.5022	1.2079	
.			
27.1795	3.3268	1.2137	
28.8994	3.3225	1.2147	
30.7701	3.3152	1.2148	
84 11			wing wake port
2.0876	4.3141	-0.1080	
2.1754	4.3140	-0.1067	
2.2587	4.3138	-0.1057	
.			
27.1795	3.3746	1.1915	
28.8994	3.3703	1.1924	
30.7701	3.3629	1.1925	
84 11			wing wake star
2.1039	3.4745	1.3457	
2.1917	3.4748	1.3305	
2.2749	3.4735	1.3158	
.			
27.1766	3.1356	2.7902	
28.8976	3.1316	2.7913	
30.7693	3.1248	2.7915	

Nomenclature:

$$Fr = U_{BOAT} / \sqrt{GRAV * XL_{BOAT}}$$

Standard FORTRAN Formatted Input Conventions:

Each input value must appear in its designated column range.

Values for integer variables (those beginning with I-N) must not contain a decimal point.

Values for real variables (those beginning with A-H and O-Z) must contain a decimal point.

Input for character string variables (those expressly identified as such) should be left-justified.

Standard FORTRAN Format-Free Input Conventions:

Similar to formatted input, but inputs may appear in any column, as long as multiple inputs are each separated by one or more blank spaces and/or a comma.

Comment lines appear at specific locations throughout the SPLASH standard-input file. They are typically used to describe input on the line(s) to follow. They contain valid character strings appearing in columns 1-80. During program execution, the content of comment lines is ignored.

GENERAL TEST INPUTS

The first line specifies the case title:

title (columns 1-80) A character string for identification purposes, such as to identify the model, test details, test points, etc.

The next line, which is preceded by a comment line, specifies the following parameters: reference parameters for force and moment coefficient nondimensionalization; nominal configuration center of gravity; and symmetry-plane/finite-water-depth y-coordinate (active if IISYM>0 only).

sref (columns 1-10) Reference area for aerodynamic/hydrodynamic force and moment coefficients (if SREF=0.0, then SREF=1.0 is used).

cref (columns 11-20) Reference chord for longitudinal moment coefficient (if CREF=0.0, then CREF=1.0 is used).

bréf (columns 21-30) Reference span for lateral/directional moment coefficients (if BREF=0.0, then BREF=1.0 is used).

xcg (columns 31-40) Global coordinate system X-coordinate of model center of gravity.

ycg (columns 41-50) Global coordinate system Y-coordinate of model center of gravity.

zcg (columns 51-60) Global coordinate system Z-coordinate of model center of gravity.

ysym (columns 61-70) Global coordinate system Y-coordinate of Y plane of symmetry / depth of water (used only if IISYM≠0)

The next line, which is preceded by a comment line, specifies numerical test and hydrodynamic reference parameters.

uboat (columns 1-10) Steady boat speed (if UBOAT<0.0, UBOAT=0.0). If UBOAT=0.0, then only the basis flow is calculated (and the free-surface flow is not).

xlboat (columns 11-20) Boat length (if XLBOAT=0.0, then XLBOAT=1.0 is used). This parameter is also used to control number of decimal places in output file data fields.

grav (columns 21-30) Gravitational constant (if GRAV=0.0, then GRAV=32.174 is used).

alp (columns 31-40) Aero freestream flow angle of attack, in degrees: $U_\infty = \cos(\beta)\cos(\alpha)$, $W_\infty = \cos(\beta)\sin(\alpha)$. For free-surface flows, ALP is equivalent to yaw angle.

bet (columns 41-50) Aero freestream flow angle of yaw, in degrees: $V_\infty = \sin(\beta)$. For free-surface flows, BET is the freestream flow angle relative to horizontal, so BET=0.0.

rnf (columns 51-60) Panel-radius influence coefficient near-field factor (if RNF=0.0, then RNF=2.5 is used). **RNF=0.0 is recommended.**

rff (columns 61-70) Panel-radius influence coefficient far-field factor (if RFF=0.0, then RFF=5.0 is used). **RFF=0.0 is recommended.**

The next line, which is preceded by a comment line, specifies model hydrodynamic test conditions.

heel (columns 1-10) Boat heel angle, in degrees. Used to convert foil section lift data back to DWL (Design Water Line) coordinates.

sink (columns 11-20) Boat sinkage, at center of gravity. Used to convert foil section lift data back to DWL (Design Water Line) coordinates.

trim (columns 21-30) Boat trim angle, in degrees. Used to convert foil section lift data back to DWL (Design Water Line) coordinates.

If the final moments to be recorded in the force/moment/sink/trim iteration history file *tfms* are to be referenced to a datum point (see input parameter IFMST), rather than to the center of gravity, then the user is required to specify the coordinates *xdatum*, *ydatum*, and *zdatum*.

xdatum (columns 31-40) Global coordinate system X-coordinate of model-fixed datum point.

ydatum (columns 41-50) Global coordinate system Y-coordinate of model-fixed datum point.

zdatum (columns 51-60) Global coordinate system Z-coordinate of model-fixed datum point.

dkeel (columns 61-70) Keel deflection angle. Used for printout only.

drudr (columns 71-80) Rudder deflection angle. Used for printout only.

The next line, which is preceded by a comment line, specifies the fluid physical properties.

density (columns 1-13) Fluid density.

viscosity (columns 14-26) Fluid viscosity (for future use).

The next line, which is preceded by a comment line, specifies free-surface boundary condition options.

iupvwl (columns 1-10) Applies to differencing of doublets for in-plane panel velocity contribution to pressure gradient term in free-surface boundary condition. If IUPVWL=0, use central difference. Otherwise, use upwind difference. **IUPVWL=1 is recommended.**

iradbc (columns 11-20) Applies to free-surface far field boundary condition at outer boundary. If IRADBC=0, use wave damping, beach type condition. Otherwise, use wave radiation (upwind-biased) type condition. **IRADBC=1 is recommended.**

iupvbc (columns 21-30) Applies to differencing of doublets for in-plane panel velocity contribution to vertical velocity term in free-surface boundary condition. If IUPVBC=0, use central difference. Otherwise, use upwind difference. **IUPVBC=0 is recommended.**

ilagbc (columns 31-40) Applies to differencing of doublets for in-plane panel velocity contribution to vertical velocity term in free-surface boundary condition. If ILAGBC=0, use free-surface flow doublet strengths. Otherwise, use basis flow doublet strengths. **ILAGBC=0 is recommended.**

xautowl (columns 41-50) Specifies a blending factor to apply between two alternate free-surface waterline boundary condition options.

Along the waterline edge of free-surface waterline panels, the user may specify on a fractional basis the degree to which the edge should be treated using a dry chine (the default), wet chine (optional input parameter *rwetch*), or dry transom (optional input parameter *rdrytr*) waterline boundary condition. If not specified, the wet chine and dry transom fractions default to zero, and the dry chine fraction (internal parameter *rdrych*) defaults to 1.0.

The input parameter *xautowl* allows the user to have the default dry chine fraction of the waterline boundary condition reallocated in whole or in part to a wet chine contribution, i.e.:

$$rdrych_{final} = (1 - xautowl) * rdrych_{specified}$$

$$rwetch_{final} = rwetch_{specified} + xautowl * rdrych_{specified}$$

When using ACCPAN for high-performance racing yachts, and at high heel angles, setting *xautowl*=0.5 may enhance the stability of nonlinear iterations.

XAUTOWL=0.5 is recommended.

The next line, which is preceded by a comment line, specifies several very important parameters for free-surface wave and waterline boundary conditions.

The use of these inputs requires that the unsmoothed developing free-surface shape, and its smoothed approximation, are available during SPLASH execution, as file *pxxf*s. This file is available during standard ACCPAN/SPLASH iterative nonlinear calculations.

inrmzero (columns 1-10) Selects the type of boundary condition applied to free-surface panels during the basis flow solution, when the requested boat speed is zero:

inrmzero=0 The vertical velocity is zero: $\mathbf{V} \cdot \mathbf{n}_y = 0$.

inrmzero=1 The velocity normal to the free-surface panel is zero: $\mathbf{V} \cdot \mathbf{n}_{\text{panel}} = 0$.

inrmzero=+2 The velocity normal to the smoothed approximation to the developing free-surface shape is zero: $\mathbf{V} \cdot \mathbf{n}_{\text{fs-sm}} = 0$.

inrmzero=-2 The velocity normal to the unsmoothed developing free-surface shape is zero: $\mathbf{V} \cdot \mathbf{n}_{\text{fs}} = 0$.

If *pxxf*s is not present, the velocity normal to the panel formulation (inrmzero=1) is used.

INRMZERO=+2 is recommended.

inrmfrsq (columns 11-20) Selects the type of boundary condition applied to free-surface panels during the basis flow solution, when the requested boat speed is nonzero:

inrmfrsq=0 The vertical velocity is zero: $\mathbf{V} \cdot \mathbf{n}_y = 0$.

inrmfrsq=1 The velocity normal to the free-surface panel is zero: $\mathbf{V} \cdot \mathbf{n}_{\text{panel}} = 0$.

inrmfrsq=+2 The velocity normal to the smoothed approximation to the developing free-surface shape is zero: $\mathbf{V} \cdot \mathbf{n}_{\text{fs-sm}} = 0$.

inrmfrsq=-2 The velocity normal to the unsmoothed developing free-surface shape is zero: $\mathbf{V} \cdot \mathbf{n}_{\text{fs}} = 0$.

inrmfrsq=+3 This option provides a blending of the two approaches described above for inrmfrsq=1 and inrmfrsq=+2. The blending depends on speed and on degree of mismatch δ between panel elevation and developing free-surface elevation. The degree of blending depends on a mismatch-based Froude number $Fr_\delta = u_{\text{boat}}/\sqrt{g\delta}$ and a user-supplied semi-empirical constant *cnorm* (see below).

A modified normal is used for the boundary condition $\mathbf{V} \cdot \mathbf{n}_{\text{mod}} = 0$. The modified normal is partially rotated away from the panel normal $\mathbf{n}_{\text{panel}}$, towards the smoothed developing free-surface normal $\mathbf{n}_{\text{fs-sm}}$, by an amount $\lambda\theta$,

where θ is the angle between $\mathbf{n}_{\text{panel}}$ and $\mathbf{n}_{\text{fs-sm}}$, and λ is given by:

$$\lambda = \text{cnorm} / [\text{cnorm} + (Fr_\delta)^2 / 2]$$

Thus if cnorm is very small, or the speed is very high, or the mismatch is very small, then the $\text{inrmfrsq}=1$ approach is favored. Conversely, if cnorm is very large, or the speed is very small, or the mismatch is very large, then the $\text{inrmfrsq}=+2$ approach is favored.

$\text{inrmfrsq}=-3$ This option provides a blending of the two approaches described above for $\text{inrmfrsq}=1$ and $\text{inrmfrsq}=-2$. It is otherwise similar to $\text{inrmfrsq}=+3$, except the modified normal is partially rotated between the panel normal $\mathbf{n}_{\text{panel}}$ and the unsmoothed developing free-surface normal \mathbf{n}_{fs} .

INRMFRSQ=+3 is recommended.

cnorm (columns 21-30) User-supplied, semi-empirical constant, for use in conjunction with basis-flow boundary condition options $\text{inrmfrsq}=\pm 3$. Suggested value ranges from 0.0 to 8.0 or greater, depending on the application.

CNORM=4.0 is recommended.

iedgzero (columns 31-40) Selects the source of the free-surface waterline elevation for injection into the wet chine and dry transom boundary conditions that are used during the free-surface flow solution, when the requested boat speed is zero:

$\text{iedgzero}=0$ The elevation is assumed to be zero: $\eta_{\text{wl}} = 0$.

$\text{iedgzero}=1$ The geometric panel elevation is used: $\eta_{\text{wl}} = \eta_{\text{panel}}$.

$\text{iedgzero}=+2$ The elevation is taken from the smoothed approximation to the developing free-surface shape: $\eta_{\text{wl}} = \eta_{\text{fs-sm}}$.

$\text{iedgzero}=-2$ The elevation is taken from the unsmoothed approximation to the developing free-surface shape: $\eta_{\text{wl}} = \eta_{\text{fs}}$.

IEDGZERO=+2 is recommended.

iedgfrsq (columns 41-50) Selects the source of the free-surface waterline elevation for injection into the wet chine and dry transom boundary conditions that are used during the free-surface flow solution, when the requested boat speed is nonzero:

$\text{iedgfrsq}=0$ The elevation is assumed to be zero: $\eta_{\text{wl}} = 0$.

$\text{iedgfrsq}=1$ The geometric panel elevation is used: $\eta_{\text{wl}} = \eta_{\text{panel}}$.

$\text{iedgfrsq}=+2$ The elevation is taken from the smoothed approximation to the developing free-surface shape: $\eta_{\text{wl}} = \eta_{\text{fs-sm}}$.

iedgfrsq=-2 The elevation is taken from the unsmoothed approximation to the developing free-surface shape: $\eta_{wl} = \eta_{fs}$.

iedgfrsq=+3 This option provides a blending of the two approaches described above for iedgfrsq=1 and iedgfrsq=+2. The blending depends on speed and on degree of mismatch δ between panel elevation and developing free-surface elevation. The degree of blending depends on a mismatch-based Froude number $Fr_\delta = u_{boat}/\sqrt{g\delta}$ and a user-supplied semi-empirical constant cedge (see below).

A modified elevation is used for the boundary condition:

$$\eta_{wl} = (1 - \lambda) \cdot \eta_{panel} + \lambda \cdot \eta_{fs-sm}$$

where

$$\lambda = cedge / [cedge + (Fr_\delta)^2 / 2]$$

Thus if cedge is very small, or the speed is very high, or the mismatch is very small, then the iedgfrsq=1 approach is favored. Conversely, if cedge is very large, or the speed is very small, or the mismatch is very large, then the iedgfrsq=+2 approach is favored.

iedgfrsq=-3 This option provides a blending of the two approaches described above for infrmfrsq=1 and iedgfrsq=-2. It is otherwise similar to iedgfrsq=+3, except the modified elevation is:

$$\eta_{wl} = (1 - \lambda) \cdot \eta_{panel} + \lambda \cdot \eta_{fs}$$

IEDGFRSQ=+3 is recommended.

cedge (columns 51-60) User-supplied, semi-empirical constant, for use in conjunction with free-surface-flow boundary condition options iedgfrsq=+/-3. Suggested value ranges from 0.0 to 8.0 or greater, depending on the application.

CEDGE=4.0 is recommended.

inotopp (columns 61-70) Option flag indicating, in the upwind free-surface boundary condition, when there is no neighboring panel in the upwind direction, whether SPLASH should consider neighboring panels in the opposite direction (downwind) in order to construct a pressure gradient stencil.

inotopp=0 Neighboring panels in the opposite direction (downstream) are considered.

inotopp≠0 Neighboring panels in the opposite direction (downstream) are not considered.

INOTOPP=1 is recommended.

The next line, which is preceded by a comment line, specifies several parameters for wake calculations, for free-surface wave and waterline elevation options, and for a viscous force and moment pass-through option.

- iwkshd** (columns 1-10) Activates the automated wake shedding algorithm:
- iwkshd=0 The automated wake shedding algorithm is not activated. All wake shedding information (typically, foil upper and lower trailing edge panels) must be input by the user.
 - iwkshd≠0 The automated wake shedding algorithm is activated. SPLASH automatically determines appropriate upper and lower surface wake shedding panels. This algorithm may not work for all cases, and the wake shedding printout can be activated and checked for correctness. User-input wake shedding information (specified later) overrides automated wake shedding results.
- iwkjmp** (columns 11-20) Activates the automated wake jump algorithm:
- iwkshd=0 The automated wake jump algorithm is not activated. All wake jump information (jumps in doublet strengths across wakes which must be accounted for in panel-to-panel doublet gradient stencils) must be input by the user.
 - iwkshd≠0 The automated wake jump algorithm is activated. SPLASH automatically determines appropriate wake jump. This algorithm may not work for all cases, and the wake jump printout can be activated and checked for correctness. User-input wake jump information (specified later) overrides automated wake jump results.
- iordst** (columns 21-30) Obsolete input option.
- iordwl** (columns 31-40) Obsolete input option.
- ivisc** (columns 41-50) Controls the treatment by SPLASH of the viscous forces and moments that are recorded in the force/moment/sink/trim iteration history file. As SPLASH itself does not perform any viscous calculations, the only available options are:
- ivisc=0 SPLASH records zero-valued viscous forces and moments to the force/moment/sink/trim iteration history file.
 - ivisc=-1 SPLASH does not record viscous forces and moments to the force/moment/sink/trim iteration history file. This option is intended for iterative calculations using the ivisc=-1 option in ACCPAN also, in which case ACCPAN will calculate the viscous forces and moments and record them to the force/moment/sink/trim iteration history file.

The next line, which is preceded by a comment line, specifies flow solver calculation and solution printout options.

iisym	(columns 1-5)	Controls the Y symmetry plane option:
		<p>iisym=0 There is no Y symmetry plane. IISYM=0 is normally used for infinite-depth free-surface flows.</p> <p>iisym=1 The flow is calculated as symmetric about the plane $y=ysym$. This is accomplished using additional panels that are the mirror images (with respect to the plane $y=ysym$) of all the normal, user-specified panels. This option can be used to calculate finite-depth free-surface flows, specifying $ysym$ as the bottom depth below the free-surface. It can also be used for zero Froude number (double-body) flows, omitting any free-surface panels and specifying $ysym=0.0$ (actually, specifying $ysym$ equal to the assumed flat free-surface symmetry plane, which is typically 0.0). Also used for aircraft half-model flow calculations.</p>
iigpr	(columns 6-10)	Controls the $Z=0.0$ symmetry plane option:
		<p>iigpr=0 There is no Z symmetry plane. IIGPR=0 is normally used for full-model free-surface flows including heel and yaw. Also used for standard aircraft flow calculations in an unbounded domain without a ground plane.</p> <p>iigpr=1 The flow is calculated as symmetric about the plane $z=0.0$. This is accomplished using additional panels that are the mirror images (with respect to the plane $z=0.0$) of all the normal, user-specified panels. IIGPR=1 is normally used for upright half-model free-surface flows. Also used for calculations involving aircraft in ground effect.</p>
ileak	(columns 11-15)	If ILEAK \neq 0, the effects of lifting-type wake networks (NTYPE=11) are not included in the calculations. ILEAK=0 is normally required, except for special calculations for leakage or surfing rudder corrections, in which case ILEAK=1 is required.
limup1	(columns 16-20)	Minimum number of panel control point pressures used in upwind free-surface boundary condition stencils. $2 \leq LIMUP1 \leq 5$. If LIMUP1=0, the code sets LIMUP1=3. LIMUP1=0 is recommended.
limup2	(columns 21-25)	Maximum number of panel control point pressures used in upwind free-surface boundary condition stencils. $2 \leq LIMUP2 \leq 5$. If LIMUP2=0, the code sets LIMUP2=5. LIMUP2=0 is recommended.
ifmst	(columns 26-30)	Controls usage and update of <i>tfms</i> force/moment/sink/trim iteration history files (ACCPAN files <i>*.fm</i>). Referred to as parameter <i>isavf</i> by ACCPAN.
		<p>ifmst=0 The <i>tfms</i> files are not used.</p> <p>ifmst\neq0 The <i>tfms</i> files are used. The files are also updated by ACCPAN and SPLASH during automated operation.</p> <p>ifmst\neq0 is required for free to sink and trim and nonlinear free-surface calculations (ifmst=4 is commonly used).</p>

Different values of ifmst result in different forms of the *tfms* force/moment/sink/trim iteration history file:

ifmst	reference point for moments and sinkage	component viscous forces and moments	separate waterline forces and moments
1	center of gravity	no	no
2	datum point	no	no
3	center of gravity	yes	no
4	datum point	yes	no
101	center of gravity	no	yes
102	datum point	no	yes
103	center of gravity	yes	yes
104	datum point	yes	yes

- itec** (columns 31-35) Controls the generation of the *teplot* flow solution output file. If ITEC≠0, the flow velocities and pressures at panel corner points are written to the *teplot* flow solution output file.
- iscan** (columns 36-40) Controls the off-body velocity scan solution algorithm. If ISCAN≠0, the off-body velocity scan input file *scinp* is read, velocities are computed at the specified points, and results are written to the velocity scan output file *scnout*.
- icorn** (columns 41-45) Controls panel corner point output. If ICORN≠0, all panel corner point coordinates are printed to the standard-output file.
- icpnt** (columns 46-50) Controls panel control point output. If ICPTN≠0, all panel control point coordinates, normal vectors, and any user-prescribed panel normal velocities or potential values are printed to the standard-output file.
- invls** (columns 51-55) Controls panel velocity-nabor information output. If INVLS≠0, panel velocity-nabor information is printed to the standard-output file. If INVLS=1, it is printed only for panels along network edges. If INVLS=2, it is printed for all panels.
- ingps** (columns 56-60) Controls panel pressure-gradient-nabor information output. If INGPS≠0, panel pressure-gradient-nabor information is printed to the standard-output file. If INGPS=1, it is printed only for panels along network edges. If INGPS=2, it is printed for all panels.
- ished** (columns 61-65) Controls wake shedding information output. If ISHED>0, wake shedding information is printed to the standard-output file.
- iuvwp** (columns 66-70) Controls panel control point velocity and pressure output. If IUVWP≠0, values are printed to the standard-output file. If IUVWP=1, only the basis flow values are printed. If IUVWP=2, only the free-surface flow values are printed. If IUVWP=3, both the basis flow values and the free-surface flow values are printed.

The next line, which is preceded by a comment line, specifies various parameters, some obsolete, the others reserved for internal use.

- idm1** (columns 1-5) **IDM1=0 is recommended.**
- idm2** (columns 6-10) **IDM2=0 is recommended.**
- idm3** (columns 11-15) **IDM3=0 is recommended.**
- iread1** (columns 16-20) If IREAD1>0, write the computed basis flow solution source and doublet strengths to file *dub1*. If IREAD1<0, read the basis flow solution source and doublet strengths from file *dub1* instead of computing them. **IREAD1=0 is recommended.**
- iread2** (columns 21-25) If IREAD2>0, write the computed free-surface flow solution source and doublet strengths to file *dub2*. If IREAD2<0, read the free-surface flow solution source and doublet strengths from file *dub2* instead of computing them. **IREAD2=0 is recommended.**

The next line, which is preceded by a comment line, specifies parameters and options used to solve the basis flow matrix equations.

- imeth1** (columns 1-5) Indicates general method used to solve basis flow solution matrix.
- imeth1=3 Direct solution method (LAPACK to factor and solve).
- imeth1=6 Gauss-Seidel type of blocked iterative solution method (LAPACK to factor and invert diagonal blocks). A GMRES-type residual-based acceleration scheme is also incorporated.
- If the iterative solver is attempted, but fails, the direct solver is invoked.
- The iterative solver is recommended (IMETH1=6). Unless there is reason to expect that it will fail, in which case the direct solver may be specified to avoid the run time required for the iterative solver.**
- icond1** (columns 6-10) Basis flow solution matrix preconditioning flag. Reserved for future use.
- iperm1** (columns 11-15) Basis flow solution matrix permutation flag. Reserved for future use.
- iblsz1** (columns 16-20) Maximum block size (panels per block) used during block-iterative solve of the basis flow solution matrix (IMETH1=6). If IBLSZ1=0, an internal default maximum is calculated. **IBLSZ1=0 is recommended.**
- nblok1** (columns 21-25) Number of blocks used during iterative solve of the basis flow solution matrix (IMETH1=6).
- nblok1=0 The number of blocks is internally calculated, based on number and arrangement of panels and maximum block size IBLSZ1.
- nblok1>0 Directly specifies the number of blocks. Block size is internally calculated, based on number of panels and number of blocks.

nblok1<0 Directly specifies the number of blocks, as |nblok1|. User-specified block sizes (JBLSZ1(N)) are input on the next line.

NBLOK1=0 is recommended.

itermx1 (columns 26-30) Maximum number of iterations allowed during iterative solve of the basis flow solution matrix (IMETH1=6). If ITERMX1=0, an internal default maximum is used. **ITERMX1=0 is recommended.**

solres1 (columns 31-40) The Gauss-Seidel residual convergence criteria, expressed as a fraction of the maximum of the absolute values of the equation right-hand-sides, used during iterative solve of the basis flow solution matrix. If SOLRES1 < 1.0 x 10⁻¹², a default value 1.0 x 10⁻⁵ is used. **SOLRES1=0.0 is recommended.**

The next set of lines, which is preceded by a single comment line, specify block sizes to use during iterative solve of the basis flow solution matrix. These lines are input only if NBLOK1<0.

jb1sz1 (n) (columns 1-80) Block sizes (number of panels per block N). Use FORTRAN format (1615) specification. Repeat lines until N=|NBLOK1| values have been specified.

The next line, which is preceded by a comment line, specifies parameters and options used to solve the free-surface flow matrix equations.

imeth2 (columns 1-5) Indicates general method used to solve free-surface flow solution matrix.

imeth2=3 Direct solution method (LAPACK to factor and solve).

imeth2=6 Gauss-Seidel type of blocked iterative solution method (LAPACK to factor and invert diagonal blocks). A GMRES-type residual-based acceleration scheme is also incorporated.

If the iterative solver is attempted, but fails, the direct solver is invoked.

The iterative solver is recommended (IMETH2=6). Unless there is reason to expect that it will fail, in which case the direct solver may be specified to avoid the run time required for the iterative solver.

icond2 (columns 6-10) Free-surface flow solution matrix preconditioning flag. Reserved for future use.

iperme2 (columns 11-15) Free-surface flow solution matrix permutation flag. Reserved for future use.

ib1sz2 (columns 16-20) Maximum block size (panels per block) used during block-iterative solve of the free-surface flow solution matrix (IMETH2=6). If IBLSZ2=0, an internal default maximum is calculated. **IBLSZ2=0 is recommended.**

nblok2 (columns 21-25) Number of blocks used during iterative solve of the free-surface flow solution matrix (IMETH2=6).

nblok2=0 The number of blocks is internally calculated, based on number and arrangement of panels and maximum block size IBLSZ2.

nblok2>0 Directly specifies the number of blocks. Block size is internally calculated, based on number of panels and number of blocks.

nblok2<0 Directly specifies the number of blocks, as |nblok2|. User-specified block sizes (JBLSZ2(N)) are input on the next line.

NBLOK2=0 is recommended.

itermx2 (columns 26-30) Maximum number of iterations allowed during iterative solve of the free-surface flow solution matrix (IMETH2=6). If ITERMX2=0, an internal default maximum is used. **ITERMX2=0 is recommended.**

solres2 (columns 31-40) The Gauss-Seidel residual convergence criteria, expressed as a fraction of the maximum of the absolute values of the equation right-hand-sides, used during iterative solve of the free-surface flow solution matrix. If SOLRES2 < 1.0×10^{-12} , a default value 1.0×10^{-5} is used. **SOLRES2=0.0 is recommended.**

The next set of lines, which is preceded by a single comment line, specify block sizes to use during iterative solve of the free-surface flow solution matrix. These lines are input only if NBLOK2<0.

jb1sz2 (n) (columns 1-80) Block sizes (number of panels per block N). Use FORTRAN format (16I5) specification. Repeat lines until N=|NBLOK2| values have been specified.

The next line, which is preceded by a comment line, specifies network and general boundary condition parameters.

nnet (columns 1-5) Total number of free-surface, configuration-surface, and wake-surface panel networks making up the complete panel model.

nwls (columns 6-10) Controls waterline integral options.

nwls=0 Waterline integrals are not included in the calculations.

nwls≠0 Waterline integrals will be included in the calculations. A subsequent input section will specify the waterline integral particulars on a panel-by-panel basis.

ntbc (columns 11-15) Controls waterline boundary condition options.

ntbc=0 No dry transom or wet chine waterline boundary condition particulars will be input. All waterline boundary conditions will nominally be of the default, dry chine type.

ntbc≠0 Dry transom and wet chine waterline boundary particulars can be specified on a panel-by-panel basis in a subsequent input section.

ntrn (columns 16-20) If NTRN≠0, additional input consisting of x,y,z coordinate and other data relating to the location of the waterline/transom intersection will be included in a subsequent input section.

NTRN=0 is recommended. Any results using NTRN≠0 should be checked against those using NTRN=0.

ynvert (columns 21-30) For a free-surface panel for which the vertical component of the panel normal unit vector is less than the specified value of YNVERT, both panel doublet strength and source strength will be included as distinct unknowns in the free-surface solution matrix. This is necessary since, as the vertical component of the free-surface normal approaches zero, it is no longer possible to eliminate the source strength directly from the solution matrix. As the number of unknowns for such panels increases from one to two, the matrix to be solved correspondingly increases in size. The approach allows treatment of, for example, vertically wall-sided free-surface panels modeled downstream of a dry immersed transom or wet chine.

YNVERT=0.5 is recommended for typical cases, resulting in free-surface panels being treated as near-vertical if and only if they are fairly steep.

GENERAL NETWORK INPUTS

The next set of lines, which is preceded by a single comment line, specify various panel network parameters.

There must be NNET specification lines, one for each network. Free-surface networks must be input first, followed by configuration-surface networks, and finishing with wake-surface networks. Each network is thereafter identified by the number corresponding to the order in which it was input.

ntype (columns 1-5) Type of network:

- ntype=1 Free-surface network, with external free-surface boundary condition, and internal zero perturbation boundary condition.
- ntype=2 Solid-surface configuration network, with external normal velocity boundary condition, and internal zero perturbation boundary condition. Default is zero normal velocity.
- ntype=3 Separated base flow surface configuration network, with external total potential boundary condition, and internal zero perturbation boundary condition. Default is zero perturbation potential.
- ntype=4 Doublet only, thin lifting surface configuration network with zero source strength and single normal velocity boundary condition. Default is zero normal velocity. **Use of NTYPE=4 networks is no longer supported.**
- ntype=11 Lifting-type wake network, with convected doublet strength boundary condition. Use for wakes shed at trailing edges of

lifting surface networks (NTYPE=2 or NTYPE=4). If ILEAK≠0, the effects of NTYPE=11 wake networks are not considered in the calculations.

ntype=12 Separated base flow wake network, with convected doublet strength boundary condition. Use for wakes shed at edges joining separated base flow surface (NTYPE=3) and solid-surface (NTYPE=2) networks. The effects of NTYPE=12 wake networks are always considered in the calculations, even if ILEAK≠0.

komp (columns 6-10) Component group number to which this network belongs.

For configuration surface (NTYPE=1-4) networks, KOMP is the component group number to which this network belongs. Forces and moments will be printed to standard output on a component-by-component basis (as well as on a network basis, and for the total model). The component assignments are therefore just convenient groupings of network force and moment data.

Component numbering should start at 1 and thereafter increase by 1 for each new component introduced.

For wake surface (NTYPE=11-12) networks, a value of KOMP≠0 indicates that the wake should be included in wake-integration lift and induced drag calculations. A value of KOMP=0 indicates that the wake should not be included in such calculations (for example, for a keel wake which terminates at a rudder leading edge).

klas (columns 11-15) Assembly group number to which this network belongs.

For configuration surface (NTYPE=1-4) networks, only panels belonging to the same assembly group will be considered for forming the panel-to-panel velocity stencil neighbor relationships.

Assembly numbering should start at 1 and thereafter increase by 1 for each new assembly introduced.

jcorn (columns 16-20) Similar to ICORN, activates corner point output for single network.

jcpnt (columns 21-25) Similar to ICPNT, activates control point geometry output for single network.

jvls (columns 26-30) Similar to INVLS, activates velocity neighbor output for single network.

jngps (columns 31-35) Similar to INGPS, activates pressure gradient neighbor output for single network.

jshed (columns 36-40) Similar to ISHED, activates wake shedding output for single wake network.

juvwp (columns 41-45) Similar to IUWVP, activates control point solution output for single network.

nspan (columns 46-50) For NSPAN=0 there is no action.

If NSPAN≠0, detailed 2D-type sectional load (lift) distribution information will be generated and printed in the standard output, and to the SPLASH spanload output file "spanload".

Intended for foil-type surfaces only, otherwise use NSPAN=0.

nstrip (columns 51-55) Reserved for future use.

********* (columns 56-80) These fields are not read by the program. For ease of use, a brief comment describing the network may be located here.

FREE-SURFACE RADIATION CONDITIONS

The next set of lines, which is preceded by a single comment line, specifies the free-surface far field (outer boundary) wave radiation boundary conditions.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels) and the radiation boundary condition to apply to those panels. For any one panel, the last specification will apply. NKDMP=0 terminates the set (no further input).

nk dmp (columns 1-5) Network number containing the panels to which the radiation boundary condition will be applied. Must be a free-surface (NTYPE=1) network.

i1 dmp (columns 6-10) Starting row I-value for this group of panels.

i2 dmp (columns 11-15) Ending row I-value for this group of panels.

j1 dmp (columns 16-20) Starting column J-value for this group of panels.

j2 dmp (columns 21-25) Ending column J-value for this group of panels.

k dmp (columns 26-30) Radiation boundary condition specification for this group of panels. An integer value, indicating nominal order of far-field (outer boundary) wave free-surface boundary condition.

If IRADBC=0, use KDMP to damp waves at the outer boundary. KDMP limits the maximum number of panel control point pressures used in upwind free-surface boundary condition stencils on the specified panels. Starting with outer boundary edge panels, and moving inward away from the outer boundary, set KDMP values in a 0/0/2/2/3/3/4/4 pattern. Thereby creating a numerical "beach" covering the outermost 8 rows or columns of panels. Applied at upstream and side as well as downstream boundaries.

If IRADBC≠0, then KDMP merely designates panels lying along or next to the outer boundary. Set KDMP=0 on outer boundary edge panels, and on panels adjacent to outer boundary edge panels. Applied at upstream and side as well as downstream boundaries. See Figure 4.

If IRADBC≠0, free-surface boundary conditions depend on the basis flow velocity relative to the panel and the outer edge. If the velocity across the edge is onto the panel, it is an upstream type outer boundary, and no

upstream waves are permitted. Any free-surface stencil attempting to include a panel with an upstream type edge will instead terminate prematurely (the number of panels in the stencil will be decreased by one, rather than increased by one). Conversely, if the velocity across the edge is off the panel, it is a downstream type outer boundary, and wave propagation is allowed. No change is required to the standard free-surface boundary conditions at downstream type outer boundaries.

NONZERO NORMAL VELOCITY BOUNDARY CONDITIONS

The next set of lines, which is preceded by a single comment line, specifies nonzero normal velocity boundary conditions (used to approximate surface deflection, boundary layer displacement thickness, flow through a surface, intake or exhaust, etc.). If no value is specified for a panel, the default is zero normal velocity.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels) and the nonzero normal velocity boundary condition to apply to those panels. For any one panel, the last specification will apply. NVNRM=0 terminates the set (no further input).

nvnm (columns 1-5) Network number containing the panels to which the normal velocity boundary condition will be applied. Must be a solid surface (NTYPE=2) network.

i1nm (columns 6-10) Starting row I-value for this group of panels.

i2nm (columns 11-15) Ending row I-value for this group of panels.

j1nm (columns 16-20) Starting column J-value for this group of panels.

j2nm (columns 21-25) Ending column J-value for this group of panels.

vnm (columns 26-35) Normal velocity boundary condition specification for this group of panels.

If IHINGE=0, then VNRM specifies panel nondimensional normal velocity.

If IHINGE≠0, then IHINGE is instead a hinge line identifier, corresponding to one of the hinge lines (to be specified below), and VNRM specifies the rotation of the panels in degrees about the hinge line.

ihinge (columns 36-45) Hinge-line identifier. See the description for VNRM above.

HINGE LINE INPUTS

The next set of lines, which is preceded by a single comment line, specifies hinge line coordinates and the types of nonzero normal velocity boundary conditions for associated surface deflections.

Each line specifies a hinge line and a boundary condition type. IHTYP=0 terminates the set (no further input). Hinge lines are numbered according to their order of input. There must be at least as many hinge lines specified as implied by the nonzero normal velocity boundary condition specifications.

If no hinge lines will be required, then this set of lines (including the starting comment line) must be omitted altogether.

The hinge line is directed, from the first input point to the second, and positive and negative surface rotation is thereafter defined according to the right-hand rule.

- xhnge1** (columns 1-10) Global X-coordinate of first point on hinge axis.
- yhnge1** (columns 11-20) Global Y-coordinate of first point on hinge axis.
- zhnge1** (columns 21-30) Global Z-coordinate of first point on hinge axis.
- xhnge2** (columns 31-40) Global X-coordinate of second point on hinge axis.
- yhnge2** (columns 41-50) Global Y-coordinate of second point on hinge axis.
- zhnge2** (columns 51-60) Global Z-coordinate of second point on hinge axis.
- ihryp** (columns 61-70) Type of nonzero normal velocity boundary condition to be used for surface deflections and rotations about this hinge line.
 - ihryp=+1 Implicit boundary condition to simulate surface rotation due to rotation about the hinge line. The velocity normal to the rotated surface is specified to be zero, but the panel itself is not rotated. Results in an implicit relationship between local source strength (panel normal velocity) and local surface gradient of doublet strength (panel tangential velocity). **IHTYP=+1 is the only value that is recommended.**
 - ihryp=+2 Implicit boundary condition to simulate surface rotation and surface displacement due to rotation about the hinge line. Similar to ihryp=+1, but in the second (free-surface) solution accounts for the difference in velocity between the original and displaced field locations. The difference is determined from the first (basis flow) solution. **IHTYP=+2 is not recommended.**
 - ihryp=-1 Explicit boundary condition to simulate surface rotation due to rotation about the hinge line. The velocity normal to the rotated surface is specified to be zero by considering the panel to have rotated with respect to the freestream flow. Results in an explicit relationship for local source strength. The change in normal is treated as small and linear. **IHTYP=-1 is not recommended.**
 - ihryp=-2 Explicit boundary condition to simulate surface rotation and surface displacement due to rotation about the hinge line. Similar to ihryp=-1, but in the second (free-surface) solution accounts for the difference in velocity between the original and displaced field locations. The difference is determined from the first (basis flow) solution. The displacement is treated as small and linear. **IHTYP=-2 is not recommended.**

TOTAL POTENTIAL BOUNDARY CONDITIONS

The next set of lines, which is preceded by a single comment line, specifies surface total potential values applied to panels with separated base flow type boundary conditions (to simulate base flow separation, fully wet immersed transom, flow exhaust, etc.). If no value is specified for a panel, the default is zero perturbation potential.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels) and the total potential value to apply to those panels. For any one panel, the last specification will apply. NPTOT=0 terminates the set (no further input).

- nptot** (columns 1-5) Network number containing the panels to which the total potential boundary condition will be applied. Must be a separated base flow (NTYPE=3) network.
- i1tot** (columns 6-10) Starting row I-value for this group of panels.
- i2tot** (columns 11-15) Ending row I-value for this group of panels.
- j1tot** (columns 16-20) Starting column J-value for this group of panels.
- j2tot** (columns 21-25) Ending column J-value for this group of panels.
- ptot** (columns 26-35) Specified total potential for this group of panels.

VELOCITY NABOR RELATIONSHIPS

The next set of lines, which is preceded by a single comment line, specifies panel-to-panel "velocity nabor" relationships used for construction of panel-to-panel finite difference stencils required to calculate in-plane surface velocities (panel doublet gradients) and, nominally, free-surface panel pressure gradients.

Velocity nabor relationships may only be specified between two solid surface panels with internal zero-perturbation boundary conditions, or between two thin lifting surface panels with doublets only. The first group consists of free-surface panels (NTYPE=1), solid surface panels (NTYPE=2), and separated base flow panels (NTYPE=3). The second group consists of thin lifting surface panels (NTYPE=4) only.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels), a panel side edge (1-4), and the corresponding information for the naboring group of panels. Nabor relationships specified in this section override those determined automatically by SPLASH. For any one panel edge, the last specification will apply. N1VLN=0 terminates the set (no further input).

The user may also specify a single wake jump to be accounted for in any surface velocity (doublet gradient) stencils which rely upon the panel-to-panel nabor relationship being specified. This input has largely been rendered obsolete, due to addition of a new input section devoted solely to input of wake jump information. The new section has enhanced inputs for specifying jumps across multiple wakes, and for specifying weights used to prorate wake jump contributions to velocity stencils. Wake jumps specified here override those determined automatically by SPLASH (assuming the latter were requested).

- n1v1n** (columns 1-5) Network number containing the panels for which panel-to-panel edge nabor relationships will be specified.
- n1v1i1** (columns 6-10) Starting row I-value for this group of panels.
- n1v1i2** (columns 11-15) Ending row I-value for this group of panels.
- n1v1j1** (columns 16-20) Starting column J-value for this group of panels.
- n1v1j2** (columns 21-25) Ending column J-value for this group of panels.
- n1v1s** (columns 26-30) Edge or side of panels involved in nabor relationship.
- n2v1n** (columns 31-35) Network number containing the group of naboring panels.
- n2v1i1** (columns 36-40) Starting row I-value for the naboring group of panels.
- n2v1i2** (columns 41-45) Ending row I-value for the naboring group of panels.
- n2v1j1** (columns 46-50) Starting column J-value for the naboring group of panels.
- n2v1j2** (columns 51-55) Ending column J-value for the naboring group of panels.
- n2v1s** (columns 56-60) Edge or side of naboring panels involved in nabor relationship. A negative side edge value indicates that the naboring panels are the symmetry plane or ground plane images of the specified panels.
- nv1wn** (columns 61-65) Indicates the network number of a wake network (NTYPE=11 or NTYPE=12) across which the jump in potential must be accounted for in panel surface velocity (doublet gradient) stencils which rely upon the nabor relationships being specified.
- [NVLWN] indicates the wake network number. If NVLWN>0, then the panels are located to the upper side of the wake network panels, and the naboring panels are located to the lower side of the wake network panels. Conversely, if NVLWN<0, then the panels are located to the lower side of the wake panels, and the naboring panels are located to the upper side of the wake panels.
- nv1wj1** (columns 66-70) Starting column j-value for wake panels involved in the nabor relationship.
- nv1wj2** (columns 71-75) Ending column j-value for wake panels involved in the nabor relationship.

PRESSURE GRADIENT NABOR RELATIONSHIPS

The next set of lines, which is preceded by a single comment line, specifies alternate panel-to-panel “free-surface pressure gradient nabor” relationships to be used for the construction of panel-to-panel finite difference stencils required to calculate free-surface panel pressure gradients. These nabors are nominally the same as the velocity nabor relationships used for panel surface velocity (doublet gradient) stencils. This

input can be used to specify different nabor relationships to use for constructing the free-surface panel pressure gradient stencils.

This input has largely been rendered obsolete, due to enhancements in other areas such as wake jump and transverse surface boundary condition treatments . Due to these enhancements, it is much less likely that separate nabor relationships are needed for free-surface pressure gradient stencils versus doublet gradient stencils.

Free-surface pressure gradient nabor relationships may only be specified between two solid surface panels with internal zero-perturbation boundary conditions. This includes free-surface panels (NTYPE=1), solid surface panels (NTYPE=2), and separated base flow panels (NTYPE=3).

Input format is similar to that for velocity nabor relationships, except that no wake jump information is specified (because it is assumed that there is no jump in pressure across wakes). For any one panel edge, the last specification will apply. N1GPN=0 terminates the set (no further input).

- n1gpn** (columns 1-5) Network number containing the panels for which panel-to-panel edge nabor relationships will be specified.
- n1gpi1** (columns 6-10) Starting row I-value for this group of panels.
- n1gpi2** (columns 11-15) Ending row I-value for this group of panels.
- n1gpj1** (columns 16-20) Starting column J-value for this group of panels.
- n1gpj2** (columns 21-25) Ending column J-value for this group of panels.
- n1gps** (columns 26-30) Edge or side of panels involved in nabor relationship.
- n2gpn** (columns 31-35) Network number containing the group of naboring panels.
- n2gpi1** (columns 36-40) Starting row I-value for the naboring group of panels.
- n2gpi2** (columns 41-45) Ending row I-value for the naboring group of panels.
- n2gpj1** (columns 46-50) Starting column J-value for the naboring group of panels.
- n2gpj2** (columns 51-55) Ending column J-value for the naboring group of panels.
- n2gps** (columns 56-60) Edge or side of naboring panels involved in nabor relationship. A negative side edge value indicates that the naboring panels are the symmetry plane or ground plane images of the specified panels.

WAKE SHEDDING INFORMATION

The next set of lines, which is preceded by a single comment line, specifies wake shedding information. For each column of wake panels, this information includes the upper and lower surface wake shedding panels, and the upper and lower surface panel edges, from which the wakes are shed.

Each line specifies a group of wake panel columns (a J subset of a wake network's panel columns), and the corresponding upper and lower surface wake shedding panels and edges. The same number of wake

columns and upper and/or lower wake shedding panels must be specified. Wake shedding information specified in this section overrides any determined automatically by SPLASH (assuming the latter were requested). For any one wake column, the last specification will apply. NNETW=0 terminates the set (no further input).

- nnetw** (columns 1-5) Network number of the wake network (NTYPE=11 or NTYPE=12) containing the wake panel columns for which wake shedding information will be specified.
- j1w** (columns 6-10) Starting column J-value for this group of wake panel columns.
- j2w** (columns 11-15) Ending column J-value for this group of wake panel columns.
- nwaku** (columns 16-20) Configuration-surface network (NTYPE=1-4) to which upper surface wake shedding panels belong. If there is no upper wake shedding panel (and only a lower wake shedding panel), set NWAKU=0.
- i1u** (columns 21-25) Starting row I-value for upper surface wake shedding panels.
- i2u** (columns 26-30) Ending row I-value for upper surface wake shedding panels.
- j1u** (columns 31-35) Starting column J-value for upper surface wake shedding panels.
- j2u** (columns 36-40) Ending column J-value for upper surface wake shedding panels.
- nsidu** (columns 41-45) Upper surface wake shedding panel edge number from which wake is shed.
- nwakl** (columns 46-50) Configuration-surface network (NTYPE=1-4) to which lower surface wake shedding panels belong. If there is no lower wake shedding panel (and only an upper wake shedding panel), set NWAKL=0.
- i1l** (columns 51-55) Starting row I-value for lower surface wake shedding panels.
- i2l** (columns 56-60) Ending row I-value for lower surface wake shedding panels.
- j1l** (columns 61-65) Starting column J-value for lower surface wake shedding panels.
- j2l** (columns 66-70) Ending column J-value for lower surface wake shedding panels.
- nsidl** (columns 71-75) Lower surface wake shedding panel edge number from which wake is shed.

WAKE JUMP INFORMATION

The next set of lines, which is preceded by a single comment line, specifies wake jump information used during construction of panel-to-panel surface velocity (doublet gradient) finite difference stencils.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels), a panel side edge (1-4), and the corresponding wake jump information. The same total number of wake columns as panel columns must be specified, or just one wake column may be specified. Wake jumps specified here override those determined automatically by SPLASH (assuming the latter were requested), as well as those specified

previously (in the velocity nabor relationship input set). For any one panel edge, the specifications here are cumulative. NNWJ=0 terminates the set (no further input).

- nnwj** (columns 1-5) Network number of the surface network (NTYPE=1-4) containing the panels for which edge wake jump information will be specified.
- nnwji1** (columns 6-10) Starting row I-value for this group of panels.
- nnwji2** (columns 11-15) Ending row I-value for this group of panels.
- nnwj1** (columns 16-20) Starting column J-value for this group of panels.
- nnwj2** (columns 21-25) Ending column J-value for this group of panels.
- nnwjs** (columns 26-30) Edge or side of panels involved in wake jump.
- nwwj** (columns 31-35) Network number of the wake network (NTYPE=11 or NTYPE=12) across which the jump in potential must be accounted for in surface velocity (doublet gradient) stencils crossing the specified panel edges to join with their naboring panels.

|NWWJ| indicates the wake network number. If NWWJ>0, then the panels are located to the upper side of the wake network panels, and the naboring panels are located to the lower side of the wake network panels. Conversely, if NWWJ<0, then the panels are located to the lower side of the wake panels, and the naboring panels are located to the upper side of the wake panels.

- nwwj1** (columns 36-40) Starting column j-value for wake panel columns across which the jump in potential must be taken into account.
- nwwj2** (columns 41-45) Ending column j-value for wake panel columns across which the jump in potential must be taken into account.
- rnwj** (columns 46-55) A weighting factor, normally set to 1.0, but can be used in special circumstances to prorata wake jump contributions. Contributions to surface velocity (doublet gradient) stencils due to the specified wake jumps will be multiplied by the factor RNWJ.

One use of weighting factors is to account in a very simple fashion for a foil surface which intervenes between a panel edge and its would-be nabor. This requires an estimate of the fraction of the foil lift developed upstream of and along the panel edge. The weighting factor is then set to the average value of this fraction of lift along the panel edge, and otherwise differencing across the foil as usual. A corresponding weighting factor of (1.0-rnwj) should also be specified for any upstream coplanar wake which terminated at the foil leading edge.

COPLANAR WAKE INFORMATION

The next set of lines, which is preceded by a single comment line, specifies coplanar lifting surface and wake information.

Each line specifies a group of downstream lifting surface panels (an I/J or row/column subset of a network's panels), and the corresponding upstream wake panel columns with which the surface panels are coplanar. The same total number of panel columns and wake columns must be specified. For any one panel, the specifications here are cumulative. NNCW=0 terminates the set (no further input).

-
- | | | |
|---------------|-----------------|--|
| nncw | (columns 1-5) | Network number of the downstream surface network (NTYPE=1-3) containing the panels for which coplanar wake information will be specified. |
| nncwi1 | (columns 6-10) | Starting row I-value for this group of panels. |
| nncwi2 | (columns 11-15) | Ending row I-value for this group of panels. |
| nncwj1 | (columns 16-20) | Starting column J-value for this group of panels. |
| nncwj2 | (columns 21-25) | Ending column J-value for this group of panels. |
| nncw | (columns 26-30) | Network number of the upstream wake network (NTYPE=11 or NTYPE=12) containing the wake panel columns that are coplanar with the downstream surface panels. |
| | | [NWCW] indicates the wake network number. If NWCW>0, then the wake panels are oriented in the same direction as the surface panels. Conversely, if NWCW<0, then the wake panels will be oriented in the opposite direction as the surface panels. |
| | | Usually, wake network NWCW panels will terminate at the leading edge of the downstream surface network. |
| nncwj1 | (columns 31-35) | Starting column j-value for the wake panel columns which are coincident with the surface panels. |
| nncwj2 | (columns 36-40) | Ending column j-value for the wake panel columns which are coincident with the surface panels. |
| rncw | (columns 41-50) | A weighting factor, normally set to 1.0, but can be used in special circumstances to prorate wake jump contributions. Contributions to surface velocity (doublet gradient) stencils due to the specified coplanar wakes will be multiplied by the factor RNCW. |

STEADY WATERLINE INTEGRALS

The next set of lines, which is preceded by a single comment line, specifies information for the calculation of steady waterline integrals. These integrals lead to additional forces and moments by accounting for any mismatch at the waterline between panel geometric elevations and computed free-surface wave elevations.

This set of lines (including the starting comment line) should only be included in the input file if NWLS≠0, and must be omitted altogether if NWLS=0.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels), the panel side edge (1-4) along the waterline, and additional waterline integral information. Both standard dry chine and special transom type integral contributions may be specified for the same panel edge. Otherwise, for any panel edge, the last specifications will apply. NWLS=0 terminates the set (no further input).

- ntwls** (columns 1-5) Network number of the surface network (NTYPE=2-3) containing the panels for which waterline integral information will be specified.
- i1wls** (columns 6-10) Starting row I-value for this group of panels.
- i2wls** (columns 11-15) Ending row I-value for this group of panels.
- j1wls** (columns 16-20) Starting column J-value for this group of panels.
- j2wls** (columns 21-25) Ending column J-value for this group of panels.
- nswls** (columns 26-30) Edge or side of panels involved in waterline integral.
- rwlint** (columns 31-40) A weighting factor, normally set to 1.0, but can be used in special circumstances to prorate waterline integral contributions. Contributions to waterline integrals due to the specified information will be multiplied by the factor RWLINT.
- nwltyp** (columns 41-50) Denotes the type of waterline integral, and its treatment with respect to inclusion in total waterline integral forces and moments, and in total hydrodynamic forces and moments.

nwltyp=+1 Standard (dry chine) waterline integral. The hull (or other solid surface) waterline panel edge is imagined to move up or down in the plane of the panel and parallel to itself, so as to extend or reduce the wetted area of the panel, from the geometric panel waterline to the final calculated waterline wave height. The waterline integral result is also included in the total waterline integral forces and moments and in the total hydrodynamic forces and moments.

nwltyp=-1 Similar to nwltyp=+1, but the waterline integral result is not included in the total waterline integral forces and moments or in the total hydrodynamic forces and moments.

nwltyp=+2 Transom waterline integral. Waterline integral area is estimated to be the area extending vertically upward from the panel edge

up to the calculated free-surface wave height. The waterline integral result is also included in the total waterline integral forces and moments and in the total hydrodynamic forces and moments.

nwltyp=-2 Similar to nyltyp=+2, but the waterline integral result is not included in the total waterline integral forces and moments or in the total hydrodynamic forces and moments.

WET CHINE AND DRY OR PARTIALLY WET TRANSOM BOUNDARY CONDITIONS

The next set of lines, which is preceded by a single comment line, specifies wet chine and dry or partially wet transom boundary condition information.

This set of lines (including the starting comment line) should only be included in the input file if NTBC≠0, and must be omitted altogether if NTBC=0.

Each line specifies a group of panels (an I/J or row/column subset of a network's panels), the panel side edge (1-4) along the waterline, and additional waterline boundary condition information. For any one panel edge, the specifications here are cumulative. NWLS=0 terminates the set (no further input).

- nttbc** (columns 1-5) Network number of the free-surface network (NTYPE=1) containing the panels for which waterline boundary conditions will be specified.
- i1tbc** (columns 6-10) Starting row I-value for this group of panels.
- i2tbc** (columns 11-15) Ending row I-value for this group of panels.
- j1tbc** (columns 16-20) Starting column J-value for this group of panels.
- j2tbc** (columns 21-25) Ending column J-value for this group of panels.
- nstbc** (columns 26-30) Edge or side of panels involved in waterline boundary condition.
- rwetch** (columns 31-40) Wet chine waterline boundary condition weighting factor. Normally set to either 0.0 or 1.0, but can be used in special circumstances to prorate wet chine waterline boundary conditions. Wet chine contributions to waterline boundary conditions will be multiplied by the factor RWETCH. The standard dry chine contribution will simultaneously be reduced by a corresponding amount.
- rdrytr** (columns 41-50) Dry or partially wet immersed transom waterline boundary condition weighting factor. Normally set to either 0.0 or 1.0, but can be used in special circumstances to prorate dry transom waterline boundary conditions. Dry transom contributions to waterline boundary conditions will be multiplied by the factor RDRYTR. The standard dry chine contribution will simultaneously be reduced by a corresponding amount.

WATERLINE AND TRANSOM EDGE INTERSECTIONS

The next set of lines, which is preceded by a single comment line, specifies the global coordinates of the exact points where waterlines and a transoms edge intersect.

In some panel models, the intersection between the running waterline and the dry immersed transom may not be adequately captured. Instead, a panel may simply straddle the intersection, with one corner point forward of the intersection (on the running waterline) and the next corner point below the intersection (along the immersed transom edge). The inputs here are used to indicate that a triangular area, formed by the specified panel waterline edge and the specified intersection point, should be added to the true panel area during the pressure integration calculation of forces and moments.

This set of lines (including the starting comment line) should only be included in the input file if NTRN≠0, and must be omitted altogether if NTRN=0.

Each line specifies a panel (by its network and I/J or row/column designation), the panel side edge (1-4) along the waterline, and the global coordinates of the true waterline/transom intersection point. NTRN=0 terminates the set (no further input).

ntrn (columns 1-5) Network number of the surface network (NTYPE=2-3) containing the panel for which the true waterline/transom intersection point will be specified.

itrn (columns 6-10) Row I-value for this panel.

jtrn (columns 11-15) Column J-value for this panel.

nstrn (columns 16-20) Waterline edge or side of panel (1-4) with which the true waterline/transom intersection point is associated.

xtrnsm (columns 21-30) Global X-coordinate of the true waterline/transom intersection point.

ytrnsm (columns 31-40) Global Y-coordinate of the true waterline/transom intersection point.

ztrnsm (columns 41-50) Global Z-coordinate of the true waterline/transom intersection point.

TRANSVERSE BOUNDARY CONDITION SPECIFICATIONS

The next line, which is preceded by a comment line, specifies the type of transverse boundary conditions that will be implemented for the overall calculations.

iedgpts (columns 1-10) **iedgpts≠0** Transverse boundary condition data will be used to construct values of potential at midpoints of specified panel edges, based on potential values extrapolated from an adjacent transverse surface. These edge midpoint values can be included in otherwise standard surface velocity (doublet gradient) stencils between panel control points. Panels on the transverse surface and the corresponding weights (extrapolation coefficients) will be specified.

iedgpts=0 Panel edge midpoint potential values will not be constructed. Instead, for the specified panels, transverse boundary condition data will be used to prorate the contribution of one-sided stencils (in a direction away from the transverse surface panels). All data should be input as if iedgpts≠0 had been specified.

iedgpts=0 is recommended.

iedgcps (columns 11-20) iedgcps≠0 The pressures at the panel edge midpoints are also extrapolated from the adjacent transverse surface. These pressures can be included in otherwise standard free-surface pressure gradient stencils between panel control points. **Requires iedgpts≠0.**

iedgcps=0 The pressures at the panel edge midpoints are not extrapolated from the adjacent transverse surface, and are not included in free-surface pressure gradient stencils. **If iedgpts=0, then iedgcps=0 is also required.**

iedgcps=0 is recommended, especially if extrapolation coefficients include contributions to account for jumps in potential across intervening non-coplanar wakes (as described later).

iedgcpv (columns 11-20) iedgcpv≠0 Flow variables at the panel edge midpoints are also extrapolated from the adjacent transverse surface, and used during the final post-solution interpolation of variables from panel control points to panel corner points. **Requires iedgpts≠0.**

iedgcpv=0 Flow variables at the panel edge midpoints are not extrapolated from the adjacent transverse surface, and are not used during the final post-solution interpolation of variables from panel control points to panel corner points. **If iedgpts=0, then iedgcpv=0 is also required.**

iedgcpv=0 is recommended, especially if extrapolation coefficients include contributions to account for jumps in potential across intervening non-coplanar wakes (as described later).

The remaining set of lines specifies the detailed transverse boundary condition information. All remaining information is input for the first panel edge to which transverse boundary conditions are to be applied, then for the next panel edge, and so on. NNEDG=0 terminates the set (no further input).

The next line identifies the panel and edge to which the subsequent transverse boundary condition information will apply.

nnedg (columns 1-5) Network number of the surface network (NTYPE=1-3) containing the panel for which the transverse boundary condition information will be specified.

iedg (columns 6-10) Row I-value for this panel.

jedg (columns 11-15) Column J-value for this panel.

nsedg (columns 16-20) Edge or side of this panel (1-4) for which the transverse boundary condition information will be specified.

For the current panel edge, the next line identifies the panel and edge to which it would normally nabor, if not for the presence of the intervening transverse surface. If the sum of the transverse surface extrapolation coefficients to be specified below is less than 1.0, then the missing fraction (1.0 minus the sum) represents a portion of the current panel edge not abutting the transverse surface and instead communicating directly with its would-be nabor. The final velocity stencil will include a corresponding prorated contribution from the standard stencil formed with the would-be nabor.

nnab (columns 1-5) Network number of the surface network (NTYPE=1-3) containing the would-be panel nabor.

inab (columns 6-10) Row I-value for the would-be panel nabor.

jnab (columns 11-15) Column J-value for the would-be panel nabor.

nsnab (columns 16-20) Naboring edge or side of the would-be panel nabor (1-4). A negative side edge value indicates that the would-be naboring panel is the symmetry plane or ground plane image of the specified panel.

For the current panel edge, the next subset of lines specifies the transverse surface extrapolation coefficients. These represent the contributions of panels on the adjacent transverse surface to an extrapolation along that surface to the current panel edge midpoint (actually, to an arclength-weighted average value along the current panel edge). The sum of the extrapolation coefficients should be equal to the fraction of the current panel edge that is blocked from communicating directly with its would-be nabor by the intervening transverse surface.

The extrapolation coefficients can also be used to include the jump across any non-coplanar upstream wake which intervenes between the current panel and the value of potential as extrapolated from the adjacent transverse surface. This is accomplished by including contributions from the corresponding wake upper and lower surface wake shedding panels, with extrapolations coefficients of +1.0 and -1.0, or -1.0 and +1.0, as required to properly adjust the final extrapolated value due to the presence of the intervening wake. Note that the sum of all the extrapolation coefficients remains unchanged. This approach works for extrapolation of potentials from the transverse surface, but it invalidates using the coefficients for extrapolating the velocity (which occurs if $iedgcpv \neq 0$) or the pressure (which occurs if the current panel is on the free-surface and $iedgcpv \neq 0$) from the adjacent transverse surface.

The following line is repeated until all extrapolation coefficients have been specified. NNPEDG=0 terminates the extrapolation coefficient input for the current panel (no further coefficient input for the current panel).

nnpedg (columns 1-5) Network number of the panel on the adjacent surface network (with NTYPE=1-3) for which the extrapolation coefficient will be specified. A negative network number indicates that the desired panel is actually the symmetry plane or ground plane image of the specified panel on the adjacent network surface.

ipedg (columns 6-10) Row I-value for the panel on the adjacent surface network.

jpedg (columns 11-15) Column J-value for the panel on the adjacent surface network.

- rpedg** (columns 16-25) Extrapolation coefficient to apply to the panel on the adjacent surface network.
- kpvsym** (columns 26-30) If $nnpedg < 0$, use $kpvsym = -1$ if the adjacent surface image panel is located on the other side of the y-coordinate symmetry plane. Otherwise use $kpvsym = +1$.
- kpwgpr** (columns 31-35) If $nnpedg < 0$, use $kpwgpr = -1$ if the adjacent surface image panel is located on the other side of the z-coordinate ground plane. Otherwise use $kpwgpr = +1$.

If $nnpedg < 0$, and both $kpvsym \geq 0$ and $kpwgpr \geq 0$, then the internal values of $kpvsym$ and $kpwgpr$ will instead be set automatically by SPLASH. It is therefore usually sufficient to just specify $kpvsym = 0$ and $kpwgpr = 0$.

For the current panel edge, the next subset of lines specifies information about wake jumps to be accounted for between the current panel and its would-be nabor (this is similar to, but overrides, the previous wake jump input section).

The following line is repeated until all such wake jumps have been specified. $NNWEDG = 0$ terminates the wake jump input for the current panel (no further wake jump input for the current panel).

- nnwedg** (columns 1-5) Network number of the wake network ($NTYPE = 11$ or $NTYPE = 12$) across which the jump in potential must be accounted for in panel surface velocity (doublet gradient) stencils as they cross the current panel edge onto the would-be naboring panel.

$|NNWEDG|$ indicates the wake network number. If $NNWEDG > 0$, then the current panel is located to the upper side of the wake network, and the would-be naboring panel is located to the lower side of the wake network. Conversely, if $NNWEDG < 0$, then the current panel is located to the lower side of the wake, and the would-be naboring panel is located to the upper side of the wake panel.

- jwedg** (columns 6-10) Column j-value for wake panel column across which the jump in potential must be taken into account.

- rwedg** (columns 11-20) A weighting factor, normally set to 1.0, but can be used in special circumstances to prorated the wake jump contribution. Contributions to surface velocity (doublet gradient) stencils due to the specified wake jump will be multiplied by the factor $RWEDG$

In certain circumstances, it is possible that a panel communicates directly with its would-be nabor both upstream and downstream of an intervening transverse surface. In such cases the wake jumps upstream and downstream of the intervening transverse surface should be prorated according to the degree of corresponding communication. For example, if twice as much of the panel edge is downstream of the intervening surface, compared to the amount of panel edge that is upstream of the intervening surface, then wake jumps upstream of the intervening surface should be given a weighting factor of $1/3$, and wake jumps downstream of the intervening surface should be given a weighting factor of $2/3$.

As discussed in the more general wake jump input section, one use of weighting factors is to account in a very simple fashion for a foil surface which intervenes between a panel edge and its would-be neighbor, based on an estimate of the fraction of foil lift developed along the panel edge. Here, via appropriate manipulation of both the extrapolation coefficients and the wake jump weight factors, a blend of any desired degree between a true transverse boundary condition and simply differencing across the foil is possible.

This blended approach is used by ACCPAN. The blend varies in a smooth fashion with the ratio of panel edge length to foil root chord. If the edge length is small compared to the foil chord, the bias is towards a true transverse boundary condition. If the edge length is large compared to the foil chord, the bias is towards simply differencing across the foil.

NETWORK PANEL CORNER POINT DATA

This final section is used to input the network panel corner point data. Data is specified for each network in the same order as was specified previously in the "General Network Inputs" section.

The first line for each network specifies the number of panel corner points in each of the network I/J (row/column) directions, and a character string describing the network. SPLASH output will print this string to identify a network by name.

nrow (columns 1-5) Number of rows of panel corner points on network in I direction.

ncol (columns 6-10) Number of rows of panel corner points on network in J direction.

(columns 11-20) These columns are left blank.

name (columns 21-80) Alphanumeric text describing the network.

The remaining lines specify the global X/Y/Z coordinates of each panel corner point in the network. An X/Y/Z data triplet for each corner point is specified starting at I=1 and proceeding to I=NROW, first at J=1, then at J=2, and so on, until completing at J=NCOL. The data is read using FORTRAN format-free or list-directed sequential (5,*) specification. Data can therefore be in a variety of formats, for example with individual data values separated by blank, comma, or newline characters.

x, y, z X,Y,Z coordinates of panel corner point.

Standard-Output File

The SPLASH standard output file is created during program execution and contains the following execution details:

Copyright information.

Echo of input data.

Network summary information.

Panel corner point coordinates (if requested).

Panel control point coordinates, normals, areas, and boundary condition information (if requested).

Panel-to-panel doublet gradient nabor relationship information, before and after wake shedding, used for velocity calculations (if requested).

Panel-to-panel pressure gradient nabor relationship information, before and after wake shedding, used for free-surface boundary condition calculations (if requested).

Wake shedding information (if requested).

Wake jump information used in panel-to-panel doublet gradient nabor relationships.

Information generated during solution of basis flow matrix.

Information generated during solution of free-surface flow matrix.

Hydrostatic results ($Fr^2/2$ x aerodynamic coefficients, i.e., $F/\rho gSL$ and $M/\rho gSL$):

- network total force summaries.
- component total force summaries.
- configuration total force summary.

Basis flow results:

- panel control point coordinates, velocities, pressures, source and doublet strengths, and network column sectional force summary (if requested).
- network total force summaries.
- component total force summaries.
- configuration total force summary.

Free-surface flow results:

- panel control point coordinates, velocities, pressures, source and doublet strengths, and network column sectional force summary (if requested).
- network total force summaries.
- component total force summaries.

configuration total force summary.

Wake integration results:

wake network column sectional force distributions.
wake network total force summaries.
configuration total wake force summary.

CPU time and memory usage information.

Where appropriate, force summaries include wetted areas, planform areas, sectional geometric characteristics, and all six forces and moments in both global and "wind axes" coordinate systems.

Developing Free-Surface Elevation File (filename "*pxxf*s")

If file *pxxf*s is present during program execution, it can be accessed by SPLASH and used to implement more sophisticated boundary conditions on free-surface panels during both the basis flow and free-surface flow solutions. The file must have been created by other means (for example, by ACCPAN). It is only read, and not modified, by SPLASH.

The file contains developing free-surface network panel corner point coordinates and predicted wave elevations. Two versions of the data are included: an unsmoothed version, and a smoothed version (for example, smoothed by ACCPAN prior to repanelization). The file is in Tecplot POINT data format with VARIABLES=*x,y,z,yfs,xsmth,ysmth,zsmth,yfssmth*.

The implementation of the more sophisticated boundary conditions on free-surface panels during basis flow and free-surface flow solutions using the data in file *pxxf*s is described in detail in the previous discussions for input parameters INRMZERO, INRMFRSQ, CNORM, IEDGZERO, IEDGFRSQ, and CEDGE.

Force/Moment/Sink/Trim Iteration History File (filename "*tfms*")

If parameter IFMST is not zero, then SPLASH will append one or more lines to the end of file *tfms*.

The supporting automated panelization package ACCPAN also uses this file, to keep track of configuration details and flow conditions, sink and trim, wetted areas and lengths, crew and sail forces and moments, hydrostatic forces and moments, viscous forces and moments, inviscid (wave plus lift-induced) forces and moments, and waterline integral forces and moments.

For free-to-sink-and-trim and/or nonlinear free-surface solutions, ACCPAN uses this file to iteratively and convergently drive SPLASH to the desired steady solution. In similar fashion, a restart capability is also provided. Several post-processing tools can also use this file: to collate results; to make leakage, surfing rudder, and other corrections to the results; or to generate stripping estimates for viscous forces and moments based on calculated wetted areas and lengths.

A sample SPLASH force/moment/sink/trim iteration history file is included below, followed by a description of those lines that are generated and appended by SPLASH:

speed	heel	yaw	dkeel	drudr	sink	trim	4
swethl	swetkl		swetbl	swetbb	swetrd		swetwg
xwethl	xxxxxx		xxxxxx	wcrew	xcrew		wxcrew
cfxsl	cfysl		cfzsl	cmxsl	cmysl		cmzsl
cfxst	cfyst		cfzst	cmxst	cmyst		cmzst
cfxvhl	cfyvhl		cfzvhl	cmxvhl	cmyvhl		cmzvhl
cfxvkl	cfyvkl		cfzvkl	cmxvkl	cmyvkl		cmzvkl
cfxvbl	cfyvbl		cfzvbl	cmxvbl	cmyvbl		cmzvbl
cfxvvg	cfyvvg		cfzvvg	cmxvvg	cmyvvg		cmzvvg
cfxvrd	cfyvrd		cfzvrd	cmxvrd	cmyvrd		cmzvrd
cfxvfr	cfyvfr		cfzvfr	cmxvfr	cmyvfr		cmzvfr
cfxcf	cfycf		cfzcf	cmxcf	cmycf		cmzcf
cfxdy	cfydy		cfzdy	cmxdy	cmddy		cmzdy
6.17329	20.00000	4.00000	5.00000	4.00000	-0.05524	-0.27315	4
5.24756E+01	6.99614E+00	6.48255E+00	4.34105E-03	3.35800E+00	1.33385E+00		
1.74690E+01	0.00000E+00	0.00000E+00	1.95000E+04	8.12500E-01	2.76552E+03		
-3.42347E+03	8.69173E+01	5.99670E-03	4.04975E+02	1.59540E+04	-4.37855E+04		
-1.06586E-01	-2.09480E+05	-1.34902E-02	-1.32780E+05	-1.34197E+00	-1.49857E+05		
1.73351E-03	0.00000E+00	1.21218E-04	3.16222E-06	1.44565E-05	-4.52219E-05		
3.47403E-04	0.00000E+00	2.42928E-05	2.62157E-06	1.31538E-05	-3.74903E-05		
2.85896E-04	0.00000E+00	1.99918E-05	3.98645E-06	2.05107E-05	-5.70089E-05		
6.48209E-05	0.00000E+00	4.53271E-06	9.35721E-07	4.37733E-06	-1.33814E-05		
1.70477E-04	0.00000E+00	1.19210E-05	8.02965E-07	-1.86722E-06	-1.14830E-05		
0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00		
2.60210E-03	0.00000E+00	1.81957E-04	1.15089E-05	-3.82819E-05	-1.64586E-04		
4.21862E-03	1.87295E-02	4.49112E-02	5.40128E-03	-3.16919E-03	9.94460E-03		
6.17329	20.00000	4.00000	5.00000	4.00000	0.00556	-0.18090	4
5.63898E+01	6.99614E+00	6.48255E+00	4.34105E-03	3.49831E+00	1.33385E+00		
1.88004E+01	0.00000E+00	0.00000E+00	1.95000E+04	8.12500E-01	2.76552E+03		
-1.31505E+04	2.15308E+04	-5.83802E+04	8.47945E+05	1.00440E+05	-1.53963E+05		
-6.09079E+01	-2.39576E+05	-3.99090E+01	-1.53345E+05	-5.44329E+02	-1.90272E+05		
1.84462E-03	0.00000E+00	1.28988E-04	3.13832E-06	-7.95484E-05	-4.48801E-05		
3.47405E-04	0.00000E+00	2.42929E-05	2.62239E-06	1.31581E-05	-3.75020E-05		
2.85896E-04	0.00000E+00	1.99918E-05	3.98684E-06	2.05172E-05	-5.70146E-05		
6.48208E-05	0.00000E+00	4.53271E-06	9.36529E-07	4.37883E-06	-1.33930E-05		
1.77369E-04	0.00000E+00	1.24028E-05	8.13724E-07	-2.10510E-06	-1.16368E-05		
0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00		
2.72011E-03	0.00000E+00	1.90208E-04	1.14978E-05	-4.35994E-05	-1.64426E-04		
4.62374E-03	2.57582E-02	4.64246E-02	5.75681E-03	-2.99833E-03	1.10541E-02		

(intermediate iteration records)

6.17329	20.00000	4.00000	5.00000	4.00000	0.06882	-0.08220	4
5.75827E+01	6.99614E+00	6.48255E+00	4.34104E-03	3.56618E+00	1.33385E+00		
2.03253E+01	0.00000E+00	0.00000E+00	1.95000E+04	8.12500E-01	2.76552E+03		
-1.42823E+04	2.25237E+04	-6.10359E+04	8.86513E+05	1.07495E+05	-1.67775E+05		
-3.30272E+02	-2.63885E+05	-6.94030E+02	-1.71425E+05	-9.67732E+03	-2.31030E+05		
1.86414E-03	0.00000E+00	1.30353E-04	2.95290E-06	-8.14808E-05	-4.22284E-05		
3.47407E-04	0.00000E+00	2.42931E-05	2.62326E-06	1.31627E-05	-3.75145E-05		
2.85897E-04	0.00000E+00	1.99919E-05	3.98726E-06	2.05241E-05	-5.70204E-05		
6.48207E-05	0.00000E+00	4.53271E-06	9.37393E-07	4.38042E-06	-1.34054E-05		
1.80694E-04	0.00000E+00	1.26353E-05	8.24669E-07	-2.22315E-06	-1.17933E-05		
0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00		
2.74296E-03	0.00000E+00	1.91806E-04	1.13255E-05	-4.56368E-05	-1.61962E-04		
5.15666E-03	2.97914E-02	4.75344E-02	6.12098E-03	-2.64535E-03	1.18953E-02		
6.17329	20.00000	4.00000	5.00000	4.00000	0.06903	-0.07761	4
5.75471E+01	6.99614E+00	6.48255E+00	4.34105E-03	3.56624E+00	1.33385E+00		
2.03314E+01	0.00000E+00	0.00000E+00	1.95000E+04	8.12500E-01	2.76552E+03		

```

-1.43093E+04  2.25287E+04 -6.10478E+04  8.86685E+05  1.07628E+05 -1.68116E+05
-3.50621E+02 -2.63777E+05 -7.42912E+02 -1.71375E+05 -1.01637E+04 -2.32135E+05
 1.86291E-03  0.00000E+00  1.30267E-04  2.94917E-06 -8.14065E-05 -4.21752E-05
 3.47407E-04  0.00000E+00  2.42931E-05  2.62330E-06  1.31629E-05 -3.75150E-05
 2.85897E-04  0.00000E+00  1.99919E-05  3.98728E-06  2.05244E-05 -5.70207E-05
 6.48207E-05  0.00000E+00  4.53271E-06  9.37433E-07  4.38050E-06 -1.34059E-05
 1.80697E-04  0.00000E+00  1.26356E-05  8.25197E-07 -2.22319E-06 -1.18009E-05
 0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
 2.74173E-03  0.00000E+00  1.91720E-04  1.13224E-05 -4.55619E-05 -1.61918E-04
 5.17664E-03  2.97458E-02  4.75320E-02  6.11952E-03 -2.61355E-03  1.19275E-02

```

Here, each iteration history record consists of 13 lines (since IFMST=4). Depending on various user inputs, SPLASH appends one or more of the lines appearing at the end of each record. A complete description of the file format is given in the ACCPAN Reference Manual.

The first line to possibly be appended by SPLASH contains the 6 global axis forces and moments due to viscous effects, denoted by *cxfcf*, ... (FORTRAN format 6e13.5).

If input parameter IVISC=0, then SPLASH viscous force and moment results are appended to the file. Unfortunately, SPLASH itself currently has no capability to calculate viscous effects, and so these will all be zero. If viscous effects are subsequently desired, they can be estimated by viscous stripping using auxiliary post-processing software.

If input parameter IVISC=-1, then viscous force and moment results are not appended by SPLASH. It is assumed that ACCPAN (or some other tool) has already appended the viscous results to the file. ACCPAN uses a more sophisticated viscous stripping compared to that available using our auxiliary post-processing software.

The next line is always appended by SPLASH, and contains the inviscid hydrodynamic forces and moments acting on the model, denoted by *cfxdy*, ... (FORTRAN format 6e13.5). These will include waterline integral contributions for which input parameter NWLTYP is greater than zero, and will exclude those for which NWLTYP is less than zero.

The last line to possibly be appended by SPLASH contains the 6 global axis forces and moments due to waterline integral contributions alone, denoted by *cfxwl*, ... (FORTRAN format 6e13.5). These will include waterline integral contributions for which input parameter NWLTYP is greater than zero, and will exclude those for which NWLTYP is less than zero. This line is appended by SPLASH only if input parameter IFMST is set to 101, 102, 103 or 104.

Flow Solution File (filename "tecout")

The solution file is in **Tecplot** format, and can be viewed using **Tecplot** or other flow visualization software. Experienced users will find many uses for this file. For nonlinear free-surface solutions, supporting automated panelization packages such as ACCPAN can use the flow solution in this file to update the nonlinear free-surface shape and to generate an updated panel model. In similar fashion, a nonlinear restart capability (from a previous model test) is also provided.

For each free-surface and configuration surface network, the flow solution file contains the following global coordinate system information: corner point coordinates, Cartesian velocity components, and pressure coefficient. The information is output using one line per panel corner point.

Off-Body Velocity Scan Files

Off-Body Velocity Scan Input File (filename "*scninp*"):

For each off-body point at which velocities are to be calculated, input the x,y,z coordinates of the point in the global coordinate system. Use one line per point and a (3e13.5) FORTRAN format.

Off-Body Velocity Scan Output File (filename "*scnout*"):

For each off-body point at which velocities are calculated, the x,y,z coordinates of the point in the global coordinate system and the three Cartesian velocity components are output. One line per point and a (6e13.5) FORTRAN format are used.

Spanload File (filename "*spanload*")

Spanload distribution files only when the input parameter NSPAN is non-zero for one or more foil- or lifting-type surfaces.

The spanload file contains the following information:

- summary of test conditions
- number of foils
- for each foil:
 - planform area
 - corresponding 3D lift coefficient
 - number of sections
 - for each section on foil:
 - global and design-waterline Y- and Z-coordinates of section (based on panel column trailing edge midpoint)
 - chord
 - corresponding 2D lift coefficient

Program Execution

Sufficient memory and hard disk space to run SPLASH must be available.

SPLASH can be run manually from a C-shell. Before executing the code, be sure to copy the "tfms", "pxxf", and "scninp" files if required, as well as the standard-input file, to the current directory or temporary execution subdirectory. To execute SPLASH, change to that directory and enter the following command (the following syntax assumes a C-shell environment):

```
splash_cw < [your standard-input filename]
```

To redirect standard-output and error-output to another file, use:

```
splash_cw < [your standard-input filename] >& [your standard-output filename]
```

To run in the background, use:

```
splash_cw < [standard-input filename] >& [standard-output filename] &
```

To run in the background in its own shell, use:

```
nohup splash_cw < [standard-input filename] >& [standard-output filename] &
```

This latter form is highly recommended.

At the end of code execution, if desired, copy output files such as the standard-output file, "tfms", "tecout", and "scnout", to a permanent directory. It is good practice to then erase all files in the temporary execution subdirectory. Otherwise, repeated code executions may pick up the wrong file by accident, or needlessly consume hard disk space.

The supporting automated panelization package ACCPAN can be used to create automated shell scripts to accomplish these tasks. Execution of ACCPAN and the shell scripts, and hence SPLASH, can be further automated, for more or less "hands off" iterative free to sink-and-trim and nonlinear free-surface results. Please refer to the Reference Manual for ACCPAN for further information.

Licensing Information

SPLASH software is primarily intended to run on UNIX systems, and contains a workstation node-locked licensing feature. To obtain a valid license file password, do the following.

1. On the workstation for which a license is to be requested, run the "sbsinfo" program supplied by South Bay Simulations. This will output the information needed to generate license keys for that workstation.
2. Fax, phone, or mail the output of the sbsinfo program to South Bay Simulations, and a license file password will be supplied.
3. Enter the license file password on a separate line in the license file. The license file is the filename pointed to by the shell environment variable **\$SBS_FILE** or, if this variable is not defined, the filename **\$HOME/sbs/license.sbs**.

Suggested Reading

Rosen, B.S., Laiosa, J.P. and Davis, W.H., "CFD Design Studies for America's Cup 2000," AIAA Paper 2000-4339, Aug. 2000.

Rosen, B.S. and Laiosa, J.P., "SPLASH Nonlinear and Unsteady Free-Surface Analysis Code for Grand Prix Yacht Design," 13th Chesapeake Sailing Yacht Symposium, Annapolis, Jan. 1997.

Rosen, B.S., Laiosa, J.P., Davis, W.H. and Stavetski, D., "SPLASH Free-Surface Flow Code Methodology for Hydrodynamic Design and Analysis of IACC Yachts," 11th Chesapeake Sailing Yacht Symposium, Annapolis, Jan. 1993.

Boppe, C.W., Rosen, B.S., Laiosa, J.P. and Chance, B., Jr., "Stars and Stripes '87: Computational Flow Simulations for Hydrodynamic Design," 8th Chesapeake Sailing Yacht Symposium, Annapolis, Mar. 1987.

DeBord, F., Jr., Reichel, J., Rosen, B. and Fassardi, C., "Design Optimization for the International America's Cup Class," Transactions of the 2002 SNAME Annual Meeting, Boston, Sep. 2002.

Reichel, J., Pugh, J., Rosen, B. and DeBord, F., Jr., "Grand Prix Yacht Design with the Aid of Computational and Experimental Techniques," Yacht Vision '94 International Yacht Design Symposium, Auckland, Feb. 1994.

Maskew, B., "Program VSAERO: A Computer Program for Calculating the Non-linear Aerodynamic Characteristics of Arbitrary Configurations," NASA CR-166476, Dec. 1982.

Dawson, C.W., "A Practical Computer Method for Solving Ship-Wave Problems," The Proceedings, 2nd International Conference on Numerical Ship Hydrodynamics, Berkeley, Sep. 1977.

Teeters, J.R., "Refinements in the Techniques of Tank Testing Sailing Yachts and the Processing of Test Data," 11th Chesapeake Sailing Yacht Symposium, Annapolis, Jan. 1993.