Aqwa Reference Manual

Ansys

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Chapter 1: Introduction

The Aqwa suite is a set of advanced hydrodynamic analysis programs. This document is the Reference Manual for the Aqwa suite of programs.

The programs in the suite are:

Aqwa-Line

Aqwa-Librium

Aqwa-Fer

Aqwa-Drift

Aqwa-Naut

The Reference Manual defines the input data format for the above programs. Most of the input information is applicable to more than one program. When the information relates to only one program, this is made clear in the text.

The suite of Aqwa programs can be run in a Windows environment using a Hydrodynamic system in Workbench, or from the Windows command line using an input file. In a Linux environment, only the command line (p. 307) capability is available.

Note:

Aqwa is not supported on the SUSE Linux platform.

The manual also contains details of certain topics common to all the programs.

1.1. The Ansys Product Improvement Program

This product is covered by the Ansys Product Improvement Program, which enables Ansys, Inc., to collect and analyze *anonymous* usage data reported by our software without affecting your work or product performance. Analyzing product usage data helps us to understand customer usage trends and patterns, interests, and quality or performance issues. The data enable us to develop or enhance product features that better address your needs.

How to Participate

The program is voluntary. To participate, select **Yes** when the Product Improvement Program dialog appears. Only then will collection of data for this product begin.

How the Program Works

After you agree to participate, the product collects anonymous usage data during each session. When you end the session, the collected data is sent to a secure server accessible only to authorized Ansys employees. After Ansys receives the data, various statistical measures such as distributions, counts, means, medians, modes, etc., are used to understand and analyze the data.

Data We Collect

The data we collect under the Ansys Product Improvement Program are limited. The types and amounts of collected data vary from product to product. Typically, the data fall into the categories listed here:

Hardware: Information about the hardware on which the product is running, such as the:

- brand and type of CPU
- number of processors available
- amount of memory available
- brand and type of graphics card

System: Configuration information about the system the product is running on, such as the:

- operating system and version
- country code
- time zone
- language used
- values of environment variables used by the product

Session: Characteristics of the session, such as the:

- interactive or batch setting
- time duration
- total CPU time used
- product license and license settings being used
- product version and build identifiers
- command line options used
- number of processors used
- amount of memory used
- errors and warnings issued

Session Actions: Counts of certain user actions during a session, such as the number of:

- project saves
- restarts
- meshing, solving, postprocessing, etc., actions
- times the Help system is used
- times wizards are used
- toolbar selections

Model: Statistics of the model used in the simulation, such as the:

- number and types of entities used, such as nodes, elements, cells, surfaces, primitives, etc.
- number of material types, loading types, boundary conditions, species, etc.
- number and types of coordinate systems used
- system of units used
- dimensionality (1-D, 2-D, 3-D)

Analysis: Characteristics of the analysis, such as the:

- physics types used
- linear and nonlinear behaviors
- time and frequency domains (static, steady-state, transient, modal, harmonic, etc.)
- analysis options used

Solution: Characteristics of the solution performed, including:

- the choice of solvers and solver options
- the solution controls used, such as convergence criteria, precision settings, and tuning options
- solver statistics such as the number of equations, number of load steps, number of design points, etc.

Specialty: Special options or features used, such as:

- user-provided plug-ins and routines
- coupling of analyses with other Ansys products

Data We Do Not Collect

The Product Improvement Program does *not* collect any information that can identify you personally, your company, or your intellectual property. This includes, but is not limited to:

- names, addresses, or usernames
- file names, part names, or other user-supplied labels
- geometry- or design-specific inputs, such as coordinate values or locations, thicknesses, or other dimensional values
- actual values of material properties, loadings, or any other real-valued user-supplied data

In addition to collecting only anonymous data, we make no record of where we collect data from. We therefore cannot associate collected data with any specific customer, company, or location.

Opting Out of the Program

You may *stop* your participation in the program any time you wish. To do so, select **Ansys Product Improvement Program** from the Help menu. A dialog appears and asks if you want to continue participating in the program. Select **No** and then click **OK**. Data will no longer be collected or sent.

The Ansys, Inc., Privacy Policy

All Ansys products are covered by the Ansys, Inc., Privacy Policy.

Frequently Asked Questions

1. *Am I required to participate in this program?*

   No, your participation is voluntary. We encourage you to participate, however, as it helps us create products that will better meet your future needs.

2. *Am I automatically enrolled in this program?*

   No. You are not enrolled unless you explicitly agree to participate.

3. *Does participating in this program put my intellectual property at risk of being collected or discovered by Ansys?*

   No. We do not collect any project-specific, company-specific, or model-specific information.

4. *Can I stop participating even after I agree to participate?*

   Yes, you can stop participating at any time. To do so, select **Ansys Product Improvement Program** from the Help menu. A dialog appears and asks if you want to continue participating in the program. Select **No** and then click **OK**. Data will no longer be collected or sent.

5. *Will participation in the program slow the performance of the product?*

   No, the data collection does not affect the product performance in any significant way. The amount of data collected is very small.

6. *How frequently is data collected and sent to Ansys servers?*

   The data is collected during each use session of the product. The collected data is sent to a secure server once per session, when you exit the product.

7. *Is this program available in all Ansys products?*

   Not at this time, although we are adding it to more of our products at each release. The program is available in a product only if this *Ansys Product Improvement Program* description appears in the product documentation, as it does here for this product.

8. *If I enroll in the program for this product, am I automatically enrolled in the program for the other Ansys products I use on the same machine?*

   Yes. Your enrollment choice applies to all Ansys products you use on the same machine. Similarly, if you end your enrollment in the program for one product, you end your enrollment for all Ansys products on that machine.

9. *How is enrollment in the Product Improvement Program determined if I use Ansys products in a cluster?*

   In a cluster configuration, the Product Improvement Program enrollment is determined by the host machine setting.

10. *Can I easily opt out of the Product Improvement Program for all clients in my network installation?*

    Yes. Perform the following steps on the file server:

    a. Navigate to the installation directory: `[Drive:]\v251\commonfiles\globalsettings`

    b. Open the file **ANSYSProductImprovementProgram.txt**.

    c. Change the value from "on" to "off" and save the file.

1.2. Conventions

The following conventions are adopted in Aqwa programs. You should keep them in mind during input data preparation and results interpretation.

1.2.1. Axes Systems

Two sets of axes are used in the Aqwa suite; these are shown in Figure 1.1: Axes Systems (p. 22). They are the FRA (Fixed Reference Axes) and the LSA (Local Set of Axes).

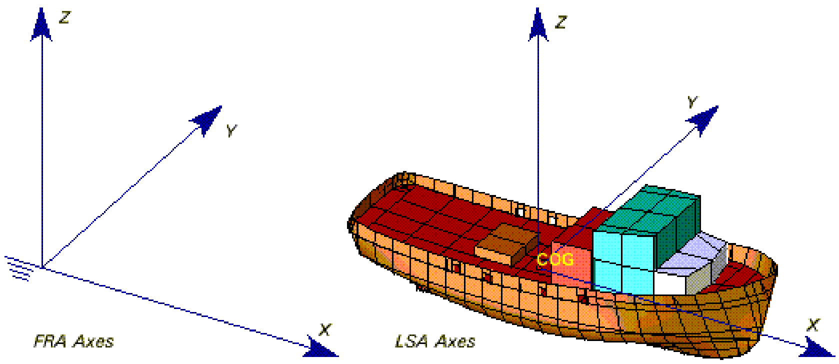
Fixed Reference Axes (FRA): X,Y,Z in the free-surface with Z pointing vertically

This is also known as the Global Axis Systerm. This system has its origin on the mean water surface with Z axis pointing upwards, X and Y on the mean water surface. The mean water surface is at Z=0. This axis system will not move at any stage of the Aqwa analysis.

Local System Axes (LSA): x,y,z with origin through the body's center of gravity

The Local System Axis (LSA) has its origin at the CoG of the vessel, with X, Y and Z axes parallel to the FRA (see 1 above) when the vessel is in its initial definition position. With conventional modelling, X is along the length of the vessel, Y along the beam to port, and Z in the direction of the cross product of X and Y. This axis system moves with the vessel.

Figure 1.1: Axes Systems



1.2.2. Wave/Wind/Current Direction

The Aqwa suite employs a single common sign convention with the axes defined as in the previous section.

The wave direction is defined as the angle from the positive global X axis to the direction in which the wave is travelling, measured anti-clockwise when seen from above. Therefore waves travelling along the X axis (from -X to +X) have a 0 degree wave direction, and waves travelling along the Y axis (from -Y to +Y) have a 90 degree wave direction.

Forces and moments are positive in the same direction as corresponding motions.

The incident wave elevation h is measured positive upwards:

$$h = a\cos\left(-\omega t + kx\cos(\theta) + ky\sin(\theta)\right)$$

where:

a = wave amplitude

ω = wave frequency (rad/s)

t = time (s)

k = wave number

x, y = position in the FRA at which the wave height is given

θ = direction of wave propagation

The phase (φ) of a quantity Q with amplitude Q_0 is defined by the equation

$$Q = Q_0\cos\left(-\omega t + \varphi\right)$$

where:

t = time elapsed since the wave crest passed over the origin of the FRA

Q may represent forces, moments, RAOs, position, velocity, or accelerations.

1.2.3. Phase Angle

The phase angle defines the time difference between an oscillatory parameter and a reference point. In Aqwa, the reference point for the phase angle of a parameter is the zero phase angle of the incident wave, which corresponds to the time when the wave crest is at the CoG of the structure. In the Aqwa-Line output file, most calculated parameters are given in the form of an amplitude and a phase angle. A positive phase angle indicates that a parameter reaches its peak value after the wave crest has passed the CoG of the structure, and the time difference is decided by:

$$dt=\frac{T\varphi}{360}$$

where:

T = wave period

φ = phase (degrees)

1.3. The Structure Definition and Analysis Position

In the description of the geometry and mass distribution, the user may define the structure in any position. There are, however, three considerations when choosing the position in which to define the structure.

1. Having defined the structure in a particular position in the FRA axis system (this is termed the *definition position* in the documentation), the user may then move the structure by specifying the appropriate position for the particular analysis (this is termed the *analysis position* in the documentation). This means that the user can define a barge with the keel on the X-axis of the FRA, and then lower the barge into the water for analysis. The analysis position will depend on the type of analysis performed. The requirement for each program is summarized as follows:

   Aqwa-Line - Equilibrium position, vertical position specification only

   Aqwa-Fer - Equilibrium position

   Aqwa-Librium - Initial estimate of equilibrium position

   Aqwa-Naut/Drift - Position at the start of the time history

   When running Aqwa-Line, it is important to note that the structure may only be moved vertically from its definition position (that is, only the draft may be altered) for the diffraction/radiation analysis. This restriction is imposed to ensure that the axes in which the hydrodynamic coefficients are defined is the FRA. Therefore, if the user cannot achieve the correct position for the diffraction/radiation analysis by altering only the draft of the structure, **the definition position is not valid**.

   There are no restrictions for Aqwa-Drift/Fer/Librium/Naut on the movement from the definition to the analysis position.

2. If a structure is symmetrical about one or more axes, only a part of the structure is required to be defined. This means that

   (i) only ½ or ¼ of the structure needs to be modeled

(ii) substantial saving in computer time in the diffraction/radiation analysis in Aqwa-Line may be achieved. This saving is model-dependent but is typically

- for 2-fold symmetry = 50 - 75 percent

- for 4-fold symmetry = 75 - 90 percent

3. Motions of the structure are often output in the Aqwa suite in the form of translations and rotations about the X, Y and Z axis and are termed surge, sway, heave, roll, pitch, and yaw. These motions may be successive 'LARGE' rotations about the X, Y and Z axes of the FRA axes system in the definition position (Aqwa-Drift/Librium/Naut) or 'small' rotations in arbitrary order about the analysis position in the local LSA axes system (Aqwa-Line/Drift/Fer). It can be seen that interpretation of the results can be made extremely difficult by an unsuitable choice of the definition position of the structure.

   For example, if the structure is a ship or barge, conventional terminology for motion along, and rotation about, the longitudinal center line, is surge and roll. However, if the longitudinal center line is defined parallel to the FRA Y-axis, then rotational motion about this axis will be termed pitch, and translational motion along the axis, sway.

   For other structures, e.g. semi-submersibles, this may not be relevant. The user must take due note of the terms associated with the motions about the axes and is recommended to define all ship/barge shaped structures with the longitudinal axis parallel to the FRA X-axis.

1.4. Units

The units used in Aqwa are decided by the input values for the water density and gravitational acceleration. For example, if metre, Newton are to be used as the units for the length and force, users should use 1025 for the water density and 9.806 for the gravitational acceleration.

In the output, the unit for the rotational motions is in degrees (although they are originally calculated in radians), while the rotational terms in the stiffness and damping matrices are output in radians.

The user is free to choose any system of units for the data, with the proviso that the system **must be consistent**. This means that the unit of mass must be consistent with the units of length and force already selected.

Examples of consistent sets of units are:

- **SI units**: force in Newtons, length in meters, mass in kilograms, time in seconds, acceleration in meters/sec^2
- **Imperial units**: force in poundals, length in feet, mass in pounds, time in seconds, acceleration in feet/sec^2, or force in pounds, length in feet, mass in slugs, time in seconds, acceleration in feet/sec^2
- For any other set of units, the consistent unit of mass will be a multiple of the basic unit of mass because it is a derived unit.

The consistent unit of mass is obtained by dividing the unit of force by the acceleration due to gravity, which itself has units of length divided by time squared. A change in the unit of length, for example, from feet to inches or metres to millimeters, requires a corresponding change in the unit of mass used for calculating the density. A list of sets of consistent units is given below.

Force	Length	Value of E for steel	Acceleration due to gravity	Unit of mass	Density (mass/volume)	
					Steel	Seawater
Newton	Meter	2.1 x 10^{11}	9.81	1.0 kg	7850	1025
Newton	Centimeter	2.1 x 10^{7}	981	100 kg	7.85 x 10^{-5}	1.025 x 10^{-5}
Newton	Millimeter	2.1 x 10^{5}	9810	1000 kg	7.85 x 10^{-9}	1.025 x 10^{-9}
Kilopond	Meter	2.14 x 10^{10}	9.81	9.81 kg	800	104.5
Kilopond	Centimeter	2.14 x 10^{6}	981	981 kg	8.00 x 10^{-6}	1.045 x 10^{-6}
Kilopond	Millimeter	2.14 x 10^{4}	9810	9810 kg	8.00 x 10^{-10}	1.045 x 10^{-10}
Kilonewton	Meter	2.1 x 10^{8}	9.81	1000 kg	7.85	1.025
Kilonewton	Centimeter	2.1 x 10^{4}	981	1.0 x 10^{5} kg	7.85 x 10^{-8}	1.025 x 10^{-8}
Kilonewton	Millimeter	2.1 x 10^{2}	9810	1.0 x 10^{6} kg	7.85 x 10^{-12}	1.025 x 10^{-12}
Tonne	Meter	2.14 x 10^{7}	9.81	9.81 x 10^{3} kg	0.800	0.1045
Tonne	Centimeter	2.14 x 10^{3}	981	9.81 x 10^{5} kg	8.0 x 10^{-9}	1.045 x 10^{-9}
Tonne	Millimeter	2.14 x 10^{1}	9810	9.81 x 10^{6} kg	8.0 x 10^{-13}	1.045 x 10^{-13}
Poundal	Foot	1.39 x 10^{11}	32.2	1.0 lb	491	64.1
Poundal	Inch	9.66 x 10^{8}	386	12 lb	2.37 x 10^{-2}	3.095 x 10-3
Pound	Foot	4.32 x 10^{9}	32.2	32.2 lb	15.2	1.985
Pound	Inch	3.0 x 10^{7}	386	386 lb	7.35 x 10^{-4}	9.597 x 10^{-5}
Kip	Foot	4.32 x 10^{6}	32.2	3.22 x 10^{4}	1.52 x 10^{-2}	1.985 x 10^{-3}
Kip	Inch	3.0 x 10^{4}	386	3.86 x 10^{5}	7.35 x 10^{-7}	9.597 x 10^{-8}
Ton	Foot	1.93 x 10^{6}	32.2	7.21 x 10^{4}	6.81 x 10^{-3}	8.892 x 10^{-4}
Ton	Inch	1.34 x 10^{4}	386	8.66 x 10^{5}	3.28 x 10^{-7}	4.283 x 10^{-8}

Note:

1 kip = 1000 pounds force

1 kilopond = 1 kilogram force

All times are in seconds

Specific gravity of steel = 7.85

Specific gravity of sea water = 1.025

1.5. Aqwa Files

The Aqwa Suite uses both ASCII files and binary files for its input and output. All the files are defined by a generic name with a 3 character file extension. The maximum length of the filename is 28 characters (32 with the extension). It is strongly recommended that the filename is related to the program used.

The extension names are related to the file type. The following is a list of the file extension names commonly used in Aqwa and Aqwa Graphical Supervisor (AGS).

Note:

If you are running Aqwa on Linux, file names are case-sensitive. Aqwa file names are all upper case, including the extensions. Aqwa jobs will produce output files with names in all upper case. On Windows, file names are case-insensitive.

Binary files generated on Linux can be read on Windows systems for post-processing and further data manipulation.

Input Files

- `DAT` -- ASCII file for model definition and analysis parameters. Used by all Aqwa programs.
- `XFT` -- ASCII file defining a time history of external force on a structure or structures in six degrees of freedom in local axis system. Used for time domain analysis (optional).
- `WVT` -- ASCII file defining a time history of wind velocity and direction. Used for time domain analysis (optional).
- `WHT` -- ASCII file defining a time history of water surface elevation. Used for time domain analysis (optional).
- `LIN` -- ASCII file defining ship offsets. Used by AGS Mesh Generator to define hull shape.
- `MSD` -- ASCII file defining the mass distribution of a vessel. Used by AGS for shear force and bending moment calculation.
- `SFM` -- ASCII file defining the mass distribution of a vessel. Used by AGS for splitting force calculation.
- `EQP` -- Binary file containing the equilibrium positions of structures. Created by Aqwa-Librium and used (optional) by Fer, Drift or Naut; see RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)).
- `MOR` -- ASCII file for importing mooring configuration in Data Category 14 (optional).

Output Files

- LIS -- ASCII file containing model definition/analysis parameters and the analysis results.
- MES -- ASCII file containing messages issued during an Aqwa analysis.
- QTF -- ASCII file containing fully populated matrix of Quadratic Transfer Functions.
- HYD -- Binary file containing the hydrodynamic results calculated in Aqwa-Line. Can be used for further Aqwa analysis.
- RES -- Binary file containing the model definition/analysis parameters and the hydrodynamic results calculated in Aqwa-Line. Can be used for further Aqwa analysis or structure visualisation etc in AGS.
- EQP -- Binary file containing the equilibrium positions of structures. Created by Aqwa-Librium and used (optional) by Fer, Drift or Naut; see RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)).
- ENL -- Binary file containing Morison element/nodal loading. Only created for tether analysis, or tube elements at analysis stage 6.
- POS -- Binary file containing structures' positions at each time step. Used by AGS for generating animation.
- PLT -- Binary file containing Aqwa analysis results. Used by AGS for plotting graphs.
- POT -- Binary file containing potentials. Used by AGS or AqwaWave for element pressure calculation.
- USS -- Binary file containing source strengths. Used by AqwaWave for Morison force calculation.
- SEQ -- Binary file containing the animation of structure motion. Created and used by AGS.
- TAB -- ASCII file containing the statistics table from Aqwa-Drift tether analysis.
- PAC -- Binary file containing pressures at element centroids. Used by AGS for post-processing involving pressures and Aqwa-Naut for time domain pressure calculation.
- VAC -- Binary file containing fluid velocities at element centroids. Used by AGS for wave contour plotting and Aqwa-Naut for time domain pressure calculation of structures with forward speed.
- DCP -- Binary file containing dynamic cable profiles at each required time step in Aqwa-Drift/Naut analysis or at structure equilibrium state in multiple mooring configurations and wind/wave definitions in Aqwa-Librium/Fer analysis. Used by AGS for mooring system visualization or animation.
- TET -- Binary file containing tether nodal and element responses at each required time step in Aqwa-Drift/Naut analysis or at structure equilibrium state in multiple mooring configurations and wind/wave definitions in Aqwa-Librium analysis.
- TPT -- Binary file containing potentials at diffraction element centroids on internal tank surface.
- TUS -- Binary file containing source strengths at diffraction element centroids on internal tank surface.
- TPC -- Binary file containing pressures at element centroids on internal tank surface.

- TVC -- Binary file containing fluid velocities at element centroids on internal tank surface.
- MFK -- ASCII file containing mooring forces and stiffness matrices at equilibrium positions from Aqwa-Librium analysis.
- PRS -- Binary file that stores panel pressures on external hull and internal tank surfaces, and forces on Morison elements. Created by Aqwa-Naut when pressure output is requested.
- AH1 -- ASCII file containing hydrodynamic database (the .HYD file). Created by Aqwa-Line; see the AHD1 (p. 314) option.
- FRC -- Binary file that stores structural force components at the required time steps. Created in Stage 6 by Aqwa-Drift/Naut; see Data Record ISEL/LSEL (p. 303) in Data Category 21.
- MQT -- Binary file that stores the directional coupling mean drift QTF matrices. Created by Aqwa-Line; see the MQTF (p. 314) option.
- PLD – Direct access binary file (.PLT) containing Aqwa analysis results. Used by AGS for plotting graphs.
- PLS – Direct access binary file containing the steering information of .PLD. Used by AGS for plotting graphs.
- SHB – Binary file containing the shear force and bending moment. Created by AGS, or by Aqwa-Line; see the SFBM (p. 314) option.
- SBD – ASCII file containing the shear force and bending moment. Created by Aqwa-Line; see the SFBM (p. 314) option.
- PAG -- Binary file containing pressures at the mean free surface grids. Created by AGS, or by Aqwa-Line; see the SEAG (p. 83) Data Record in Data Category 2.
- RSS -- Binary file containing significant values of the structure responses. Created by Aqwa-Fer.
- ADM -- An ASCII file containing the fluid added mass matrix at the infinite frequency and some other Aqwa model information needed by the Aqwa-Rigid Dynamics co-simulation analysis.

1.6. Memory Usage

In general, the Aqwa solver has minimal memory requirements. For radiation/diffraction analysis, however, a highly optimized solver is employed, and this requires that the complete source strength matrix be stored in memory. The program allocates memory based on the number of diffraction panels in the simulation. The approximate amount of memory (in MBytes) required for a radiation/diffraction analysis is determined by:

$$300+\left(\frac{N}{1000}\right)^2\cdot 8$$

where N is the maximum number of diffraction panels in the simulation.

If Aqwa fails to allocate the required amount of memory in a radiation/diffraction analysis, a multi-block linear equation solver is used, which requires at least 400 MB of available memory. This solver is significantly slower than the standard solver.

On Linux, an environment variable (AQWA_STACKLIMIT) is provided to allow you to set the maximum size of the stack space needed to run Aqwa. The default value is 1048576 kbytes (1Gbyte). Stack limits are reset to their original value after the run.

Chapter 2: Analysis Stages

The following sections discuss the various analysis stages in a hydrodynamics analysis using the Aqwa suite.

2.1. General Description

All programs in the Aqwa suite have a facility for gradual progression through any given analysis. This facility is made possible by structuring each program into a number of distinct stages, called *Restart Stages*. These are common to all programs in the suite and the user may run, in sequence, any number (there are six stages). Since the restart stages are common to all programs, this allows the user to run more than one program within any analysis (e.g. the user may run the first three stages of Aqwa-Line and then run the last two stages of Aqwa-Fer, to complete a specific type of analysis).

Aqwa-Line can also be used for geometrical scaling when comparing to model tests, and for requesting nodal information related to the radiation/diffraction results.

When the restart facility is invoked, via a program RESTART option (see Administration and Calculation Options for the Aqwa Suite (p. 314)), input information must be supplied from a backing file from a previous program run, and not from the normal data record input file. The required backing files, called restart files, are created automatically when a program is run. This process is also used to transfer information from one program to another so that data input is minimized.

Each of the six Aqwa Restart Stages may be categorized by two classes of activity, which are:

- Data Input and Processing of the Data.
- Specific Analysis or Post-Processing Activity.

This Aqwa Reference Manual is mainly concerned with the format details required for the data input. The individual Program User Manuals are concerned with the approach that should be adopted for a specific type of motion analysis.

Drag Linearization

There are several types of nonlinear drag in Aqwa, most of which can be linearized and included in the linear programs Aqwa-Line and Aqwa-Fer. TUBE, DISC and STUB elements have drag calculated according to Morison's equation and can be included in both Aqwa-Line and Aqwa-Fer. Hull drag is modeled with drag force coefficients input in Data Category 10. As with most other Stage 4 data, this is not used in Aqwa-Line but can be included in Aqwa-Fer.

For more information, see Morison Drag Linearization in the *Aqwa Theory Manual*.

2.2. The Restart Stages

The Aqwa suite Program Restart Stages may be identified as follows:

Stage 1 - Input of Geometric Definition and Static Environment (p. 32)

This input is contained in Data Categories 1 to 5.

Stage 2 - Input of the Radiation/Diffraction Analysis Parameters (p. 36)

This input is contained in Data Categories 6 to 8.

Stage 3 - The Radiation/Diffraction Analysis (p. 39)

No input required.

Stage 4 - Input of the Analysis Environment (p. 40)

This input is contained in Data Categories 9 to 18.

Stage 5 - Motion Analysis or Post-Processing Activity (p. 43)

No input required.

Stage 6 - Post-processing of loads on TUBE elements (p. 43)

This input is contained in Element and Nodal Loads - ENLD (Data Category 21) (p. 303).

The Restart Stage activities for each program, together with the data that may be input, are described in the following sections.

2.3. Restart Stage 1

Data Categories 1 to 5 - Geometric Definition and Static Environment

The primary function of these data categories is to describe the structure being modeled. This includes the mass and inertia of the structure and its geometry, from which the hydrostatic and hydrodynamic properties are calculated. In addition, the coordinates of all positions referenced in subsequent data categories and the parameters relating to the environment (for example, density of water) are input. These parameters are normally considered to remain constant for an analysis of a particular structure.

All the Aqwa programs require Data Categories 1 to 5, if starting an analysis from Stage 1.

The data that may be input via Data Categories 1 to 5 are as follows:

Data Category 1 (p. 59)

Node and coordinate information

Data Category 2 (p. 67)

Element topology

Data Category 3 (p. 93)

Material properties

Data Category 4 (p. 95)

Geometric properties

Data Category 5 (p. 99)

Water depth

Water density

Acceleration due to gravity

The following sections show the specific required data when including tethers in an analysis.

Tethers may be included in a simulation either in a towing operation, or in an installed condition, subjected to wave environmental loading. Installed tethers may go slack and impact during operation. Tethers are considered by Aqwa as flexible tubes whose diameters are small compared to the wavelength. Tethers are classified as a type of mooring.

The analysis of towed tethers is an independent process and requires no backing files from other programs in the Aqwa suite. For installed tethers, an Aqwa-Line run is required for diffracting structures but for non-diffracting structures which do not require an Aqwa-Line analysis, a tube model can be used.

As tethers are regarded as a mooring capability, a nominal structure must be input for towed tethers. This defines the position of the axis system, in which the towed tether displacements are output, and in which the eigenvalue solution is performed. The structure plays no other part in the analysis.

The modeling techniques are based on the following limitations and assumptions of the program.

- No Axial Motion - Towed tethers are not considered to move in the axial direction or rotate about the axis of the tether; that is, displacements of the tether are 2 translations and 2 rotations at each node. These displacements are considered as small motions from the tether axis (TLA q.v.)

> **Note:**
>
> Although current in the axial direction will produce stabilizing effects, if the tether spring at the ends are very soft, large rotations (>30 degrees) may be produced, which will invalidate the analysis. The program also takes full account of the change in encounter frequency, due to the component of the current in the direction of the waves.

- Axial Tension - Both the wall and effective tensions in a towed tether are assumed to be zero, and hence the bending stiffness is purely structural. The tether responses, especially in the fundamental mode, may be inaccurate if this tension is significant.

Note:

This also means that the tether may not be analyzed, if any point moves to a depth where the effective tension is significant, i.e. for upending.

- Small Motions - It is assumed that the lateral and rotational motions of the tether from the defined tether axis are small. This means that the program is unsuitable for large rotations about the Y or Z axis, e.g. for upending. However, full account is taken of the phase shift of the waves, due to movement in the direction of the wave/wave spectrum.
- Mass/Stiffness - The mass/stiffness ratio of any element must not be too small. Very short elements inherently have small mass/stiffness ratios. This gives rise to very high frequencies. These high frequencies may cause stability problems and roundoff errors in the programs. A general rule is that natural periods of less than 1/100th second are not allowed. These periods are output from the eigenvalue analysis.

  Very short elements should therefore be modelled with a value of Young's modulus reduced so that no periods less than 1/100th second are present. The user can check that the bending of short elements is still small, using the graphical output.
- Timestep - The timestep must be small enough to resolve the response motion of the tether. This includes any transients that may be present either initially or, more importantly, throughout the analysis. Although a good rule of thumb is that the timestep should be 1/10th of the period of any response, the best method of checking the timestep is to re-run a short simulation with half the timestep and compare the bending moments or stresses for both runs. These should be approximately the same for both runs. Timesteps of 0.25 seconds are typically used.

  For towed tethers, the local axis (TLA) must be defined parallel to, and in the same direction as, the X axis of the fixed reference axes (FRA) i.e. XY in the water plane and Z vertical. The X axis coincides with the zero current wave direction. The nodes of the tether increase with positive X. The last node of the tether, at zero FRA displacement, lies at the TLA origin. For installed tethers, the TLA is parallel to the FRA, when the tether is vertical. In general, the TLA X axis goes from the anchor node to the attachment node, the Y axis is in the plane of the XY FRA, and the Z axis follows the right hand rule. The TLA origin is at the anchor node.

Input for Towed Tethers

Data Category 1 (p. 59)

The coordinates of the nominal vessel center of gravity. This should always be zero, but must be input.

The coordinates of the trailing end of the tether. The X coordinate should be **minus** the total tether length. The Y value must be zero. Z value may be input as zero but see below.

The Z coordinate may be input to define the TLA (tether axis) above or below the water surface. Input of a Z coordinate will mean that:

- the eigenvalue analysis will be performed with the tether axis at this Z value. Depending on the value of Z, the tether may be
  - completely out of water (Z greater than the largest element diameter)
  - partially submerged
  - fully submerged.
- all displacements will be output with reference to this Z value.
- the initial position of the tether (for the motion response analysis stage) will have this Z value. It is not recommended to "drop" the tether into the water from a height (positive Z value) as this will produce large initial transients.

The relative coordinates of the towed tether nodes are defined along the X axis, with the Y values zero.

Data Category 2 (p. 67)

A point mass element to represent the vessel

Data Category 3 (p. 93)

A mass to represent the vessel

One or more densities for the tether elements

Data Category 4 (p. 95)

Inertia of the point mass representing the vessel

Diameter, thickness, drag and added mass coefficients for each different tether element

Data Category 5 (p. 99)

Water depth

Water density

Acceleration due to gravity

Input for Installed Tethers

For installed tethers the vessel must be described using the standard data requirements. For the tether itself the following **additional** data is required.

Data Category 1 (p. 59)

The coordinates of the tether attachment points to the vessel

The coordinates of the tether anchor points

The relative coordinates of the installed tether nodes are defined along the Z axis, with the X and Y values zero.

Data Category 3 (p. 93)

One or more densities for the tether elements

Data Category 4 (p. 95)

Diameter, thickness, drag and added mass coefficients for each different tether element

2.4. Restart Stage 2

Data Categories 6 to 8 - the Radiation/Diffraction Analysis Parameters

The data input in these data categories relate to the equation of motion of a diffracting structure or structures in regular waves, for a range of frequencies and directions.

Data Category 6 (p. 101)

Required frequencies

Required directions

Data Category 7 (p. 117)

Linear hydrostatic stiffness matrix

The buoyancy force at equilibrium

The Z coordinate of the center of gravity at equilibrium

Added mass matrix

Radiation damping matrix

Diffraction forces

Froude-Krylov forces

Response motions (or RAOs)

Usually, not all of the above data are required for a particular mode of analysis, in which case, the user may simply omit the data which are not applicable.

Note:

Although the Radiation/Diffraction parameters calculated by Aqwa-Line can be transferred to other programs in the Aqwa suite, this is not mandatory. This means that, if the backing file produced by an Aqwa-Line run is not available (i.e. Aqwa-Line has not been run previously) or if the user wishes to input values from a source other than Aqwa-Line, he may do so in these data categories.

The following sections show the required data input for the available modes of analysis:

Input for Aqwa-Line with no previous Aqwa-Line runs

The Radiation/Diffraction parameters (i.e. added mass, wave damping, drift coefficients, etc) are to be calculated.

Data Category 6 (p. 101)

Required frequencies

Required directions

Data Category 7 (p. 117)

The Z coordinate of the center of gravity at equilibrium

Input for Aqwa-Line adding additional frequencies to a previous Aqwa-Line run

If the whole range of frequencies at which the parameters are defined is specified in a single run, large computer costs can be incurred if the program has to be re-run for any reason. Aqwa-Line therefore permits the user to specify selected frequencies in the initial run and additional frequencies in subsequent runs.

If Aqwa-Line has been run with the data input described in the previous section, the program may be restarted at RESTART Stage 2. This is done by using the RESTART option and RESTART data record (p. 56), and omitting Data Categories 1 to 5. The user then specifies, in Data Category 6 (p. 101), **only** the additional frequencies at which the parameters are to be calculated.

Data Category 6 (p. 101)

One or more additional frequencies

Note that the frequencies input in Aqwa-Line runs must differ from those in previous runs or they will be automatically rejected. As all parameters are defined for a unique range of directions, these directions may not be redefined General Description (p. 101).

Input for Aqwa-Line specifying known values of the radiation/diffraction analysis parameters

The new user is advised to ignore this facility

Known Radiation/Diffraction parameters may be input in Data Categories 7 and 8. This applies when using Aqwa-Line either initially or in RESTART mode (see notes A and B).

This facility may be used to input additional values of the parameters when the user is unable to describe the structure fully with a conventional Radiation/Diffraction model (e.g. additional damping or added mass due to a structural appendage). Additional linear stiffness is often used where the structure contributes to the water plane area but not to the Radiation/Diffraction model.

The user may also wish to extend the lower range of frequencies (where analysis costs can be prohibitive) with experimental data.

Recovery from errors may also be achieved by manual input of previous results where the backing file has been lost.

The data definition keyword (see Wave Frequency Dependent Parameters and Stiffness Matrix - WFS* (Data Category 7) (p. 117) and Drift Force Coefficients - DRC* (Data Category 8) (p. 139)) indicates whether Aqwa-Line will:

(a) OMIT the calculation of those parameters which are input, or

(b) ADD the input parameters to those calculated.

In case (a), input of the linear hydrostatic stiffness matrix and its associated buoyancy force means that Aqwa-Line will omit the calculations of these parameters. Input of the other parameters (which are all frequency dependent) means that Aqwa-Line will omit **all** calculations at this particular frequency.

Data Category 6 (p. 101)

One or more frequencies

Data Category 7 (p. 117)

Input known parameters

Data Category 8 (p. 139)

Input known parameters

All parameters input, together with those calculated by Aqwa-Line, will be contained in the backing file as input for further runs. The user should refer to the individual Data Category description for details of the actual data record input format.

Input for Aqwa-Drift/Fer/Librium/Naut with results from a previous Aqwa-Line run

The relevant Radiation/Diffraction information will be stored on the backing file created by a previous Aqwa-Line run. No additional input is required.

Input for Aqwa-Drift/Fer/Librium/Naut with results from a source other than Aqwa-Line

All data appropriate to the analysis may be input in Data Categories 6 to 8. The parameters which are input will depend on the type of analysis and the particular structure analyzed.

Data Category 6 (p. 101)

Required frequencies

Required directions

Data Category 7 (p. 117)

Linear hydrostatic stiffness matrix

The buoyancy force at equilibrium

The Z coordinate of the center of gravity at equilibrium

Added mass matrix

Radiation damping matrix

Diffraction forces

Froude-Krylov forces

Response motions (or RAOs)

Input for Aqwa-Drift/Fer/Librium/Naut with results from a previous Aqwa-Line run and a source other than Aqwa-Line

If you wish to APPEND to or CHANGE the parameters calculated by a previous Aqwa-Line run for the current analysis, this is achieved by using the backing file from a previous Aqwa-Line run (i.e. automatically read), together with specifying the parameters to be appended or changed.

To APPEND to the parameters calculated in a previous run, additional frequencies which differ from those existing may be input in Data Category 6 (p. 101), together with values of the appropriate frequency dependent parameters in Data Category 7 (p. 117) and Data Category 8 (p. 139), at these additional frequencies. Note that, as all parameters are defined for a unique range of directions, these directions **may not be re-defined**.

To CHANGE the parameters calculated in a previous run, these parameters are simply input in Data Category 7 (p. 117) and Data Category 8 (p. 139) and, depending on the type of input, the parameters will be either overwritten with the input values or become the sum of input values and original values.

Data Category 7 (p. 117)

Input appended or changed data

Input for Towed Tethers

Towed tethers require specific data to describe the towing vessel.

Data Category 7 (p. 117)

Nominal linear hydrostatic stiffness matrix for the vessel

The depth below the still water level of the center of gravity, which must be the same as the coordinate of the trailing end of the tether, input in Data Category 1 (p. 59)

The hydrostatic force on the vessel, which must be equal to the weight (mass * acceleration due to gravity)

Input for Installed Tethers

For installed tethers no additional data is required.

2.5. Restart Stage 3

Stage 3 is the Radiation/Diffraction analysis performed by the program Aqwa-Line. It has no analysis activity in any of the other programs. When performing a Stage 3 analysis with Aqwa-Line, *no input* *data categories are required for this stage*. If starting from Stage 1, then only the Stage 1 and Stage 2 data categories (i.e. Data Categories 1 to 8) are required.

If the user has progressed to Stage 2 within Aqwa-Line and wishes to perform the Stage 3 Radiation/Diffraction analysis alone, with no subsequent post-processing (i.e. Stages 4 and 5), then only the Preliminary Data Category is required and the associated restart data record will start at Stage 3 and finish at Stage 3 (see The Preliminary Data (Data Category 0) (p. 53)).

2.6. Restart Stage 4

The data input in these data categories relates to the type of analysis required and the program being used.

The data that may be input via Data Categories 9 to 18 may be summarized for each program as follows. Data Categories which require no input have been omitted.

Aqwa-Line

Data Category 9 (p. 145)

- Drift Added Mass and Damping (only used for scaling, Data Category 16 (p. 269))

Data Category 13 (p. 177)

- Spectrum Information (PSMZ (p. 183)/JONS (p. 184)/JONH (p. 185)/UDEF (p. 189)), only used when linearizing Morison drag using the LDRG (p. 316) option

Data Category 16 (p. 269) - Geometrical Changes

- Length Scaling of Results
- Mass Scaling of Results
- Change of Body's Center of Gravity
- Change of Body's Inertia
- Definition of New Hydrodynamic Reference Point

Data Category 18 (p. 287) - Printing Options for Nodal RAOs

Aqwa-Librium

Data Category 9 (p. 145) - Drift Added Mass and Damping

Data Category 10 (p. 153) - Hull Drag

- Current Drag Coefficients
- Wind Drag Coefficients
- Thruster Forces

Data Category 11 (p. 165) - Current Velocity Profile and Direction

Data Category 12 (p. 169) - Elimination of Degrees of Freedom

- Articulations between Bodies
- Articulations between Global Points and Bodies

Data Category 13 (p. 177) - Wave Spectra Details

Data Category 14 (p. 209) - Mooring Lines

Data Category 15 (p. 255) - Motion Analysis Starting Positions

Data Category 16 (p. 269) - Iteration Limits

Data Category 18 (p. 287) - Printing Options for Nodal Positions

Aqwa-Fer

Data Category 9 (p. 145) - Drift Added Mass and Damping

Data Category 10 (p. 153) - Hull Drag

- Current Drag Coefficients
- Wind Drag Coefficients
- Thruster Forces

Data Category 12 (p. 169) - Elimination of Degrees of Freedom

- Articulations between Bodies
- Articulations between Global Points and Bodies

Data Category 13 (p. 177) - Wave Spectra Details

Data Category 14 (p. 209) - Hawser/Mooring Lines

Data Category 15 (p. 255) - Motion Analysis Starting Positions

Data Category 18 (p. 287) - Printing Options for Nodal Positions

Aqwa-Naut

Data Category 10 (p. 153) - Hull Drag

- Current Drag Coefficients
- Wind Drag Coefficients
- Thruster Forces

Data Category 11 (p. 165) - Current Velocity, Direction and Profile

- Wind Velocity and Direction

Data Category 12 (p. 169) - Elimination of Degrees of Freedom

- Articulations between Bodies
- Articulations between Global Points and Bodies

Data Category 13N (p. 205) - Regular Wave Properties - default analysis

Data Category 13 (p. 177) - Wave Spectrum Details - irregular wave analysis

Data Category 14 (p. 209) - Hawser/Mooring Lines

Data Category 15 (p. 255) - Motion Analysis Starting Positions

Data Category 16 (p. 269) - Time Integration Parameters

Data Category 17 (p. 281) - Hydrodynamic Scaling Factors for Morison Elements

Data Category 18 (p. 287) - Printing Options for Nodal positions

Aqwa-Drift

Data Category 9 (p. 145) - Drift Added Mass and Damping

- Yaw Rate Drag Coefficient

Data Category 10 (p. 153) - Hull Drag

- Current Drag Coefficients
- Wind Drag Coefficients
- Thruster Forces

Data Category 11 (p. 165) - Current/Wind Velocity and Direction (only when no spectrum)

Data Category 12 (p. 169) - Elimination of Degrees of Freedom

- Articulations between Bodies
- Articulations between Global Points and Bodies

Data Category 13 (p. 177) - Wave Spectrum Details

Data Category 14 (p. 209) - Hawser/Mooring lines

Data Category 15 (p. 255) - Motion Analysis Starting Positions for both Wave and Drift Frequency Motions

Data Category 16 (p. 269) - Time Integration Parameters

Data Category 18 (p. 287) - Printing Options for Nodal Positions

Additional Data Requirements for Towed and Installed Tethers

For Aqwa-Librium, Aqwa-Naut and Aqwa-Drift the following data is required in addition to whatever may be necessary for other modelling requirements, as given in the descriptions above.

Data Category 11 (p. 165) (for towed tethers)

- Current speed and direction
- Tow speed and direction

Data Category 13 (p. 177) (for towed tethers)

- Tow speed and direction

Data Category 14 (p. 209)

- Description of tether elements and boundary conditions
- Fatigue and extreme value information (for towed tethers in Aqwa-Drift only)

Data Category 15 (p. 255) (for towed tethers)

- Initial position of the vessel, which must be the same as the coordinate of the center of gravity

Data Category 17 (p. 281) (for towed tethers)

- Slam coefficient multiplier if required

Data Category 18 (p. 287)

- Frequency of tether information output to both the listing file and the plot file
- Start and finish times for the statistical/fatigue analysis (for towed tethers in Aqwa-Drift only)

2.7. Restart Stage 5

Following the input of analysis dependent parameters at Stage 4, Stage 5 performs the particular form of analysis. No further input data is needed save the finishing restart level given on the Restart data record (The Preliminary Data (Data Category 0) (p. 53)).

Note that the user need not progress through the analysis procedure one stage at a time. Each Aqwa program may be run with multiple stages but, for the new user, it is best to progress slowly until confidence is gained in using the programs.

2.8. Restart Stage 6

Stage 6 is a post-processing stage used to calculate the loads on Morison elements for use in a structural analysis. At present, this is only available for TUBE elements in Aqwa-Drift and Naut.

Chapter 3: Data Preparation for the Aqwa Suite

Data input in the Aqwa suite of programs is divided into two or more sections called *data categories*. All programs in the Aqwa suite have 18 main data categories. However, many of these data categories will not be applicable in normal use. Only in highly specialized applications will the user need knowledge of them all.

The first data category is called the Preliminary Data Category. This supplies the job type, user identification and options (which control the overall administration of the program).

The remaining data categories (referred to as Data Categories 1 to 18) consist of:

- A data category header, which tells the program to expect a new category of data with (usually) a different format of input.
- One or more data records containing numerical input categorized by the name of the data category keyword, for example:

```
                _(1) Optional User Identifier (A2) (see Optional User Identifier (p. 47))
               |
               |        _(2) Compulsory Data Category Keyword (A4) (see Compulsory Data Category Keyword (p. 47))
               |       |
               |       |
         2   5|     11 |
       - --- -- ---- ---- ---------------------
      |X|XXX|  |XXXX|COOR|XXXXXXXXXXXXXXXXXXXX  )
       - --- -- ---- ---- ---------------------
      |             .                           )
                    .
      |             .                           )
                    .
      |             .                           ) etc.
       ----------------------------------------
      |              numerical input.....       ) to 80
       ----------------------------------------
      |              numerical input.....       ) columns
       - --- ----------------------------------
      |X|END|        numerical input.....       )
       - --- ----------------------------------
          |
          |
          |
          |_(3) Compulsory END Code (see Compulsory 'END' Statement (p. 47))
```

  The 'X' characters in columns 1-4, 7-10, etc. indicate that no data is to be input in these columns. Note that the data category keyword for Data Category 1 is 'COOR' (COORdinate positions). The keyword will be different for other data categories.

The precise format for every data record in every data category is given in the following sections:

The Preliminary Data (Data Category 0) (p. 53)

Node Number and Coordinates (Data Category 1) (p. 59)

Options for to be used when running the Aqwa suite are discussed in Options for Use in Running Aqwa Programs (p. 307).

3.1. Features Common to All Data Categories

The following features are common to all data categories:

3.1.1. Optional User Identifier

This two character field is not used by the Aqwa suite of programs and is available for the convenience of the user who may label the data record data category with any two characters. It may be left blank, but many users find it helpful to put the data category number of the data category in this field.

3.1.2. Compulsory Data Category Keyword

The four character data category keyword is a predefined abbreviation or mnemonic indicating the type of data that is to be input, e.g. COOR - COORdinate positions, MATE - MATErial properties, etc. Every data category must contain at least a data category keyword. If a particular application of the program does not require the information pertaining to a certain data category, then the user *must enter 'NONE' as the data category keyword* to indicate this.

3.1.3. Compulsory 'END' Statement

The program must be able to recognize the end of the information contained in a data category. To ensure this, the user *must enter the characters 'END' on the last data record of every data category* (in columns 2-4).

3.1.4. Format Requirements

All Aqwa ascii input files will accept the following:

- Comments starting in any column, but the 1st non-blank character must be one of *** ! /**
- Blank lines
- Upper or lower case

'Free format' files, i.e. those with values separated by commas or blanks, will also accept TAB characters.

In the descriptions of the data format for the Data Category Headers and Data Records, the following syntax is used to describe the type of data required, and how many characters are provided for each field:

- A*n* - Alphanumeric with *n* characters; e.g. A4
- I*n* - Integer (no decimal point) value with *n* digits; e.g. I5
- F*x*.*y* - Real number, with or without decimal point, with *x* digits in total, and *y* digits of precision after the decimal point. Can be provided in exponent format. The precision of the real number is at the user’s discretion, within the bounds of how many digits are available for that particular data item. E.g. F10.0

  Real number formats may have an optional preceding value that allows for repeating of that format. Thus 3F10.0 is for three values each with 10 digits.

Note that for some data the F prefix may be replaced by E; e.g. 6E10.0 These two forms represent the same definition, but E is generally used where the magnitude of the numbers is expected to require exponent form.

3.2. Classification of Data Categories 1 to 18

This section is intended to give an overall understanding of the general format and function of the input data required for an analysis of a particular structure or structures and to outline which information usually remains constant and which information changes for each run of the program. The user should refer to the sections on Data Preparation contained in each of the Aqwa Program User Manuals for details of data input required for a particular type of analysis.

Note that in the following sections the term 'backing file' is used to describe a file which is read in by the program at one stage of the analysis having been output by the same or another program in the Aqwa suite from a previous run. This transference of data is essentially transparent to the user as it is only required to indicate whether the file exists, or not, for the program to read this file automatically.

3.2.1. Stopping and Starting the Program During an Analysis

In order to minimize the computer costs, all programs in the Aqwa suite have the optional facility of stopping and starting at various stages of the analysis. These stages are referred to in the documentation as Restart Stages.

This facility enables the user to check the results of the preliminary stages and detect any misinterpretation of the data input instructions or errors before the more expensive stages of the analysis are performed. When the user is satisfied that the results are correct, the data categories relating to the previous stages are removed for the remaining part of the analysis, as they are stored in a backing file.

When errors are detected, the user instructs the program to start the analysis again, at any of the preceding stages, before the error occurred. This process is referred to in the documentation as a restart. If the previous stage was correctly performed, the user instructs the program to execute the next stage, i.e. simply continue the analysis.

Use of the RESTART process thus implies that information is available on a backing file from a previous program run and hence is also used to transfer information from one program to another program in the Aqwa suite.

The data input in Data Categories 1 to 18 fall into three main categories which also correspond to Restart Stages 1, 2 and 4. These categories are described in Data Categories 1 to 5 - Geometric Definition and Static Environment (p. 48), Data Categories 6 to 8 - The Radiation/Diffraction Analysis Parameters (p. 49), and Data Categories 9 to 18 - Definition of Analysis-Dependent Parameters (p. 49) in the following text. It is worth noting that Stages 3 and 5 are those which perform specific analysis tasks.

3.2.2. Data Categories 1 to 5 - Geometric Definition and Static Environment

The primary function of these data categories is to describe the structure or structures being modeled. This includes the mass and inertia of the structure and its geometry from which the hydrostatic and hydrodynamic properties are calculated.

In addition, the coordinates of all positions referenced in subsequent data categories and the parameters relating to the static environment (e.g. density of water) are input.

These parameters are normally considered to remain constant throughout the analysis of a particular structure. This means that for further program runs *these data categories must be removed*, as the information will be contained in a backing file and will be read automatically.

3.2.3. Data Categories 6 to 8 - The Radiation/Diffraction Analysis Parameters

The information in these data categories relates to the equation of motion of a diffracting structure in regular waves.

For Aqwa-Line, the input specifies a range of frequencies and directions at which these parameters are to be calculated.

For Aqwa-Drift/Fer/Librium/Naut, these parameters are read from backing file automatically or are input manually.

Note that, although the parameters calculated by Aqwa-Line can be transferred automatically to other programs in the Aqwa suite, this is *not* mandatory. This means that if the backing file produced by an Aqwa-Line run is *not* available, e.g. Aqwa-Line has not been run previously, or the user wishes to input parameters from a source other than Aqwa-Line, he may do so in these data categories.

These parameters usually remain constant for an analysis of a particular structure. This means that once the values of the Radiation/Diffraction analysis have been calculated or input, *these data categories must be removed*, as the information will be contained in a backing file and will be read automatically.

3.2.4. Data Categories 9 to 18 - Definition of Analysis-Dependent Parameters

The information input in these data categories is dependent on the type of analysis and the external forces acting on the structure, additional to those due to wave diffraction or radiation. Additional hydrodynamic coefficients may also be required for analyses involving drift frequency and nonlinear current/wind forces.

These fall into the following categories, any or none of which may be required for a particular analysis (see Default Values Assumed by the Program (p. 49)):

- accuracy and conditions of analysis, e.g. initial position of structure
- hydrodynamic coefficients for drift frequency forces or nonlinear current/wind forces
- environmental conditions of current, wind, waves
- external constraints of mooring lines or articulations
- hydrodynamic coefficient multipliers for parametric studies
- requests for additional output information

3.3. Default Values Assumed by the Program

The following sections describe the default behavior when various actions are taken:

3.3.1. Omission of Data Categories

As explained in Compulsory Data Category Keyword (p. 47), the user should enter 'NONE' for the data category keyword, if the information contained in the data category is not relevant to his application. Then simply omit the rest of the data category. This is quite common when running Aqwa programs.

Some data categories cannot be meaningfully omitted, for example, Data Categories 1, 2, 3 and 4 in a Stage 1 analysis. (If the user does enter 'NONE' for the data category keyword, error messages will be issued saying that the data is missing.)

The user should note that whenever 'NONE' is entered, the program will automatically supply default values for all the quantities associated with that data category. The user may therefore use this mechanism as a default facility (but see Default Values (p. 51) below).

3.3.2. Omission of Data Records within a Data Category

The user may omit a data record from within a data category if the information contained on the data record is not relevant to his application. This is quite common when running Aqwa programs.

Some data records cannot be meaningfully omitted, for example, the frequency data record (defining the frequencies to be analyzed) in Data Category 6. (If the user does omit this data record, the program will assume zero frequencies to be analyzed and will terminate normally without actually doing anything!)

The user should note that if a data record is omitted, the program may automatically supply default values for all the quantities associated with that data record. The user may therefore use this mechanism as a default facility (but see Default Values (p. 51) below).

3.3.3. Omission of Fields on a Data Record

Certain fields on a data record may be left blank. The program will supply appropriate default values. The is the basic default mechanism for the Aqwa suite (but see Default Values (p. 51) below). The fields which may be left blank are indicated in the appropriate places in the text (The Preliminary Data (Data Category 0) (p. 53)).

Note that, due to a peculiarity of the Fortran language, the program cannot distinguish between a blank field and one in which a zero value has been entered. Therefore, if zero is entered in a field which the manual indicates can take default values, the default value (which may be non-zero) will be invoked.

3.3.4. Default Values

The actual numerical values supplied by the program are given in the appropriate places in the text (The Preliminary Data (Data Category 0) (p. 53)).

> **Warning:**
>
> THE DEFAULT VALUES SUPPLIED ARE IN S.I. UNITS

Therefore, where Aqwa returns non-zero default values (for physical quantities), only users employing S.I. units may make use of the default facility.

In any event, all data either input by the user or assumed by the program are automatically sent to the listing file, unless the user specifically requests otherwise.

3.4. The Data Category Series for One or More Structures

3.4.1. Data Category Series - Definition

In the case of Data Categories 2, 6, 7, 8, 9 and 10, all input data refers to that associated with a particular structure. Therefore, each structure has its own data category, e.g. if there are three structures being analyzed there will be Data Categories 2.1, 2.2, 2.3, 6.1, 6.2, 6.3, 7.1, 7.2, 7.3 etc. Such a group of data categories (i.e. 2.1, 2.2, 2.3 or 6.1, 6.2, 6.3) is known as a *data category series*. The data category keyword indicates this by having the structure number incorporated into the data category keyword, e.g. for Data Category 6 (Frequency and Direction Tables) we have, for three structures, FDR1 as the data category keyword for Structure 1, FRD2 as the data category keyword for Structure 2, etc. The documentation will refer to these as Data Category FDR* to mean all three data categories, i.e. the Data Category Series 6.1, 6.2, and 6.3.

3.4.2. The Data Category Series Terminator - FINI

The number of structures is defined by the number of Data Category 2's where the structural, hydrodynamic and hydrostatic model is input, e.g. if the user inputs two data categories (Data Categories 2.1 and 2.2), the number of structures will have been defined as 2. However, as the program is unable to anticipate that Data Category 2.3 will not be input, the Data Category 2 series must be terminated with a 'FINI' data record, that is, a data record formatted as above with 'FINI' (FINIsh) as the data category keyword. However, if the maximum number (50) of structures is input, the 'FINI' data record *must be omitted*, as termination of the data category series is then mandatory.

3.4.3. Omission of Data Categories within a Data Category Series

The data category series terminator 'FINI' must subsequently be used, if necessary, to terminate the series of Data Categories 6, 7, 8, 9, and 10. The program expects the number of data categories input to be equal to the number of structures defined. If this is not the case, the last data category input must be followed by a FINI data category series terminator. For example, if the user has three structures and wishes to omit the data for Structure 2 from Data Category 9, the remaining data categories (9.1 and 9.3) must be followed by the data category terminator 'FINI'. If the user omits data for Structures 1 *and* 2 then the only remaining data category (9.3) must be followed by the data category terminator 'FINI'. However, if all Data Category 9's are omitted, the data category keyword 'NONE' must be used to indicate that there is no input for any of the defined structures (see also Compulsory Data Category Keyword (p. 47)).

Chapter 4: The Preliminary Data (Data Category 0)

The function of this Data Category is to define the overall administration parameters of the analysis. This includes the type of analysis (JOB data record), various options (OPTIONS data record) controlling facilities, printing etc, and the definition of the stages of the analysis at which the user wishes to start and finish (RESTART data record).

The JOB data record defines the program and analysis type of the analysis that the user wishes to perform. It is also used to input a 4-letter user-defined identifier for a particular run. As Aqwa-Drift, Aqwa-Fer and Aqwa-Librium have two distinct types of analysis (drift and wave frequency for Aqwa-Drift/Fer and static and dynamic stability at drift frequency for Aqwa-Librium) the user is able to select which type of analysis to perform.

The TITLE data record is used simply to input a title for the program run. This is stored and output at various stages, including the graphical plotting, and the annotation of the results.

The OPTIONS data record enables the user to select additional optional facilities and to control the quantity of printing output by the analysis. Note that the OPTIONS relating to printing are supplemented by further options in Data Category 18 (printing options). The latter are used to control output where more detailed information is required to define its extent and format.

In order to minimize the computer costs, all programs in the Aqwa suite have the facility of stopping and starting at various stages of the analysis. These stages are referred to as Restart Stages and are specified using the RESTART data record.

4.1. The JOB Data Record

```
 1     5      11      17      23
 --- - ---- -- ---- -- ---- -- ------------------
|JOB|X|UDJI|XX|DRIF|XX|WFRQ|XX|HASH
 --- - ---- -- ---- -- ---- -- ------------------
  |     |       |       |       |
  |     |       |       |       |_(4)Aqwa Workbench JOB SHA1 Hash(A40)
  |     |       |       |
  |     |       |       |_(3)Analysis Type(A4)
  |     |       |
  |     |       |_(2)Program Name(A4)
  |     |
  |     |_(1)User Defined Job Identifier(A4)
  |
  |_Compulsory data record keyword(A3)
```

(1) The 4-letter code is for the convenience of the user and is not used by the program. If the user wishes to have the same title for several runs, the 4-letter character identifier (which should always be unique) enables the user to distinguish between these runs. This is particularly relevant when using the graphics, as this code is output on every plot.

(2) An abbreviation of the program name must be input to specify the overall data input format to be expected by the program. If left blank, or the incorrect name is input, the program will output an error

message and abort after the preliminary data category has been read. The accepted abbreviations for the program names are as follows:

Aqwa-Drift = DRIF

Aqwa-Fer = FER

Aqwa-Line = LINE

Aqwa-Librium = LIBR

Aqwa-Naut = NAUT

(3) As all of the programs have two distinct types of analysis, the user may state which type of analysis is required for each run. If this field is left blank, then the default analysis type will be used. These defaults and the optional analysis types are as follows:

Aqwa-Line Default - Radiation/Diffraction analysis

Option 1 - **FIXD** - Structure fixed

Aqwa-Librium Default - Static AND dynamic stability

Option 1 - **STAT** - Static stability only

Option 2 -**DYNA** - Dynamic stability only

Aqwa-Drift Default - Drift frequency motions only

Option 1 - **WFRQ** - Drift frequency AND wave frequency motions

Aqwa-Fer Default - Drift frequency AND wave frequency motions

Option 1 - **DRFT** - Drift frequency motions only

Option 2 - **WFRQ** - Wave frequency motions only

Aqwa-Naut Default - Time history regular wave response

Option 1 - **IRRE** - Time history analysis in irregular waves. This applies to both diffracting structures (when convolution (p. 314) is used) and Morison structures. Note that in Aqwa-Naut, wave drift force is not included in either regular or irregular waves.

(4) The Aqwa Workbench project ID (SHA1 hash string), which is produced when the input data file is created by Aqwa Workbench. It is optional and consists of a string of 40 characters. During the solve, this hash value is output to the LIS and RES files. This field is used to link the results produced with the input solver DAT file to ensure consistency.

4.2. The TITLE Data Record

```
  1     6              21
  ----- --------------- ---------------------------------------------
 |TITLE|XXXXXXXXXXXXXXX|THIS IS A TITLE OF THE PROGRAM RUN            ...
  ----- -------------- ----------------------------------------------
```

```
     |                  |
     |                  |
     |                  |_Title to be Used for Annotation of Results(15A4)
     |
     |_Compulsory Data Record Keyword.
```

4.3. The NUM_CORES Data Record

Aqwa can take advanced of multi-core machines to improve computational speed during the solution stages. For more information, see Aqwa Parallel Processing Calculation in the *Aqwa Theory Manual*. The NUM_CORES data record specifies how many cores to use in a given analysis.

```
  1         11    16    21
  ---------- ----- -----
 |NUM_CORES |XXXXX|   16|
  ---------- ----- -----
     |               |
     |               |
     |               |_(1) Number of required cores (I5)
     |
     |_Compulsory data record keyword (A9)
```

(1) For hydrodynamic diffraction analyses, the maximum number of cores used by Aqwa is the smallest of:

- The user requested number
- The total number of cores in the node on which Aqwa is executed
- The total number of available parallel licenses + 4

Note:

The total number of cores in the node on which Aqwa is executed cannot be larger than the number of available cores on the machine (whether they are physical or logical).

For time domain dynamic cable analyses, in order to maximize efficiency while minimizing total memory use, the fewest number of cores for dynamic cable parallel calculation is determined based on the total number of dynamic cables in each mooring configuration and the actual number of cores available to Aqwa. This may mean that the number of cores used (and reported in the output) may be fewer than the user requested value.

This data record is optional and only applies to Aqwa parallel processing.

4.4. The OPTIONS Data Record

```
  1         9     14     19     24     29
  ------- - ---- - ---- - ---- - ---- - ----
 |OPTIONS|X|OPT1|X|OPT2|X|OPT3|X|OPT4|X|END |
  ------- - ---- - ---- - ---- - ---- - ----
     |       |
     |       |
     |       |_(1)One or more OPTIONS. Format of each Option(A4)
```

```
        |
        |_Compulsory Data Record Keyword.
```

(1) Up to 14 options may be input on each options data record. Each data record must have the data record keyword OPTIONS in columns 1-7 and the last option on the last OPTIONS data record *must* be END as shown above. In practice, only a few options are used for any one run. It is therefore extremely unusual to input more than one OPTIONS data record.

The list of options common to all programs, and those which are have special applicability for a certain program are listed for each program in Options for Use in Running Aqwa Programs (p. 307).

4.5. The RESTART Data Record

Note:

If this data record is present a REST option must be present in the list of options on the OPTIONS data record (see The OPTIONS Data Record (p. 55)).

```
 1         9  12         21
 ------- - --- --- ------ -----------
|RESTART|X|   |   |XXXXXX|FILENAME
 ------- - --- --- ------ -----------
    |       |   |          |
    |       |   |          |_(3)Optional. Name of database to be copied (without extension)
    |       |   |
    |       |   |_(2)Finish Stage, i.e. Finish at the End of this Stage (I1)
    |       |
    |       |_(1)Start stage, i.e. Start at the Beginning of this Stage (I1)
    |
    |_Compulsory Data Record Keyword
```

(1) The start stage will depend on which stages have been previously run. Stages in the program may not be omitted. This means that the finish stage of the previous run must either be the previous stage or a later stage in the program analysis.

When errors are detected, the user may start the analysis again at any of the preceding stages before the error occurred. If the previous stage was correctly performed, the user instructs the program to execute the next stage, i.e. simply to continue the analysis.

Note that as no analysis is performed within Stage 3 (except for Aqwa-Line) a run starting and finishing at Stage 3 may be used, in conjunction with the PRDL option, to print out the contents of the restart file on the listing file. As the restart file is a binary file and cannot be printed out directly, this is very useful if there is some question as to the contents.

See Analysis Stages (p. 31) for a description and list of restart stages for each program.

(3) The program will automatically copy any relevant files with this name to use for the current run. This may be .RES, .EQP and/or .POS, depending on the program which is being run. For example, using the name ABTEST1 in the Aqwa-Fer data file `AFTEST2.DAT` will result in:

`ABTEST1.RES` being copied to `AFTEST2.RES`

`ABTEST1.EQP` being copied to `AFTEST2.EQP`.

Note that the RDEP option is still required to read the .EQP file that has been copied.

If an extension is used, for example `ABTEST1.RES`, only that one individual file will be copied.

Chapter 5: Node Number and Coordinates (Data Category 1)

5.1. General Description

The function of this data category is to define a table of coordinate positions on the structure or fixed in space, referred to in later data categories, e.g. Element Topology (Data Category 2) used for modeling the structure. These positions are referred to in the documentation as nodes. A node is defined by an integer number (called a node number) and three Cartesian coordinates which are associated with this number.

The node number is used only as an index to the values of the coordinate positions and therefore may be any numbers which are convenient to the user. Node numbers do not have to be in any order, sequenced, or referenced by another data category.

Node numbers must be unique.

Although you may find that using a series of random integers is quite valid, the hydrodynamic and hydrostatic modeling of the structure in Data Category 2 can be made considerably easier by a logical ordering of the node numbers.

For 32-bit Aqwa, there can be up to 30000 nodes explicitly defined, or 60000 if one symmetry data record is used, or 120000 if two symmetry data records are used. For 64-bit Aqwa, there can be up to 60000 nodes explicitly defined, or 120000 if one symmetry data record is used, or 240000 if two symmetry data records are used.

When The STRC Data Record - Coordinate Structure Association (p. 62) (STRC) is not used, the coordinate positions in this data category are not specifically associated with any one structure nor with any one element within that structure. This means that many elements may reference the same node number and several structures may also reference the same node number. This does not mean that the structures are joined together at a node, but that the structures are completely independent unless specified otherwise (for example, Data Category 12 (Constraints) and Data Category 14 (Mooring Lines)). When a structure moves, the node moves with the structure.

When used, The STRC Data Record - Coordinate Structure Association (p. 62) (STRC) provides a means to associate particular nodes with individual structures.

5.2. Data Category Header

```
       5      11
   ---- -- ---- ----
  |XXXX|  |XXXX|COOR|
   ---- -- ---- ----
        |        |
        |        |
        |        |_Compulsory Data Category Keyword(A4)
```

```
         |
         |
         |_Optional User Identifier(A2)
```

5.3. The Coordinate Data Record

```
     2   5  7   11    16    21        31     51        61        71
   - --- -- ---- ----- ----- --------- --   -- --------- --------- -------
  |X|   |  |   4|     |     |  54.6   |  ... |         |         |       ...
   - --- -- ---- ----- ----- --------- --   -- --------- --------- -------
  |X|END|  |  23|    3|   10|  54.6   |  ... |   4.5   |         |       ...
   - --- -- ---- ----- ----- --------- --   -- --------- --------- -------
       |  |   |     |     |      |      | |       |          |         |
       |  |   |     |     |      |--------        |-----------------------
       |  |   |     |     |      |                |
       |  |   |     |     |      |                |
       |  |   |     |     |      |        (5)3 Coordinate Increments (3F10.0)
       |  |   |     |     |      |
       |  |   |     |     |      |_(4)3 Coordinates for Start Node (3F10.0)
       |  |   |     |     |
       |  |   |     |     |
       |  |   |     |     |_(3)Increment for Node Number(I5)
       |  |   |     |
       |  |   |     |_(2)Number of Nodes to be Generated(I5)
       |  |   |
       |  |   |_(1)Starting Node Number(I4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on Last Data Record in data category (A3)
```

(1) This is the node number (N1) whose coordinate position is given by the values X, Y, Z (4).

(2) Leave blank (as in first data record shown above) if only 1 node is to be generated. A total of N2 nodes are generated automatically if this number (N2) is greater than 1. The Nth node is generated:

with a node number N1+ (N-1)N3

with coordinates X+(N-1)DX, Y+(N-1)DY, Z+(N-1)DZ

(3) Leave blank (as in first data record shown above) if only one node is to be generated. If this field is left blank when generating nodes, then a value of 1 is assumed for this Nodal Increment (N3).

(4) Coordinate Position (X,Y,Z) associated with node number N1 (1).

(5) Leave blank (as in first data record shown above) if only 1 node is to be generated. These 3 values are referred to as DX,DY,DZ in (2).

5.4. The Coordinate Data Record with Rotational Node Generation

This facility may be used to generate nodes by rotating nodes already input by a specified angle about a specified position. This is particularly useful for describing the nodes on axisymmetric bodies.

```
     2   5  7   11    16    21        31     51        61        71
   - --- -- ---- ----- ----- --------- --   -- --------- --------- -------
   R|END|  | 101|    3|  100|  20.0   |  ... |   0.0   |   0.0   |   30.0...
   - --- -- ---- ----- ----- --------- --   -- --------- --------- -------
   |  |  |    |     |     |      |      | |        |         |         |
```

```
     |  |  |    |     |     |      |--------         |----------------------
     |  |  |    |     |     |      |                 |
     |  |  |    |     |     |      |                  _(6)Angular Rotation
     |  |  |    |     |     |      |                      VECTOR(Degrees.3F10.0)
     |  |  |    |     |     |      |
     |  |  |    |     |     |      |_(5)3 Coordinates for Position about which
     |  |  |    |     |     |           to rotate(3F10.0)
     |  |  |    |     |     |
     |  |  |    |     |     |_(4)Increment for Each set of Node Numbers(I5)
     |  |  |    |     |
     |  |  |    |     |_(3)Number of Nodal Sets to be Generated(I5)(Default 1)
     |  |  |    |
     |  |  |    |_(2)The User node number of the 1st node in a set.
     |  |  |
     |  |  |_Optional User Identifier(A2)
     |  |
     |  |_Compulsory END on last data record in data category
     |
     |_(1)Indicates Rotational Node Generation
```

(1) This single letter code indicates that a set of nodes is to be generated by rotating a set of nodes already input.

(2) This is the starting node of the set to be copied (input sequence = NS1). The finish node of the set is the last node input so far (input sequence = NF1).

(3) This is the number of node sets to be generated (NSETS). The total number of nodes automatically generated in addition to those already input is given by:

Total additional nodes = NSETS (NF1-NS1+1)

If this field is left blank, or zero is input, NSETS=1 is assumed.

(4) This node increment number (N3) is the number by which the node numbers already input are to be incremented. In other words, if the nodes previously input are numbered NP1, NP2, NP3 etc., and the new node numbers are NN1, NN2, NN3 etc., these new node numbers are given by:

NN1 = NP1 + N3; NN2 = NP2 + N3; NN3 = NP3 + N3; etc.

If no increment value is present, or zero is input, the program will issue a warning and default to a value of 100.

(5) These three values are the coordinates of the point about which the rotation of the nodes already input takes place. This field may be left blank, in which case the point is assumed to be 0.0, 0.0, 0.0, i.e. the FRA origin.

(6) These three values (RX,RY,RZ) are the components of the angular vector of rotation, i.e. the angle and axis about which the rotation takes place is given by

Angle = modulus (RX,RY,RZ)

Axis = vector (RX,RY,RZ) / Modulus (RX,RY,RZ)

Although this means that the user has the facility to generate nodes rotated about any axis, the most common usage is as follows (using 30 degrees as an example)

Rotation about X-axis RX = 30.0 RY = 0.0 RZ = 0.0

Rotation about Y-axis RX = 0.0 RY = 30.0 RZ = 0.0

Rotation about Z-axis RX = 0.0 RY = 0.0 RZ = 30.0

EXAMPLE

Generation of nodes for six, 50m tall, 8m diameter cylindrical legs of an axisymmetric semi-submersible at a radius of 75 metres

```
     2   5  7    11    16    21      31      41      51      61      71
    - --- -- ---- ----- ----- ------- ------- ------- ------- ------- -------
  | |   |  |    1|    6|    1|  79.0 |  0.0  |  0.0  |  0.0  |  0.0  | 10.0  |
   - --- -- ---- ----- ----- ------- ------- ------- ------- ------- -------
  |R|   |  |     |   12|   10|  75.0 |  0.0  |  0.0  |  0.0  |  0.0  | 30.0  |
   - --- -- ---- ----- ----- ------- ------- ------- ------- ------- -------
  |R|   |  |     |    5|  200|  0.0  |  0.0  |  0.0  |  0.0  |  0.0  | 60.0  |
   - --- -- ---- ----- ----- ------- ------- ------- ------- ------- -------
```

Data Record 1 - Generates six nodal coordinate on a vertical line.

Data Record 2 - Generates 12 additional vertical lines at 30 degree intervals; that is, generates the nodes to define a single cylinder. Note that the last set of nodes (121-126) have the same coordinates as the first set (1-6). This makes the numbering sequential for all 12 faces of the regular dodecagon representing the circular surface and hence facilitates the specification of element topology (Data Category 2).

Data Record 3 - Generates five additional cylinders at 60 degree intervals.

Total number of nodes generated (see columns 11 to 15) is 6 (12+1) (5+1) = 468

5.5. The STRC Data Record - Coordinate Structure Association

The STRC (structure) data record enables the use of totally independent sets of coordinates for each structure. In other words, the USER node numbers may be the same for 2 different structures but they will be treated as separate items. The STRC data item can also be utilized in the Material (p. 93) and Geometric (p. 95) property data categories; see note below.

Fixed nodes (referred to as Structure 0) must be defined in the nodes of the structure which is connected to them, for example:

- Fixed nodes for mooring lines from Structure 1 to Structure 0 must be defined in the Structure 1 set of coordinates
- A fixed node for an articulation connecting Structure 2 to Structure 0 must be defined in the Structure 2 set of coordinates.
- Similarly for connections between other structures and Structure 0.

Note:

- If the STRC data record is not used all user node numbers must be unique.

- If the STRC data record is used in the COOR data category, then it may also be used in the MATE and GEOM data categories if the use of the same property number is required from different structures.
- If the STRC data record is not used in the COOR Data Category, it cannot be used in the MATE(materials) and GEOM(geometry) Data Categories.

The structure number has to be in columns 16-20 as shown below:

```
      5  7          16    21
- --- -- ---- ------ ----- ----
X XXX 01 STRC XXXXX     nn XXXXXX
- --- -- ---- ------ ----- ----
      |  |              |
      |  |              |
      |  |              |
      |  |              |_(3)Structure Number.
      |  |
      |  |_(2)Mandatory data record keyword.
      |
      |_(1)Optional user data category identifier
```

(3) The structure number must start from 1 on the 1st data record and increment by 1 for each structure data record input. The number of ELM* data categories must correspond to the number of structure data records.

5.6. The Coordinate Data Record with Offset

The OFFSET data record is in the following format:

```
       6        16      21        31        41
- --- -- -------------- --------- --------- ---------
O XXX 01 XXXXXXX   100      10.0      0.0       0.0
- --- -- -------------- --------- --------- ---------
|     |             |        |         |         |
|     |             |        |         |         |_(6)Z offset (F10.0)
|     |             |        |         |
|     |             |        |         |_(5)Y offset (F10.0)
|     |             |        |
|     |             |        |_(4)X offset (F10.0)
|     |             |
|     |             |_(3)Node number increment (I5)
|     |
|     |_(2)Optional user data category identifier
|
|_(1)Compulsory data record keyword (A1) NB:O = Absolute offset o=relative
```

(1) Note that upper case 'O' will define an absolute offset and lower case 'o' will define a relative offset. All node coordinates input after this data record will be generated offset by these 3 values.

For example, if the nodes for 3 identical legs along the X axis, 30m apart, with the 1st leg at X = 5.0 are defined, then the 2 absolute X offset data records input just before the node coordinate for legs 2 and 3 would be 35.0,65.0. The 2 relative X offsets would be 30.0,30.0, as the default offset is zero.

Note:

If a STRC data record (The STRC Data Record - Coordinate Structure Association (p. 62)) is input, the OFFSET will automatically be re-set to zero.

5.7. The Coordinate Data Record with Translation

This facility may be used to generate nodes by translating nodes already input by a specified translational increment:

```
   2   5  7    11    16    21   31   41    51        61         71
  - --- -- ---- ----- ----- ---- ---- ----- -------- --------- -------
 |T|   |  |1   |    3|  100|XXXX|XXXX|XXXXX|  30.0  |   0.0   |   0.0...
  - --- -- ---- ----- ----- --------- --  -- ------- --------- -------
  |  |  |  |      |     |                        |         |         |
  |  |  |  |      |     |                        |-----------------------
  |  |  |  |      |     |                        |
  |  |  |  |      |     |                        _(5)Translation values
  |  |  |  |      |     |                            VECTOR(3F10.0)
  |  |  |  |      |     |
  |  |  |  |      |     |_(4)Increment for Each set of Node Numbers(I5)
  |  |  |  |      |
  |  |  |  |      |_(3)Number of Nodal Sets to be Generated(I5)(Default 1)
  |  |  |  |
  |  |  |  |_(2)The User node number of the 1st node in a set.
  |  |  |
  |  |  |_Optional User Identifier(A2)
  |  |
  |  |_Compulsory END on last data record in data category
  |
  |
  |_(1)Indicates Translational Node Generation
```

(1) This single letter code indicates that new sets of nodes are to be generated by translating a set of nodes already input.

(2) This is the starting node of the set (input sequence = NS1). The finish node of the set is the last node input so far (input sequence = NF1).

(3) This is the number of node sets to be generated (NSETS). The total number of nodes automatically generated in addition to those already input is given by:

Total additional nodes = NSETS (NF1-NS1+1)

If this field is left blank, or zero is input, NSETS = 1 is assumed.

(4) This node increment number (N3) is the number by which the node numbers already input are to be incremented. In other words, if the node set previously input are numbered NP1, NP2, NP3, etc., and the new node numbers are NN1, NN2, NN3, etc., these new node numbers are given by:

NN1 = NP1 + N3; NN2 = NP2 + N3; NN3 = NP3 + N3

If no increment value is present, or zero is input, the program will issue a warning and default to a value of 100.

(5) This node coordinate increment number (DX,DY,DZ) is the VALUE by which the node set coordinates are to be incremented; that is, if the node set previously input are values XP1, XP2, XP3 etc and the new X coordinates XN1, XN2, XN3, etc, these new values are given by:

XN1 = XP1 + DX; XN2 = XP2 + DX; XN3 = XP3 + DX

Similarly for Y and Z.

5.8. The Coordinate Data Record with Mirror Node Generation

This facility may be used to generate nodes by reflecting nodes already input in a specified plane.

```
  2   5  7    11    16    21        31        41        51
- --- -- ---- ----- ----- --------- --------- --------- ---------
M|END|  | 101| XXXX|  100|  1.0    |   1.0   |   2.0   |  15.0   |
- --- -- ---- ----- ----- --------- --------- --------- ---------
|  |  |    |           |      |        |         |         |
|  |  |    |           |      |----------------------------
|  |  |    |           |      |
|  |  |    |           |      |_(4)4 Co-efficients to define equation
|  |  |    |           |            of mirror plane (4F10.0)
|  |  |    |           |
|  |  |    |           |_(3)Increment for each set of Node Numbers(I5)
|  |  |    |
|  |  |    |_(2)The User node number of the 1st node in a set.
|  |  |
|  |  |_Optional User Identifier(A2)
|  |
|  |_Compulsory END on last data record in data category
|
|_(1)Indicates Mirror Node Generation
```

(1) This single letter code indicates that a set of nodes is to be generated by reflecting a set of nodes already input.

(2) This is the starting node of the set to be copied (input sequence = NS1). The finish node of the set is the last node input so far (input sequence = NF1). The number of nodes generated will always be (NF1-NS1+1).

(3) This node increment number (N3) is the number by which the node numbers already input are to be incremented. In other words, if the nodes previously input are numbered NP1, NP2, NP3, etc., and the new node numbers are NN1, NN2, NN3, etc., these new node numbers are given by:

NN1 = NP1 + N3; NN2 = NP2 + N3; NN3 = NP3 + N3; etc.

If no increment value is present, or zero is input, the program will issue a warning and default to a value of 100.

(4) These are the co-efficients A, B, C, D which define the plane of reflection. The plane is defined by the equation:

$Ax + By + Cz = D$

5.9. The NOD5 Data Record - 5-digit node numbers

This data record allows node numbers with 5 digits to be defined directly.

The input format is as follows:

```
      5  7
- --- -- ---- ------
X|XXX|  |NOD5|XXXXX
- --- -- ---- ------
       |  |
       |  |
       |  |_(2)
       |
       |_(1)Optional user data category identifier
```

When the NOD5 data record is used the format for all following coordinate data records are changed slightly as shown below. The field for node numbers becomes 5 columns, while the field for the number of generated nodes is reduced to 4 columns. All the other fields are unchanged.

```
   2   5  7     12   16    21        31     51        61        71
  - --- -- ----- ---- ----- --------- --  -- --------- --------- -------
 |X|   |  |    4|    |     |  54.6   |  ... |         |         |       ...
  - --- -- ----- ---- ----- --------- --  -- --------- --------- -------
 |X|END|  |   23|   3|   10|  54.6   |  ... |   4.5   |         |       ...
  - --- -- ----- ---- ----- --------- --  -- --------- --------- -------
     |  |   |     |     |      |
     |  |   |     |     |      |_(4)3 Coordinates for Start Node (3F10.0)
     |  |   |     |     |
     |  |   |     |     |_(3)Increment for Node Number(I5)
     |  |   |     |
     |  |   |     |_(2)Number of Nodes to be Generated(I4)
     |  |   |
     |  |   |_(1)Starting Node Number(I5)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on Last Data Record in data category (A3)
```

Chapter 6: Element Topology - ELM* (Data Category 2)

When entering ELM data categories, the * indicates the structure number. In other words, enter ELM1 for Structure 1, ELM2 for Structure 2, ... EL10 for Structure 10.

6.1. General Description

This Data Category defines the structural, hydrodynamic and hydrostatic modeling by superposition of ELEMENTS of different types, each of which has its own unique properties (a summary is given in Element Topology Data Record (p. 68)). An Element is defined by specifying 1, 2, 3 or 4 node numbers (defined in Data Category 1) as is appropriate to that element. Some elements also require a material and geometric group number (defined in Data Categories 3 and 4 respectively).

Data Categories 1, 3, 4 should be thought of as a table of values which are indexed by the node, material and geometric group numbers respectively, on the Element Topology Data Record (p. 68).

Note also that all elements within a structure are considered to be part of a rigid framework and cannot move relative to one another. However, there is no requirement for the actual physical connections to be modeled within the Aqwa suite of programs.

Note:

At this stage of the modeling (i.e. input of Data Category 2) the program does not know how many structures the user wishes to define. Therefore The Data Category Series Terminator - FINI (p. 51) must be used to indicate that no more structures will be input. However, if the maximum number of structures is input, the FINI data record *must* be omitted, as termination of the Data Category series is then mandatory.

The 32-bit version of Aqwa can accept up to 18000 elements explicitly defined in Data Category 2. Of these, 12000 may be diffracting elements. These limits are raised to 36000/24000 elements with one symmetry data record, or 72000/48000 elements with two symmetry data records. These limits are for all the elements in a complete model, not for each individual structure.

The 64-bit version of Aqwa can accept up to 40000 elements explicitly defined in Data Category 2. Of these, 30000 may be diffracting elements. These limits are raised to 80000/60000 elements with one symmetry data record, or 160000/120000 elements with two symmetry data records. These limits are for all the elements in a complete model, not for each individual structure.

Aqwa can accept up to 99 structures, each including diffracting or non-diffracting elements, but the total number of elements on all structures must not exceed the limits above. It is possible for all these structures to interact hydrodynamically.

6.2. Data Category Header

```
                     -(Indicates Structure Number)
                    |
        5      11   |
     ---- -- ---- ----
    |XXXX|  |XXXX|ELM1|
     ---- -- ---- ----
          |        |
          |        |_Compulsory Data Category Keyword(A4)
          |
          |_Optional User Identifier(A2)
```

6.3. Element Topology Data Record

```
      2   5  7   11    16    21        31        41
    - --- -- ---- ----- ----- ----------------------------
   |X|   |  |QPPL| DIFF|     |(30)(11,1)(71,1)(72,1)(12,1)
    - --- -- ---- ----- ----- ----------------------------
   |X|   |  |TUBE|     |     |(10)(11,3)(71,3)(2)(1)
    - --- -- ---- ----- ----- ----------------------------
   |X|   |  |DISC|     |     |(1)(11)(71)(1)
    - --- -- ---- ----- ----- ----------------------------

       |  |   |    |      |       |
       |  |   |    |      |       |
       |  |   |    |      | (3)Columns 21-80 free format data for
       |  |   |    |      |    generating NODE,MATERIAL,and GEOMETRIC
       |  |   |    |      |    GROUP NUMBERS. Format(60A1)
       |  |   |    |      |
       |  |   |    |      |_(2)Element Group Number(I5)
       |  |   |    |
       |  |   |    |_(4) DIFF identifier (diffracting plates only)
       |  |   |
       |  |   |_(1)Element Type(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The element type (always four characters) provides the classification for a particular element, i.e. the number of nodes, and whether material and geometric properties are required. Valid codes for element types are QPPL, TPPL, TUBE, PMAS, PBOY, FPNT, DISC and STUB as shown below:

	Description	No of Nodes	Material Property	Geometric Property
QPPL	Quadrilateral Panel	4	none	none
TPPL	Triangular Panel	3	none	none
TUBE	Tube	2	density	geometry
PMAS	Point Mass	1	mass	inertia
PBOY	Point Buoyancy	1	displaced mass	none
FPNT	Field Point	1	none	none
STUB	Slender Tube	3	mass, inertia	geometry
DISC	Circular Disc	2	none	geometry

(2) The element group number associated with each element is used to divide the elements defining the structure into groups. Groups can be used for plotting and to identify special sets of elements (see The ILID Data Record - Suppression of Irregular Frequencies (p. 81) and The VLID Data Record - Suppression of Standing Waves (p. 78)), but the group number may be left blank if desired.

(3) Free Format data generation is achieved by specifying several bracketed sets of Topological variables in columns 21-80. The number of bracketed sets is given by

Number of Sets = 1 + (Number of Nodes)

+ 1 if a Material Group is required

+ 1 if a Geometry Group is required

In general we have a format of

```
(N)(N1,N2,N3)   (N1,N2,N3)     (N1,N2,N3).....
 -  --------     --------       --------
        |            |              |
        |            |              |
      first      second node    third node
      node       or parameter   or parameter
```

N - Number of elements to be generated

N_1 - Starting Node number, Material Group number or Geometric Group number

N_2 - Increment of N_1 for each element generated

N_3 - Increment of N_2 for each element generated

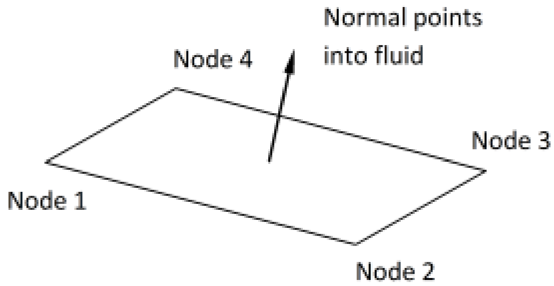
For the i^{th} element of the N elements generated (whether the set applies to a node number, material or geometric group number) each bracketed set will produce the number

$$N_i = \begin{cases} N_1 & i=1 \\ N_1+N_2 & i=2 \\ N_1+(i-1)N_2+(\sum_{j=1}^{i-2} j)N_3 & i>2 \end{cases}$$

Note:

- The nodes defining TPPL (p. 70) and QPPL (p. 70) elements must be ordered in a counter-clockwise direction from the perspective of an observer external to the structure.
- In an Aqwa-Line data file, QPPL (p. 70) and TPPL (p. 70) elements which are below the still water line in the Aqwa-Line analysis position must be denoted as diffracting elements by entering the identifier DIFF in columns 12 to 15.
- For structures which cross the waterline, the top row of diffracting plate elements must have their top edges aligned with the still water line (i.e. diffracting plates must not cross the still water line).

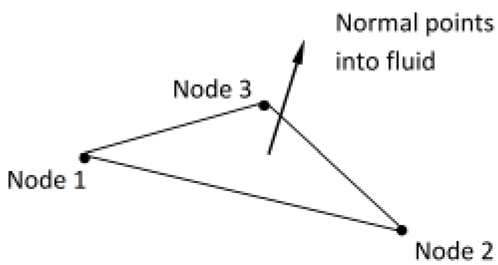
6.3.1. The QPPL Element



Quadrilateral pressure plate of zero thickness.

Element generates pressure and hydrostatic forces only.

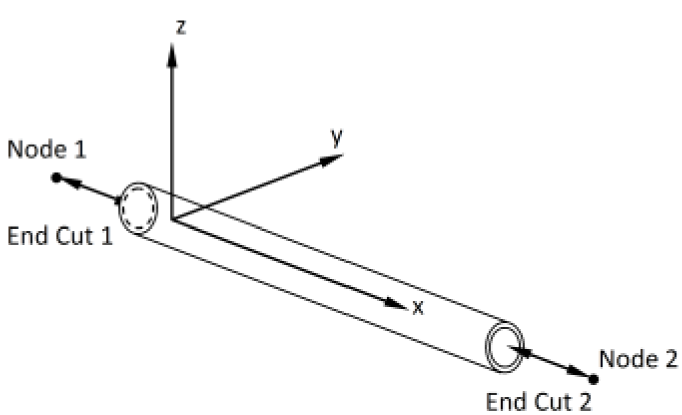
6.3.2. The TPPL Element



Triangular pressure plate of zero thickness.

Element generates pressure and hydrostatic forces only.

6.3.3. The TUBE Element



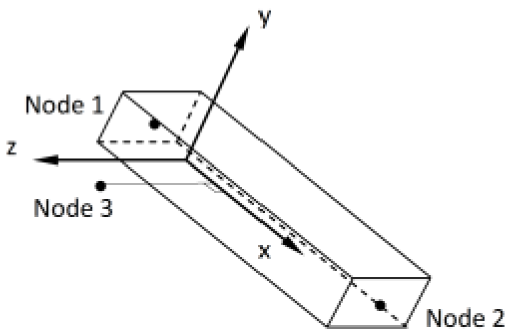
Tubular element with uniform circular cross-section and constant wall thickness.

Forces on this element are calculated using Morison's equation.

Open TUBE elements are considered to have open ends. The water surface inside the TUBE is at the same level as the surface outside. The transverse added mass is based on the outside diameter, but the axial added mass only uses the cross-sectional area of the TUBE material.

TUBE elements have an axial drag coefficient of 0.016 that cannot be changed.

6.3.4. The STUB Element



Slender tube element. The STUB element differs from the TUBE (p. 70) element in the following respects:

- STUB elements permit tubes of non-circular cross-section to be modeled, by allowing the tube properties (diameter, drag coefficient, and added mass coefficient) to be specified in two directions at right angles.
- Longer lengths of tube can be input, as the program automatically subdivides STUB elements into sections of shorter length for integration purposes.

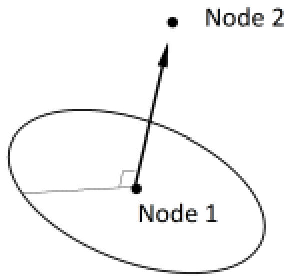
STUB elements should only be employed if the mean diameter is small compared to the length.

The local axis of the element runs from Node 1 to Node 2 (origin at Node 1). The perpendicular from Node 3 to the local X-axis, together with the local X-axis itself, defines the XZ-plane, and hence the Z-axis. The local Y-axis forms a right-handed set.

If any Z parameter for a STUB is omitted or set to zero it will default to the equivalent Y value.

If the STUB area is omitted or set to zero, the program will assume a circular cross-section if diameter Y and diameter Z are equal. If they are unequal, the cross-section is assumed to be rectangular and area will be set to the rectangular cross-sectional area. The area for the STUB element is used to calculate the displaced mass per unit length and buoyancy force. It is also used to calculate the Froude-Krylov force and default added mass. The area for the STUB element is used in the calculation of defaults for drag and added mass coefficients. Although the program will accept any value for area, warnings are issued if the value is greater than 1.05 * rectangular area or less than 0.95 * circular area.

6.3.5. The DISC Element



A circular disc element with no thickness and no mass. The DISC element has a drag coefficient and added mass coefficient in its normal direction. To add mass, the user can define a PMAS element and attach it to the DISC element.

The DISC element has two nodes; the first defines the center of the element and the second gives the normal direction of the element.

The force on a DISC element has two components: added mass force and drag force. As DISC elements have no thickness, the Froude-Krylov force and hydrostatic force are zero. This is different from a TUBE end on which the Froude-Krylov force and hydrostatic force are non-zero and therefore are calculated in Aqwa. The application point of the force is at the centroid of the DISC element when fully submerged, and at the force center computed by the program if partially submerged. The direction of the force on a DISC is parallel to the normal direction of the DISC.

DISC elements in Aqwa are *single sided*; for example, they are assumed to be adjacent to the end of a TUBE. The added mass and drag forces are based on this assumption, and are simply one-half the forces for a stand-alone disc. If the intention is to model a DISC by itself (for example, a heave plate on a TLP) the added mass and drag coefficients should be doubled.

6.3.6. The PMAS Element

Point mess element having internal mass with the center of mass coincident with a given node and specified values of second moments of mass inertia. The PMAS element generates mass forces only.

6.3.7. The PBOY Element

External point buoyancy element without mass. The PBOY element generates hydrostatic displacement forces only.

6.3.8. The FPNT Element

External fluid field point element. This element gives the pressure head amplitude at a specified point in the external fluid domain. When the element is at the water surface, it corresponds to the amplitude of the water surface elevation. Only applicable in Aqwa-Line with a radiation/diffraction analysis is run. If a hydrodynamic database is imported from a previous run it is not possible to calculate the water surface elevation.

FPNT elements are defined in the LSA axes and move with the structure in which they are defined.

FPNT elements are subject to symmetry commands.

6.3.9. Examples of Element Specifications

Example 1

For the QPPL element, the data

(30)(11,1)(71,1)(72,1)(12,1)

will generate the ELEMENTS as follows:

		node 1	node 2	node 3	node 4
Element 1	i=1	11+0(1+0) = 11	71+0(1+0) = 71	72+0(1+0) = 72	12+0(1+0) = 12
Element 2	i=2	11+1(1+0) = 12	71+1(1+0) = 72	72+1(1+0) = 73	12+1(1+0) = 13
Element 3	i=3	11+2(1+0) = 13	71+2(1+0) = 73	72+2(1+0) = 74	12+2(1+0) = 14

etc.

i.e. 30 elements are generated each with 4 node numbers where

Element 1 nodes are 11,71,72,12

Element 2 nodes are 12,72,73,13

Element 3 nodes are 13,73,74,14

etc.

Note:

N3 is zero in all cases, which is very common.

Example 2

For the TUBE element, the data

(10)(11,3)(71,3)(2)(1)

will generate the elements as follows:

		node 1	node 2	material group	geometry group
Element 1	i=1	11+0(3+0) = 11	71+0(3+0) = 71	2+0(0+0) = 2	1+0(0+0) = 1
Element 2	i=2	11+1(3+0) = 14	71+1(3+0) = 74	2+1(0+0) = 2	1+1(0+0) = 1
Element 3	i=3	11+2(3+0) = 17	71+2(3+0) = 77	2+1(0+0) = 2	1+2(0+0) = 1

etc.

i.e. 10 elements are generated

Element 1: nodes are 11,71; Material Group = 2; Geometry Group = 1

Element 2: nodes are 14,74; Material Group = 2; Geometry Group = 1

Element 3: nodes are 17,77; Material Group = 2 ; Geometry Group = 1

etc.

Note:

N2 (as well as N3) is zero for the material/geometric group number increments, which is very common. This means that all 10 elements will have the same material and geometric properties.

Example 3

For the DISC element, the data

(1)(11)(71)(1)

will generate one DISC element as indicated by the number in the first pair of brackets. The centroid position of the disc is defined by the first node number (node 11) and the normal direction of the disc is decided by the vector from the first node (11) to the second node (71). It should be noted that whether the normal vector defined as from node 11 to 71 or from node 71 to 11 has no effect on the results. The last number in the DISC data record is the geometry property group number for this DISC which is to be defined in Geometric Properties - GEOM (Data Category 4) (p. 95) (DISC has no material properties).

6.4. SYMX and SYMY Data Records - X and Y Symmetry

This facility may be used when the structure is symmetrical about the X or Y axis of the Fixed Reference Axis *in the position defined by the element topology in this data category and the node coordinates input in Data Category 1*.

```
     2   5  7
   - --- -- ----
  |X|   |  |SYMX|
   - --- -- ----
  |X|   |  |SYMY|
   - --- -- ----
      |  |   |
      |  |   |_(1)Symmetry Specification(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on Last
        Data Record in Data Category.(A3)
```

Use of the symmetry specification has two distinct advantages:

1. To save the user modeling 1/2 or 3/4 of the structure

   If the SYMX data record (only) is used, only half of the structure needs to be defined (on one side of the x axis). The other half of the structure will be generated internally by the program as a mirror image of the first half about the x axis. If the whole structure is modeled, the SYMX data record must not be used as this produces two identical structures existing in the same position.

If the SYMY data record (only) is used, only half of the structure needs to be defined (on one side of the y axis). The other half of the structure will be generated internally by the program as a mirror image of the first half about the y axis. If the whole structure is modeled the SYMY data record must not be used as this produces two identical structures existing in the same position.

If both the SYMX data record and SYMY data record are used, only one quarter of the structure needs to be defined (in one quadrant). If the half/whole structure is modeled both data records must not be used as this produces identical structures existing in the same position.

Structural symmetry about the Y-axis of the Fixed Reference Axis is not used for diffracting structures with forward speed in multiple wave directions defined by the FWDS (p. 113) and DIRN (p. 104) data records in Data Category 6 (p. 101). If the SYMY data record is defined in this case, the RMYS (p. 76) data record must be used to remove the symmetry about the Y-axis.

2. To save substantial computer time in the radiation/diffraction analysis in Aqwa-Line

   Expected saving in computer time:

   for 2-fold symmetry (SYMX OR SYMY) = 50 - 75 percent

   for 4-fold symmetry (SYMX and SYMY) = 75 - 90 percent

   These figures given are typical and saving will be model dependent. Saving may be less for small problems, and should be even greater for very large problems, i.e. greater than 250 defined (as opposed to total) elements.

Note:

The Symmetry data record only applies to TPPL and QPPL elements. All other element types are unaffected by the introduction of these data records and must be fully described as the physical geometry dictates.

6.5. The HYDI Data Record - Hydrodynamic Interaction

This data record allows the inclusion of the interaction effects when structures are in close proximity. Up to 20 hydrodynamically interacting structures can be modeled.

The interaction effects modelled include changes to both diffraction and radiation forces. All Aqwa post processing programs recognize these additional forces, including the additional radiation forces which couple the interacting structures.

The input format is as follows:

```
      5  7   11    16    21
- --- -- ---- ----- ----- --------
X|XXX|02|HYDI| LOCK|    1|XXXXX
- --- -- ---- ----- ----- --------
      |  |        |     |
      |  |        |     |
      |  |        |     |
      |  |        |     |_(3)Structure Number.
      |  |        |
      |  |        |_(4)Optional motion lock keyword.
```

```
        |  |
        |  |
        |  |_(2)Mandatory data record keyword.
        |
        |_(1)Optional user data category identifier
```

(3) All structures between the one specified on the HYDI data record and the current one will be considered to be interacting. For example, if an HYDI data record specifying structure 2 is input for structure 5, interaction effects will be calculated for structures 2,3,4 and 5. The structure number must correspond to a structure which is already defined in the element topology data category.

(4) The motions of hydrodynamically interacting structures can be locked by specifying the LOCK keyword with the HYDI data record. The RAOs calculated for the structures in the interacting group are then consistent with the RAOs of an equivalent single structure. This is particularly useful for the estimation of splitting forces and moments on a structure in a time domain (Aqwa-Drift or Aqwa-Naut) calculation. This is achieved in the time domain analysis by including a joint between each of the bodies in the interacting group to output such forces/moments.

Note:

Structures for which interaction effects are to be calculated must be defined with consecutive structure numbers.

6.6. The RMXS/RMYS Data Records- Remove Symmetry

These data records allow the symmetry of a structure to be removed, instructing Aqwa to generate new elements mirroring those already defined. They only apply to elements above them in the ELM* data category, and therefore should be the last data record(s) in the data category (before the FINI data record if used).

These data records ONLY apply to TPPL and QPPL elements (diffracting or non-diffracting). They do not operate on any other element types.

The input format is as follows:

```
      5  7
- --- -- ---- ------
X|XXX|  |RMXS|XXXXX
- --- -- ---- ------
       |  |
       |  |
       |  |_(2)Symmetry Specification
       |
       |_(1)Optional user data category identifier
```

These data records are most useful when structures have been created using the mesh generator, which automatically creates a symmetric structure using the SYMX data record. When the full structure has been created it can then be put into its correct position using the MSTR data record.

6.7. The MSTR Data Record - Move Structure

This data record allows the definition position of a structure to be changed. If it is applied to a symmetric structure the symmetry is automatically removed. It only applies to elements above it in the ELM* data category, and therefore should be the last data record in the data category (before the FINI data record if used).

The MSTR data record only applies to elements. If a node has been defined to represent the connection point of a mooring line for example, and that node is not used on any elements, the node will not be moved with the structure. Consequently any such nodes must be defined in Data Category 1 in their final position.

The input format is as follows:

```
      5  7   11    16    21
- --- -- ---- ----- ----- --------
X|   |02|MSTR|XXXXX|XXXXX| (NNN) (X,Y,RZ)
- --- -- ---- ----- ----- --------
   |   |  |                    |
   |   |  |                    |
   |   |  |                    |_ (4)Columns 21-80. Free format data to
   |   |  |                          define new position of structure.
   |   |  |
   |   |  |_(3)Mandatory data record keyword.
   |   |
   |   |_(2)Optional user data category identifier.
   |
   |_(1)Compulsory END on Last Data Record in Data Category(A3)
```

(4) The new position of the structure is defined by giving a node number on the structure, the position to which it is to be moved and the yaw angle (degrees). The vessel is yawed about the specified node. Only X and Y positions and yaw can be given as the Z position is defined by the ZCGE or ZLWL data records and Aqwa-Line does not permit the model to be rotated in roll or pitch.

Note:

All the output from Aqwa-Line (RAOs, hydrodynamic force coefficients etc.) is in the FRA. This is still so if a structure is rotated using the MSTR data record, so, for example, motions about the X-axis may no longer correspond to roll of the vessel.

6.8. The FIXD Data Record - Fix Structure

This data record allows a structure to be fixed. It has the same effect as the FIXD option on the JOB data record, but it applies only to one structure. As with the previous JOB option, this data record only applies to Aqwa-Line. If a structure has to be fixed in one of the other programs use a fixed articulation.

The input format is as follows:

```
      5  7   11    16    21
- --- -- ---- ----- ----- --------
X|   |02|FIXD|XXXXX|XXXXX|
- --- -- ---- ----- ----- --------
```

```
      |   |  |
      |   |  |
      |   |  |_(3)Mandatory data record keyword.
      |   |
      |   |_(2)Optional user data category identifier.
      |
      |_(1)Compulsory END on Last Data Record in Data Category(A3)
```

6.9. The VLID Data Record - Suppression of Standing Waves

This data record is used to define a "lid" for reduction of the standing wave that may occur in a moonpool or between two hydrodynamically interacting vessels. The lid has to be manually defined; there is no automatic generation facility as there is with the ILID data record.

The lid is modeled by horizontal diffracting elements that must be contained in a single specified group. Their effect is controlled by two parameters: a "damping factor" and a characteristic length. The elements should be at the water surface between the vessels and have their normals pointing upwards. They do not need to follow the vessel outline closely so a simple mesh should be adequate, as illustrated in the figure below.

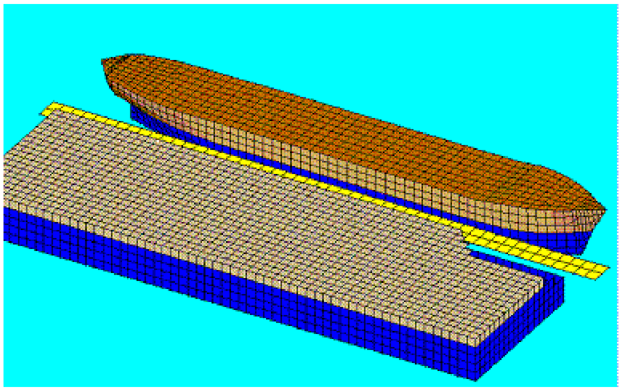
VLID elements cannot form a structure on their own; they must be part of an existing structure.

```
   2   5  7   11    16    21
 - --- -- ---- ----- ----- ----------------------------
|X|   |  |VLID|     |     |(DAMP=???,GAP=???)
 - --- -- ---- ----- ----- ----------------------------
    |  |   |           |    |
    |  |   |           |    |_(2)Mandatory parameters
    |  |   |           |
    |  |   |           |_(1)Group number
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) This is the group number that will be used for the lid elements. If there is more than one structure with a lid a different group must be used for each lid. If a group number is not specified a default value of 999 will be used.

(2) Lid Parameters

- DAMP: damping factor for the lid, typically between 0.0 and 0.2; 0 will give no effect, 0.2 will result in heavy damping of surface elevation at the elements.
- GAP: characteristic length for the lid. This will typically be the gap between two adjacent vessels or the smallest dimension of a moonpool. It is not used to define the size of the lid itself.



```
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |VLID|     |  135| (DAMP=0.02,GAP=10.0)
  - --- -- ---- ----- ----- ----------------------------
```

6.10. The ASYM Data Record - Axisymmetric Structure Generation

The ELM* data categories will now accept a new ASYM data record. This enables users to generate a structure whose elements are totally axi-symmetric by specifying line of nodes to define a 'profile' line.

- A 4-fold symmetrical structure is generated in a special order and has the effect of switching on X and Y symmetry i.e. as if the SYMX and SYMY data records have been input in Data Category 2.
- At this time only structures whose axi-symmetric axis is co-incident with the Z Fixed Reference Axis may be generated; in other words, generated nodes are rotated about this axis.
- Any number of ASYM data records may be used within the normal restrictions of the maximum number of nodes and elements.
- The maximum number of nodes in the profile line used in generating an axi-symmetric structure is 100.
- The elements generated will not necessarily produce a mesh with no modeling errors. To a large extent this will depend on the exact geometry of the profile line specified by the user. Note that with 64-fold symmetry the aspect ratio of elements next to the axis cannot be reduced to less than about 1 in 10 and for 2-fold, 1 in 5. This however should not produce significant errors.
- Aqwa-Line will automatically use a special N-fold symmetrical solution if all elements are generated by ASYM data records or the user inputs elements which obey the rule of axi-symmetrical element order. This special solution can be up to 2 orders of magnitude faster than even the 4-fold symmetrical solution. For a model with a TOTAL (in ALL quadrants) number of M diffracting elements and having X and Y symmetry, a structure will be solved as an N-fold (N=8,16,32,64) axi-symmetric structure automatically if the 1st set of M/N elements, when rotated by n*360/N degrees, produces the nth set of M/N elements within a tolerance of approximately (0.01m/0.03ft).

The input format is as follows:

```
      5  7          16    21
 - --- -- ---- - ---- ----- ------------------------
X|XXX|01|ASYM|X|DIFF|    1|(32)(111)(217)XXXXXXXXXXX
```

```
- --- -- ---- - ---- ----- -------------------------
      |  |       |      |   |    |    |
      |  |       |      |   |    |    |
      |  |       |      |   |    |    |_(7)Finish user node no.
      |  |       |      |   |    |         (MAX # nodes total = 100)
      |  |       |      |   |    |
      |  |       |      |   |    |_(6)Start user node no.
      |  |       |      |   |
      |  |       |      |   |_(5)No. of Axi-symmetric rotations 8,16,32,64
      |  |       |      |
      |  |       |      |_(4)Element Group Number
      |  |       |
      |  |       |
      |  |       |_(3)Diffracting - leave blank for non diffracting.
      |  |
      |  |_(2)Mandatory data record keyword.
      |
      |_(1)Optional User Identifier
```

(3) The above example generates diffracting elements. Leave this field blank for non-diffracting elements or elements above the water line.

(4) The element group that will be used for all elements generated by this data record. If 0 or blank is input then the group number will start from 1 and for each set of elements generated along the axis the group number will increment by 1. i.e. groups 1-32 will be generated if 32 is the number of axi-symmetric rotations.

(5) No. of Axi-symmetric rotations to produce a full 360 degree description of the structure. This is restricted to 8,16,32 and 64.

(6/7) The start/finish user node numbers of the line of nodes to be rotated. This defines the 'profile' line. For example:

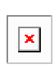
- if the start node is 111
- the finish node is 217
- and 8 nodes (111,211,113,213,115,215,117,217) exist in the coordinate data category

Then the total M, number of elements = (8-1)*32 will be generated. As 4-fold symmetry is mandatory, 56 elements will be produced in 1 quadrant.

In general, if the profile line has NN nodes in the list and N-fold symmetry is specified then M=(NN-1)*N.

The maximum number of nodes in a profile line is 100.

The following are restrictions on the node coordinates defining the profile line. Failure to comply will produce a fatal error:

- X coordinate must be positive (in other words,  0.0).
- Adjacent nodes cannot both have zero X coordinates.
- Y coordinates must be zero.
- Distance between adjacent nodes must not be too small.

- The profile line must not form a closed loop.

6.11. The ILID Data Record - Suppression of Irregular Frequencies

This data record is used to define a lid for suppression of irregular frequencies. The lid is modeled by horizontal diffracting elements that must be contained in a specified group. The elements may be defined by the user or they can be generated automatically by Aqwa.

Automatically Generated Lid

The data record shown below is used to request that the lid elements should be generated automatically. Note that the TOTAL number of elements must still be fewer than the maximum permitted, so the user must allow "space" for the lid when creating the model. The lid will be created at a z-coordinate defined on the ZLWL data record (The ZLWL Data Record - Waterline Height (p. 82)), which must also be included in Data Category 2.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ----------------------------
  |X|   |  |ILID| AUTO|     |(LID_SIZE=????,START_NODE=NNNNN)
   - --- -- ---- ----- ----- ----------------------------
      |  |   |     |     |    |
      |  |   |     |     |    |_(3)Optional parameters
      |  |   |     |     |
      |  |   |     |     |_(2)Group number
      |  |   |     |
      |  |   |     |_(1)Automatic lid generation
      |  |   |
      |  |   |_Compulsory Data Record Keyword (A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(1) This identifier specifies that the lid is to be generated automatically

(2) This is the group number that will be used for the lid elements. If there is more than one structure with a lid a different group must be used for each structure. If a group number is not specified a default value of 999 will be used.

(3) These optional parameters allow the user to specify the nominal size of the lid elements and the starting number for the nodes that will be generated. The default size of the lid elements will be based on the average size of elements in the model. If this results in the maximum allowable number of elements being slightly exceeded, the user may increase the size to reduce the total number of elements. The program will generate new node numbers starting from the last user-defined number. This parameter allows the user to specify a starting node for the lid nodes.

User-Defined Lid

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ----------------------------
  |X|   |  |ILID|     |     |
   - --- -- ---- ----- ----- ----------------------------
```

```
        |  |   |           |
        |  |   |           |_(1)Group number
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The lid elements must be put into a single group with this number. If there is more than one structure with a lid a different group must be used for each structure. If a group number is not specified a value of 999 will be assumed.

The user must then define a number of elements that should:

- be within the vessel
- have their normals pointing upwards (i.e. the nodes must be listed anti-clockwise when looking down on the elements)
- be at the still water surface

Except for the requirement that the centroids should be below the water surface, the usual modeling checks are still applied, and the TOTAL number of elements must still be fewer than the maximum permitted.

6.12. The ZLWL Data Record - Waterline Height

This data record allows the waterline height on a structure to be defined for an Aqwa-Line analysis. It can be thought of as the position of a line painted on the side of the structure. The hydrodynamic coefficients are calculated with the waterline at the specified position. Note that this data record does not change the definition position of the structure. In this respect the ZLWL data record is similar to the ZCGE data record in Data Category 7; indeed the two are related by ZLWL + ZCGE = CGPOS, where CGPOS is the position of the center of gravity when the structure is in the definition position.

The input format is as follows:

```
      5  7   11    16    21
- --- -- ---- ----- ----- --------
X|   |02|ZLWL|XXXXX|XXXXX| (HEIGHT)
- --- -- ---- ----- ----- --------
   |   |  |                    |
   |   |  |                    |
   |   |  |                    |_ (4)Columns 21-80. Free format data to
   |   |  |                          define waterline height.
   |   |  |
   |   |  |_(3)Mandatory data record keyword.
   |   |
   |   |_(2)Optional User Identifier.
   |
   |_(1)Compulsory END on Last Data Record in Data Category(A3)
```

(4) The position of the waterline is defined in the same axes as used to define the nodes in Data Category 1.

NOTES.

- If a ZLWL data record is used, the ZCGE data record in Data Category 7 is no longer required. An error message will be issued if a ZCGE data record is present and is not consistent with the ZLWL data record.
- If the ZCGE and ZLWL data records are both absent, the definition position based on the nodes in Data Category 1 will be used.
- This position is NOT USED as the starting position for an analysis using Aqwa-Librium, Fer, Drift or Naut. This must be specified in Data Category 15 or by using the RDEP option (see Administration and Calculation Options for the Aqwa Suite (p. 314)).

6.13. The SEAG Data Records - Creation of Wave Grid Pressures

This data record instructs Aqwa-Line to create a .PAG file containing pressures at wave grid points. This file is used by the AGS for plotting wave heights and pressures.

At present the grid size can only be specified from Ansys Workbench. When Aqwa-Line is run as a batch program or from the AGS it is not possible to input any values for the grid size.

```
   2   5  7   11         21
 - --- -- ---- ---------- ----------------------------------
|X|   |  |SEAG|XXXXXXXXXX| (NX, NY, Xmin, Xmax, Ymin, Ymax)
 - --- -- ---- ---------- ----------------------------------
    |  |   |                 |   |   |     |     |     |
    |  |   |                 |   |   |     |     |     |_(2)Max Y-coordinate of grid
    |  |   |                 |   |   |     |     |
    |  |   |                 |   |   |     |     |_(2)Min Y-coordinate of grid
    |  |   |                 |   |   |     |
    |  |   |                 |   |   |     |_(2)Max X-coordinate of grid
    |  |   |                 |   |   |
    |  |   |                 |   |   |_(2)Min X-coordinate of grid
    |  |   |                 |   |
    |  |   |                 |   |_(1)Number of Y grid points
    |  |   |                 |
    |  |   |                 |_(1)Number of X grid points
    |  |   |
    |  |   |_ Data Record Name(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) The first two parameters give the number of points, in the global X and Y directions, at which the wave pressures will be calculated. The limits are:

	X-direction	Y-direction
Minimum number of grid points	41	26
Maximum number of grid points	81	51
Default number of grid points	41	26

(2) The last four parameters give the X and Y limits of the grid over which the wave pressures will be calculated. These parameters cannot be set, and should be omitted, when Aqwa is run as a batch program or from the AGS.

6.14. Internal Tank Data Records

The internal tank hull surface is represented by triangular and/or quadrilateral panels.

The relevant nodes of the internal tank panels are defined in the Data Category 1 in the same manner as the other Aqwa node definitions.

You can configure multiple internal tanks associated with a structure. Each internal tank definition in the Data Category 2 starts with the ITNK data record (The ITNK Data Record – Internal Tank Definition Sub-Header (p. 84)) and ends with the FINI data record (The FINI Card – Internal Tank Separator (p. 87)). Up to 100 internal tanks per structure are allowed.

The LHFR - Calculate Low and High Frequency Hydrodynamic Properties (p. 316) option is switched on if an internal tank is defined.

6.14.1. The ITNK Data Record – Internal Tank Definition Sub-Header

This data record is used to define an internal tank associated with a structure.

It must be the first data record for defining an internal tank.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ----------------------------
  |X|   |  |ITNK|     |     |(PERM=???,ZTHT=???)
   - --- -- ---- ----- ----- ----------------------------
         |   |                |
         |   |                |_(3)Mandatory parameters
         |   |                     Columns 21-80, Free format data.
         |   |
         |   |_(2)Compulsory Data Record Keyword (A4)
         |
         |_(1)Optional User Identifier (A2)
```

(3) Internal tank parameters (free format data):

- PERM: Permeability of the internal tank, typically between 0.95 and 1.0. The default value is 1.0.
- ZTHT: Height of the internal tank liquid surface, measured in the FRA.

6.14.2. The TMAT Data Record – Internal Tank Material Properties

This data record is used to define the material properties of the internal tank.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ----------------------------
  |X|   |  |TMAT|     |     |(DENS=???, DAMP=???)
   - --- -- ---- ----- ----- ----------------------------
         |   |                |
         |   |                |_(3)Mandatory parameters
         |   |                     Columns 21-80, Free format data.
         |   |
         |   |_(2)Compulsory Data Record Keyword (A4)
         |
         |_(1)Optional User Identifier (A2)
```

(3) Internal tank material properties:

- DENS: liquid density.
- DAMP: non-dimensional damping factor, typically between 0.0 and 0.1; 0 will give no effect, 0.1 will result in heavy damping. The default value is 0.01.

6.14.3. Element Topology Data Record

```
      2   5  7   11    16    21        31        41
 - --- -- ---- ----- ----- ----------------------------
|X|   |  |TQPL|     | 80  |(10)(11,1)(12,1)(22,1)(21,1)
 - --- -- ---- ----- ----- ----------------------------
|X|   |  |TQPL|DIFF | 82  |(20)(101,1)(102,1)(152,1)(151,1)
 - --- -- ---- ----- ----- ----------------------------
|X|   |  |TTPL|     | 90  |(1)(1051,1)(1052,1)(1061,1)
 - --- -- ---- ----- ----- ----------------------------
|X|   |  |TTPL|DIFF | 92  |(1)(1151,1)(1152,1)(1161,1)
 - --- -- ---- ----- ----- ----------------------------
      |   |    |      |      |
      |   |    |      |      |
      |   |    |      |      |_ (4)Columns 21-80 free format data for
      |   |    |      |            generating node. Format(60A1)
      |   |    |      |
      |   |    |      |_(3)Element Group Number(I5)
      |   |    |
      |   |    |_(2) DIFF identifier
      |   |
      |   |_(1)Element Type(A4)
      |
      |_Optional User Identifier(A2)
```

(1) Two element types can be defined:

- TQPL: 4-nodes, internal tank quadrilateral panel.
- TTPL: 3-nodes, internal tank triangular panel.

(2) Two identifiers can be defined:

- (Blank): non-diffraction panel on the internal tank hull.
- DIFF : diffraction panel on the internal tank hull.

(3) The element group number associated with each element is used to divide the elements defining the structure into groups. The group number may be left blank if desired.

(4) Free Format data generation is achieved by specifying several bracketed sets of Topological variables in columns 21-80. See the descriptions in Element Topology Data Record (p. 68).

Note:

The normal direction of the tank hull surface panel must point inwards; in other words, the nodes defining TTPL and TQPL elements must be ordered in a counter-clockwise direction from the perspective of an observer inside the internal tank.

TTPL and TQPL elements which are below the still liquid surface in the Aqwa-Line analysis position must be denoted as diffracting elements by entering the identifier DIFF in columns 12 to 15.

For internal tanks that cross the still liquid surface, the top row of diffracting plate elements must have their top edges aligned with the still liquid line (the diffracting plates must not cross the still liquid surface).

6.14.4. TSMX AND TSMY Data Records - X and Y Symmetry

This data record may be used when the internal tank is symmetrical about the X or Y axis of the local tank axes(LTA)in the position defined by the element topology in this data category and the node coordinates input in Data Category 1.

```
      5  7   11    16    21
- --- -- ---- ----- ----- -----------
X|   |02|TSMX|XXXXX|XXXXX| (YREF=???)
- --- -- ---- ----- ----- -----------
       |  |                    |
       |  |                    |
       |  |                    |_ (3)Y reference.
       |  |
       |  |_(2)Mandatory data record keyword.
       |
       |_(1)Optional User Identifier.

      5  7   11    16    21
- --- -- ---- ----- ----- -----------
X|   |02|TSMY|XXXXX|XXXXX| (XREF=???)
- --- -- ---- ----- ----- -----------
       |  |                    |
       |  |                    |
       |  |                    |_ (3)X reference.
       |  |
       |  |_(2)Mandatory data record keyword.
       |
       |_(1)Optional User Identifier.
```

(3) Y/X reference is used to define the y-/x- coordinate of the LTA origin in the fixed reference axes. The tank is about Txz/Tyz plane symmetry.

Note:

If the yaw movement defined by the MSTR data record (see The MSTR Data Record - Move Structure (p. 77)) is not zero, the symmetry defined by these data records is automatically removed. Aqwa will generate new elements mirroring those already defined.

6.14.5. The TRMX/TRMY Data Records - Remove Internal Tank Symmetry

These data records allow the symmetry of an internal tank to be removed by instructing Aqwa to generate new elements mirroring those already defined. They apply to all elements in an ITNK data sub-category.

```
     5  7
- --- -- ---- ------
X|XXX|  |TRMX|XXXXX
- --- -- ---- ------
X|XXX|  |TRMY|XXXXX
- --- -- ---- ------

       |  |
       |  |
```

```
          |  |_(2)Symmetry Specification
          |
          |_(1)Optional user data category identifier
```

6.14.6. The TNAM Data Records - Internal Tank Name

An internal tank name can be optionally defined by this data record.

```
  2  5  7   11         21
- --- -- ---- ---------- ------------------
X|XXX|  |TNAM|XXXXXXXXXX|TANKNAME
- --- -- ---- ---------- ------------------
       |  |                   |
       |  |                   |
       |  |                   |_(3)Name of the internal tank (A60)
       |  |
       |  |_(2)Mandatory data record keyword
       |
       |_(1)Optional user data category identifier
```

6.14.7. The FINI Card – Internal Tank Separator

This data record is used to finish the definition of an internal tank when multiple internal tanks are defined.

```
 2   5  7
- --- -- ---- --
X|   |  |FINI|
- --- -- ---- --
   |  |   |
   |  |   |
   |  |   |_Compulsory Card Header(A4)
   |  |
   |  |_Optional User Identifier (A2)
   |
   |_Compulsory END on last card in deck (A3)
```

6.15. Moonpool Data Records

The multi-region matching approach is employed for moonpool hydrodynamic analysis. The moonpool hull surface, inside mean free surface and matching surface are represented by triangular and/or quadrilateral panels.

The relevant nodes of the moonpool panels are defined in the Node Number and Coordinates (Data Category 1) (p. 59) in the same manner of the other Aqwa node definition.

Multiple moonpools associated with a structure can be configurated. Each moonpool definition in the Element Topology - ELM* (Data Category 2) (p. 67) starts with The MOON Data Record—Moonpool Definition Sub-Header (p. 88) and finishes with The MFIN Card—Moonpool Separator (p. 91).

The **LHFR–Calculate Low and High Frequency Hydrodynamic Properties** option is switched on if a moonpool is defined.

6.15.1. The MOON Data Record—Moonpool Definition Sub-Header

This data record is used to define a moonpool associated to a structure. It must be the first data record for defining a moonpool.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ----------------------------
  |X|   |  |MOON|     |     |(DAMP=???,MODE=???)
   - --- -- ---- ----- ----- ----------------------------
         |   |                |
         |   |                |_(3)Mandatory parameters
         |   |                     Columns 21-80, Free format data.
         |   |
         |   |_(2)Compulsory Data Record Keyword (A4)
         |
         |_(1)Optional User Identifier (A2)
```

(3) Moonpool parameters

Free format data.

- **DAMP**: Damping factor in the moonpool free surface condition.
- **MODE**: Number of prescribed pressure modes. The value must be positive.

Note:

Aqwa can accept up to 10 moonpools associated with each structure. The maximum number of the pressure modes of a moonpool is 20. The actual total number of the prescribed pressure modes for all the moonpools associated with a structure may be automatically extended regarding to the symmetric types of moonpools. Further details are in Composite Source Distribution Method for Symmetric Moonpool Configuration.

6.15.2. The MNAM Data Record—Moonpool Name

The moonpool name can be optionally defined by this data record.

```
      2   5  7   11         21
    - --- -- ---- ---------- ------------------
   |X|XXX|  |MNAM|XXXXXXXXXX|MOONPOOL NAME
    - --- -- ---- ---------- ------------------
           |  |                  |
           |  |                  |
           |  |                  |_(3)Name of the moonpool (A60)
           |  |
           |  |_(2)Mandatory data record keyword
           |
           |_(1)Optional user data category identifier
```

6.15.3. The PMOD Data Record—Prescribed Pressure Mode Definition

This data record is used to define a prescribed pressure mode on the inside moonpool mean free surface. The center of the inside free surface area is (x_f, y_f), which is calculated automatically, based on the inside free surface panels.

```
   2   5  7   11    16    21
 - --- -- ---- ----- ----- -----------
|X|XXX|02|PMOD|MSHP |XXXXX|(MODX=???,MODY=???)
 - --- -- ---- ----- ----- ----------------
        |  |     |           |
        |  |     |           |_(4)Modal No. in X direction, n; Modal No. in Y direction, m.
        |  |     |
        |  |     |_(3)Modal Shape Function Identifier of Pressure
        |  |
        |  |_(2)Mandatory data record keyword.
        |
        |_(1)Optional User Identifier.
```

(3) Three types of pressure modal shapes are available. For further information, see Prescribed Oscillatory Pressure Distribution Approach.

Series of sine and cosine functions, four identifiers could be defined:

- **SNSN**: $\sin[\frac{n\pi}{l}(x-x_f)]\sin[\frac{m\pi}{b}(y-y_f)]$, $(n\neq 0,\ m\neq 0)$
- **SNCS**: $\sin[\frac{n\pi}{l}(x-x_f)]\cos[\frac{m\pi}{b}(y-y_f)]$, $(n\neq 0)$
- **CSSN**: $\cos[\frac{n\pi}{l}(x-x_f)]\sin[\frac{m\pi}{b}(y-y_f)]$, $(\ m\neq 0)$
- **CSCS**: $\cos[\frac{n\pi}{l}(x-x_f)]\cos[\frac{m\pi}{b}(y-y_f)]$

Series of Legendre polynomial functions:

- **LGPL**: $p_n(\frac{x-x_f}{l/2})p_m(\frac{y-y_f}{b/2})$

Series of Bessel functions for axisymmetric moonpool:

- **BESS**: $J_0(k_n r)$, $(0\leq n\leq 20)$

Note:

The value of MODE is greater than zero in the **MOON** data record and MODE data records of **PMOD** are expected to be input. Any combination of these three pressure modal shapes is permitted, but duplications should be avoided. MODY is not required for Bessel function BESS.

6.15.4. MSMX and MSMY Data Records—X and Y Symmetry

These data records may be used when the moonpool is symmetrical about the X or Y axis of the global reference axes (GRA) in the position defined by the element topology in this data category and the node coordinates input in Data Category 1.

```
       5  7
 - --- -- ----
|X|   |02|MSMX|
 - --- -- ----
        |  |
        |  |_(2)Mandatory data record keyword.
        |
```

```
        |_(1)Optional User Identifier.


       5  7
  - --- -- ----
 |X|   |02|MSMY|
  - --- -- ----
        |  |
        |  |_(2)Mandatory data record keyword.
        |
        |_(1)Optional User Identifier.
```

Note:

Elements on half or quadrant of moonpool surfaces are required to be input when one or both data records are defined. However, the symmetry of a moonpool will be aligned with the symmetric configuration of the associated structure. For example, if the associated structure's corresponding port-starboard and/or fore-aft symmetry are not activated, Aqwa will generate new moonpool elements by mirroring those already defined.

6.15.5. Element Topology Data Records of Moonpool Surfaces

```
   2   5  7   11    16    21        31        41
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MQPL|     | 80  |(10)(11,1)(12,1)(22,1)(21,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MQPL|DIFF | 82  |(20)(101,1)(102,1)(152,1)(151,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MQPL|FSUR | 84  |(15)(201,1)(202,1)(252,1)(251,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MQPL|MATC | 86  |(15)(301,1)(302,1)(352,1)(351,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MTPL|     | 90  |(1)(1051,1)(1052,1)(1061,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MTPL|DIFF | 92  |(1)(1151,1)(1152,1)(1161,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MTPL|FSUR | 94  |(1)(1251,1)(1252,1)(1261,1)
  - --- -- ---- ----- ----- ----------------------------
 |X|   |  |MTPL|MATC | 96  |(1)(1351,1)(1352,1)(1361,1)
  - --- -- ---- ----- ----- ----------------------------
       |   |    |      |      |
       |   |    |      |      |
       |   |    |      |      |_ (4)Columns 21-80 free format data for
       |   |    |      |             generating node. Format(60A1)
       |   |    |      |
       |   |    |      |_(3)Element Group Number(I5)
       |   |    |
       |   |    |_(2) DIFF/SURF/MATC identifier
       |   |
       |   |_(1)Element Type(A4)
       |
       |_Optional User Identifier(A2)
```

(1) Two element types can be defined:

- **MQPL**: 4-node moonpool surface quadrilateral panel.
- **MTPL**: 3-node moonpool surface triangular panel.

(2) Four identifiers can be defined:

- **(Blank)**: Non-diffraction panel on moonpool hull surface
- **DIFF**: Diffraction panel on moonpool hull surface
- **FSUR**: Panel on mean free surface inside moonpool
- **MATC**: Panel on matching surface between moonpool inside and outside fluid regions

(3) The element group number associated with each element is used to divide the elements defining the moonpool surface into groups. The group number may be left blank if desired.

(4) Free Format data generation is achieved by specifying several bracketed sets of topological variables in columns 21-80. See the descriptions in Element Topology Data Record (p. 68).

Note:

The normal directions of both the moonpool hull surface panel and the matching surface panel must point toward the fluid region in moonpool while the normal direction of the inside mean free surface panel points upwards.

6.15.6. The MFIN Card—Moonpool Separator

This data record is used to finish the definition of a moonpool.

```
 2   5  7
- --- -- ---- --
X|   |  |MFIN|
- --- -- ---- --
   |  |   |
   |  |   |
   |  |   |_Compulsory Card Header(A4)
   |  |
   |  |_Optional User Identifier (A2)
   |
   |_Compulsory END on last card in data category (A3)
```

Chapter 7: Material Properties - MATE (Data Category 3)

This Data Category is used to input the physical properties of materials associated with the elements input in Data Category 2. The properties are referred to as *material properties*. Material properties should be thought of as a table of values which are indexed by the material group numbers on the Element Topology Data Record (p. 68) (Data Category 2).

7.1. General Description

The parameters input within this Data Category are only referred to by the material group numbers on the Element Topology Data Record (p. 68) (Data Category 2).

The material properties set up by this Data Category are not specifically associated with any one structure (unless a STRC data record is defined within this data category) or any one element within that structure. This means that many elements may reference the same material group number and several structures may also reference the same group number.

7.2. Data Category Header

```
       5      11
 ---- -- ---- ----
|XXXX|  |XXXX|MATE|
 ---- -- ---- ----
      |        |
      |        |_Compulsory Data Category Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

7.3. Material Property Data Record

```
   2   5  7        16    21         31         41
 - --- -- --------- ----- ---------- ---------- ----------
|X|   |  |XXXXXXXXX|     |          |          |          |
 - --- -- --------- ----- ---------- ---------- ----------
    |  |             |       |__________|__________|
    |  |             |                  |_(2) Material Properties (F10.0)
    |  |             |
    |  |             |_(1)Material Group Number(I5)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last Data Record in Data Category.(A3)
```

(1) Material group number - This number is referred to in the Element Topology Data Record (Data Category 2) and is the index to the values given in columns 21-40 (2).

(2) Material property values. Material properties may, optionally, be divided into sets for each structure (see The STRC Data Record - Coordinate Structure Association (p. 62)). Any element whose material group number corresponds to that given in columns 16-20 (1) has these values associated with it. Details of the properties appropriate to each element type are given below.

Element Type	Property 1	Property 2	Property 3
T/QPPL	None	None	None
TUBE	Density	None	None
STUB	Mass/unit length	Y axis inertia/unit length	Z axis inertia/unit length
PMAS	Mass	None	None
TELM	Density	Young's Modulus	None
DISC	None	None	None

7.4. The STRC Data Record - Material Structure Association

If Coordinate Structure data records have been defined in the Coordinate data then these may also be used in defining material properties. The STRC (structure) data record enables the use of totally independent sets of material properties for each structure. In other words, the user material numbers may be the same for 2 different structures but they will be treated as separate items. If used then the material properties for all structures must be defined using STRC data records. If STRC is not utilized then all material property numbers must be unique across all structures.

The structure number has to be in columns 16-20 as shown below:

```
      5  7           16    21
- --- -- ---- ------ ----- ----
X XXX 01 STRC XXXXX     nn XXXXXX
- --- -- ---- ------ ----- ----
      |  |               |
      |  |               |
      |  |               |
      |  |               |_(3)Structure Number.
      |  |
      |  |_(2)Mandatory Keyword.
      |
      |_(1)Optional User Identifier
```

(3) The structure number must start from 1 on the 1st data record and increment by 1 for each structure data record input. The number of ELM* data categories must correspond to the number of structure data records.

Chapter 8: Geometric Properties - GEOM (Data Category 4)

8.1. General Description

This data category is used to input the physical geometry and parameters relating to the physical geometry of elements input in Data Category 2 and are referred to as GEOMETRIC PROPERTIES. Geometric properties should be thought of as a table of values which are indexed by the geometric group numbers on the Element Topology Data Record (p. 68) (Data Category 2).

The parameters input within this data category are only referred to by the geometric group numbers on the Element Topology Data Record (p. 68) (Data Category 2).

Each entry in the geometric properties table defined within this data category is associated only with a particular element type but is not specifically associated with any one structure (unless a STRC data record is defined within this data category). This means that many elements, *provided they are the same type*, may reference the same geometric group number and several structures may also reference the same group number.

8.2. Data Category Header

```
          5      11
     ---- -- ---- ----
    |XXXX|  |XXXX|GEOM|
     ---- -- ---- ----
          |        |
          |        |_Compulsory Keyword(A4)
          |
          |_Optional User Identifier(A2)
```

8.3. Geometric Property Data Record

Required for all elements having geometric properties.

```
      2   5  7   11    16    21        31        41
    - --- -- ---- ----- ----- --------- --------- --------
   |X|   |  |    |XXXXX|     |         |         |        ...
    - --- -- ---- ----- ----- --------- --------- --------
       |  |   |           |      |          |         |
       |  |   |           |      |-----------------------
       |  |   |           |      |
       |  |   |           |      |_(3)6 Geometric parameters (6F10.0)
       |  |   |           |
       |  |   |           |
       |  |   |           |_(2)Geometric Group Number(I5)
       |  |   |
       |  |   |_(1)ELEMENT Type(A4)
       |  |
```

```
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category (A3)
```

Continuation Data Record - Only required for Morison elements. It may be omitted if the appropriate default values are required (see (4) and (5) below).

```
       2   5                  21        31
     - --- -- ---- ---------- ---------- ---------
    |X|   |  |CONT|XXXXXXXXXX|          |         |
     - --- -- ---- ---------- ---------- ---------
        |  |   |                  |         |
        |  |   |                  |      (5)Added Mass Coefficient(F10.0)
        |  |   |                  |
        |  |   |            (4)Viscous Drag Coefficient(F10.0)
        |  |   |
        |  |   |_Indicates Continuation of above Data Record(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last daa record in data category (A3)
```

(1) The Element Type (always four characters) provides the classification for a particular element. This must correspond to the element type which references the geometric group number on the Element Topology Data Record in Data Category 2. Valid codes for element types in this data category are TUBE, STUB, DISC and PMAS.

Note:

QPPL, TPPL and PBOY do not have any geometric properties.

(2) Geometric group number - This number is referred to in the Element Topology Data Record (Data Category 2) and is the index to the values given in columns 21-70 (2).

(3) Geometric parameters - Any element on any structure whose geometric group number corresponds to that given in columns 16-20 (2) has up to 6 of these values associated with it. A summary of the properties appropriate to each element is shown below. (Units are consistent with the physical quantity defined by each parameter.)

(4)/(5) Viscous drag/added mass coefficient associated with elements having hydrodynamic properties in the Morison regime. If the continuation data record is omitted, or if either field is left blank, or if zero value is input, default values are used for the appropriate element type. These values are shown below in Columns 7 and 8.

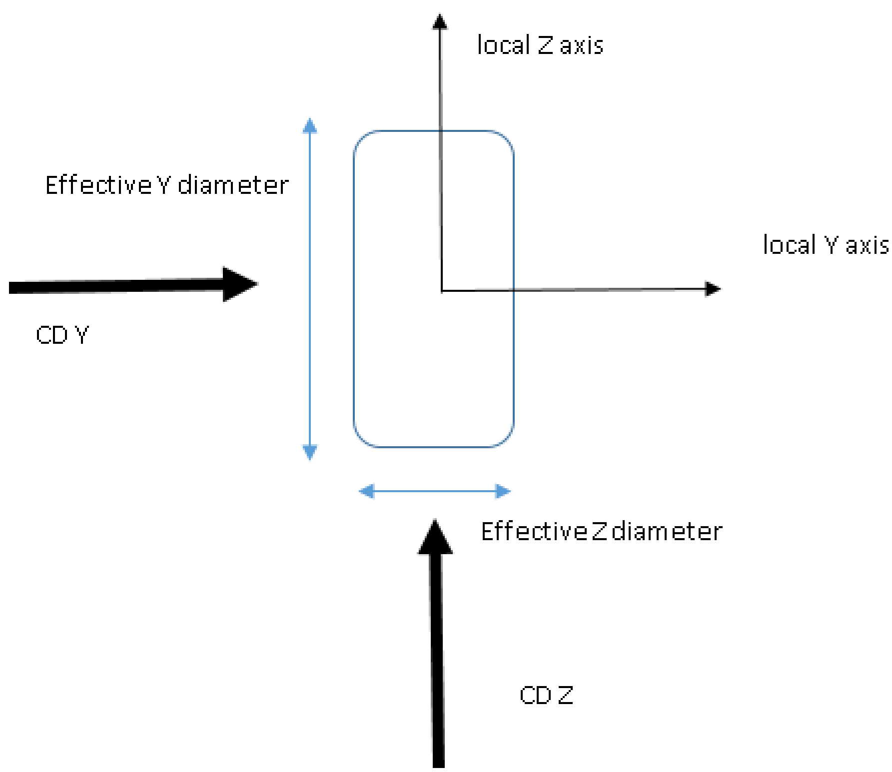
Element Type	Basic Data Record						Continuation	
	1	2	3	4	5	6	7	8
TUBE	Diameter	Thickness	0. Sealed 1. Open	Cut 1	Cut 2	X-direction drag coefficient Cd X (4)	Translational drag coefficient Cd (4)	Translational added mass coefficient Ca (4)
STUB	Effective diameter	Effective diameter	Area	Y-direction drag	Y-direction added	X-direction drag	Z-direction drag	Z-direction added mass

Element Type	Basic Data Record						Continuation	
	1	2	3	4	5	6	7	8
	normal to Y-direction (2)	normal to Z-direction (1,2)		coefficient Cd Y (2,4)	mass coefficient Ca Y (4)	coefficient Cd X (4)	coefficient Cd Z (2)	coefficient Ca Z (4)
PMAS	Ixx	Ixy	Ixz	Iyy	Iyz	Izz		
DISC	Diameter						Cd (3,4)	Ca (3,4)

1. If omitted or set to zero, defaults to value 1 (effective diameter normal to Y-direction).

   The Z-direction is defined by the third node in the element definition (data category 2 (p. 67)).

2. The following figure describes the geometry for the slender tube element:



3. See Properties of Typical Morison Elements in the *Aqwa Theory Manual* to see how these coefficients are used within the program.

4. If omitted, the default values of the coefficients of the Morison elements are as below:

TUBE	Cd X = 0.016	Cd = 0.75	Ca = 1.0
STUB	Cd X = 0.016		
DISC		Cd = 1.14	Ca = 1.0

The slender tube's default values are estimated based on the tube's geometry, Cd Z = Cd Y and Ca Z = Ca Y.

8.4. The STRC Data Record - Geometry Structure Association

If Coordinate Structure data records have been defined in the Coordinate data then these may also be used in defining material properties. The STRC (structure) data record enables the use of totally independent sets of geometric properties for each structure. In other words, the user geometry numbers may be the same for 2 different structures but they will be treated as separate items. If used then the geometric properties for all structures must be defined using STRC data records. If STRC is not utilized then all geometric property numbers must be unique across all structures.

The structure number has to be in columns 16-20 as shown below:

```
      5  7           16    21
- --- -- ---- ------ ----- ----
X XXX 01 STRC XXXXX     nn XXXXXX
- --- -- ---- ------ ----- ----
      |  |               |
      |  |               |
      |  |               |
      |  |               |_(3)Structure Number.
      |  |
      |  |_(2)Mandatory Keyword.
      |
      |_(1)Optional User Identifier
```

(3) The structure number must start from 1 on the 1st data record and increment by 1 for each structure data record input. The number of ELM* data categories must correspond to the number of structure data records.

Chapter 9: Constant Parameters - GLOB (Data Category 5)

9.1. General Description

This data category is used to input the environmental parameters which are normally constant throughout the analysis of a structure. These parameters include the Acceleration Due to Gravity and the Depth and Density of the water. It is not intended to imply that the user cannot change the depth of water on every single run of the program if he wishes to do so, only that these parameters are classified by the fact that they normally remain constant.

All data records are optional in this data category. Enter NONE for the data category keyword if no data records are input. Please note that the default values for the parameters in this data category are effectively in SI units. This means that if the user is working in a set of units other than SI, he will have to explicitly input all three parameters.

9.2. Data Category Header

```
        5      11
  ---- -- ---- ----
 |XXXX|  |XXXX|GLOB|
  ---- -- ---- ----
       |        |
       |        |_Compulsory Keyword(A4)
       |
       |_Optional User Identifier(A2)
```

Note: If data records denoted (Optional) are omitted, the program will produce the appropriate default value shown for each parameter.

9.3. The DPTH Data Record (Optional) - Water Depth

```
    2   5  7   11
 - --- -- ---- ----------
|X|   |  |DPTH|          |
 - --- -- ---- ----------
    |  |   |        |
    |  |   |        |_(1)Water Depth(F10.0)
    |  |   |             (Default Value 1000.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last data record in data category(A3)
```

(1) Note that the water depth is fundamental to the calculation of all wave properties.

9.4. The DENS Data Record (Optional) - Water Density

```
   2   5  7   11
 - --- -- ---- ----------
|X|   |  |DENS|          |
 - --- -- ---- ----------
    |  |   |        |
    |  |   |        |_Density of Water(F10.0)
    |  |   |          (Default Value 1025.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last data record in data category(A3)
```

9.5. The ACCG Data Record (Optional) - Acceleration Due to Gravity

```
   2   5  7   11
 - --- -- ---- ----------
|X|   |  |ACCG|          |
 - --- -- ---- ----------
    |  |   |        |
    |  |   |        |_(1)Acceleration Due to Gravity(F10.0)
    |  |   |             (Default Value 9.81)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last data record in data category(A3)
```

Chapter 10: Frequency and Directions Table - FDR* (Data Category 6)

When entering FDR data categories, the * indicates the structure number; for example, enter FDR1 for Structure 1, FDR2 for Structure 2, ... FD50 for Structure 50.

See Database Import (p. 114) for examples showing the import of data from an existing Aqwa-Line database.

10.1. General Description

This data category is used to input the frequencies and directions at which the values of the hydrodynamic parameters in the equations of motion of large floating structures are to be computed, or to access existing information from a previous analysis. Values of added mass, and radiation damping are associated with each frequency. Values of diffraction forces, Froude Krylov forces and Response Amplitude Operators (RAO) are associated with each frequency and with each direction.

Rules Governing Input of Frequencies/Periods

The frequencies and values of the radiation/diffraction analysis parameters are naturally of fundamental importance to all analyses of the motions of a large floating structures. Unfortunately maximum flexibility in specifying these parameters usually results in errors which can go undetected right through the analysis procedure. The format of input of these parameters is designed to avoid the errors whilst retaining this flexibility which is considered essential to the accurate modeling of a structure in such a complex environment.

The following rules and manner in which the frequencies/periods are input at first may appear complicated just to specify a single series of ascending/descending values. However, the user will rapidly become aware of value of the rules with both simple analysis procedures and use of the more advanced facilities of the program.

(a) Frequency/period numbers must be unique.

(b) There must be no 'gaps' in frequency/period numbers when all data records in this data category have been input, e.g. if a total of five frequencies/periods are input then these must be numbered 1 through 5.

(c) Frequencies/periods must be distinct and unique.

(d) When all data records in this data category have been input, ascending numbers must correspond to ascending frequency values, or, if periods are input, to descending period values.

10.2. Data Category Header

```
                       -(Indicates Structure Number)
                      |
        5      11     |
    ---- -- ---- ----
   |XXXX|  |XXXX|FDR1|
    ---- -- ---- ----
         |        |
         |        |_Compulsory Data Category Keyword(A4)
         |
         |_Optional User Identifier(A2)
```

10.3. The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Hydrodynamic Parameters are Computed

```
    2   5  7    11    16    21        31        41        51        61
   - --- -- ---- ----- ----- --------- --------- --------- --------- ---
  |X|   |  |FREQ|     |     |         |         |         |         |   ...
   - --- -- ---- ----- ----- --------- --------- --------- --------- ---
  |X|   |  |PERD|     |     |         |         |         |         |   ...
   - --- -- ---- ----- ----- --------- --------- --------- --------- ---
  |X|   |  |HRTZ|     |     |         |         |         |         |   ...
   - --- -- ---- ----- ----- --------- --------- --------- --------- ---
      |  |   |     |     |       |         |         |         |
      |  |   |     |     |       |------------------------------------
      |  |   |     |     |       |
      |  |   |     |     |       |_(4)-(9)Up to 6 Values of Frequency/Period
      |  |   |     |     |               (FREQ=radians/sec) (PERD=seconds)
      |  |   |     |     |               (HRTZ=hertz)(6F10.0)
      |  |   |     |     |
      |  |   |     |     |_(3)Terminal Frequency/Period Number (I5)
      |  |   |     |
      |  |   |     |_(2)Initial Frequency/Period Number(I5)
      |  |   |
      |  |   |_(1)Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category (A3)
```

(1) The data record keyword defines the units used for the values in columns 21-80, as follows.

- FREQ - frequencies defined in radians/sec
- HRTZ - frequencies defined in hertz
- PERD - periods defined in seconds

(2)-(3) These are the frequency/period numbers associated with the values in columns 21-80. These numbers must be used in subsequent data categories when referring to the frequency values where they are used to cross check the data input. The initial number refers to the first value input (columns 21-30) and the terminal number refers to the last value input. If the initial number is zero or blank the program will generate frequencies automatically - see below.

If the Frequency/Period Values Correspond to Numbers	Initial Number	Terminal Number
1, 2, 3, 4, 5, 6	1	6
4, 5, 6, 7	4	7
3	3	3

(4)-(9) These are the values of frequency/period at which the hydrodynamic parameters are to be calculated or input (Data Categories 7 and 8). Note that when fewer than six values are input the extra fields on the data record are ignored. These values are associated with the numbers defined in columns 11-20.

Rules Governing Input of Frequencies

(a) Frequency numbers must be unique.

(b) There must be no 'gaps' in frequency numbers; for example, if five frequencies are input they must be numbered from 1 to 5.

(c) Frequencies must be input in ascending order. Periods must be input in descending order.

(d) Although more than one frequency data record can be used, the total number of frequencies cannot exceed 100.

(e) The minimum frequency is $0.001 \cdot \max\left\{1, \sqrt{\frac{g}{d}}\right\}$ rad/s, where g = gravitational acceleration, d = water depth.

(f) If it is intended to carry out an analysis using convolution in Aqwa-Drift or Aqwa-Naut the frequency range in the preceding Aqwa-Line run should be wide enough to ensure the accuracy of the radiation force calculation. Aqwa will give a warning if the range is not wide enough. The required range depends on the size of the structure, as shown in the table below. Structure size is the maximum overall dimension of the diffracting part of the structure.

Structure Size (m)	Minimum Frequency (rad/s)	Maximum Frequency (rad/s)
$\leq$ 1.0	$\leq$ 2.5	$\geq$ 5.0
2.0	$\leq$ 1.651	$\geq$ 3.302
5.0	$\leq$ 0.898	$\geq$ 1.796
10.0	$\leq$ 0.518	$\geq$ 1.037
$\geq$ 20.0	$\leq$ 0.250	$\geq$ 0.500

Examples

These two data records define 9 frequencies, numbered from 1 to 9, with values from from 0.2 rad/s to 1.0 rad/s

```
 - --- -- ---- ----- ----- --------- --------- --------- --------- ---------- ----------
| |   |  |FREQ|    1|    6|      0.2|      0.3|      0.4|      0.5|       0.6|       0.7|
| |   |  |FREQ|    7|    9|      0.8|      0.9|      1.0|         |          |          |
 - --- -- ---- ----- ----- --------- --------- --------- --------- ---------- ----------
```

Frequency Generation

Automatic generation of frequencies is specified by setting the 1st frequency number to 0 (or blank). Aqwa will then generate frequencies numbered from the previous frequency to the final frequency number on the data record. The generated frequencies will be equally spaced between the first and last frequencies on the data record.

This data record will generate 20 frequencies numbered from 1 to 20, equally spaced between 0.1 and 1.8 hertz.

```
 - --- -- ---- ----- ----- --------- ---------
| |   |  |HRTZ|    0|   20|      0.1|      1.8|
 - --- -- ---- ----- ----- --------- ---------
```

These data records will generate 5 frequencies numbered from 1 to 5, equally spaced between 0.1 and 0.5 rad/s, followed by 10 frequencies numbered from 6 to 15, equally spaced between 0.55 and 1.0 rad/s.

```
 - --- -- ---- ----- ----- --------- ---------
| |   |  |FREQ|    0|    5|     0.10|     0.50|
| |   |  |FREQ|    0|   15|     0.55|     1.00|
 - --- -- ---- ----- ----- --------- ---------
```

10.4. The DIRN Data Record - Directions at which the Hydrodynamic Parameters are Computed

```
   2   5  7   11    16    21        31        41
 - --- -- ---- ----- ----- --------- --------- ------
|X|   |  |DIRN|     |     |         |         |      ...
 - --- -- ---- ----- ----- --------- --------- ------
    |  |   |     |     |       |         |         |
    |  |   |     |     |       |----------------------
    |  |   |     |     |       |
    |  |   |     |     |       |_(3)-(8)Up to 6 Values of Direction(6F10.0)(DEGREES)
    |  |   |     |     |
    |  |   |     |     |
    |  |   |     |     |_(2)Terminal Direction Number(I5)
    |  |   |     |
    |  |   |     |_(1)Initial Direction Number(I5)
    |  |   |
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1)-(2) These are the direction numbers associated with the values in columns 21-80. These numbers must be used in subsequent data categories when referring to the direction values where they are used to cross check the data input. The first number refers to the first value input (columns 21-30) and the second number refers to the last value input. If the first number is zero or blank the program will generate directions automatically - see below.

(3)-(8) These are the values of direction at which the hydrodynamic parameters (Data Categories 7 and 8) are to be calculated. They are also the default directions at which the hull drag coefficients (Data Category 10) are to be input. These values are associated with the numbers defined in columns 11-20 (see parameters (3)-(8) in The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Hydrodynamic Parameters are Computed (p. 102)).

Rules Governing Input of Directions

(a) Direction numbers must be unique.

(b) There must be no 'gaps' in direction numbers, e.g. if five directions are input then these must be numbered 1 through 5.

(c) Directions must be distinct and unique.

(d) If no symmetry is defined, direction values must be input for the directions from -180° to +180°.

If SYMX is specified, direction values must be input for the directions from -180° to 0° or from 0° to +180°.

If SYMY is specified, direction values must be input for the directions from -90° to +90°.

If both SYMX and SYMY are specified, direction values must be input for one 90° quadrant.

(e) When all data records in this data category have been input, ascending numbers must correspond to ascending direction values.

(f) Although more than one direction data record can be used, the total number of directions cannot exceed 41. 41 directions can be input when there is no symmetry, 21 directions can be input when there is one plane of symmetry, and 11 directions when there are two symmetry planes.

(g) The interval between two adjacent wave directions is recommended to be less than or equal to 90° for any non-forward speed case.

Examples

These two data records define 9 directions, numbered from 1 to 9, with values from -180° to 0°.

```
 - --- -- ---- ----- ----- --------- --------- --------- --------- ---------- ----------
| |   |  |DIRN|    1|    5|   -180.0|   -157.5|   -135.0|   -112.5|     -90.0|          |
| |   |  |DIRN|    6|    9|    -67.5|    -45.0|    -22.5|      0.0|          |          |
 - --- -- ---- ----- ----- --------- --------- --------- --------- ---------- ----------
```

Direction Generation

Automatic generation of directions is specified by setting the 1st direction number to 0 (or blank). Aqwa will then generate directions numbered from the previous direction to the final direction number on the data record. The generated directions will be equally spaced between the first and last directions on the data record.

This data record will generate 21 directions numbered from 1 to 21, equally spaced between 0.0° and 180°.

```
 - --- -- ---- ----- ----- --------- ---------
| |   |  |DIRN|    0|   21|      0.0|    180.0|
 - --- -- ---- ----- ----- --------- ---------
```

These data records will generate 5 directions numbered from 1 to 5, equally spaced between 0 and 40°, followed bya single direction at 45°, followed by 5 more directions numbered from 7 to 11, equally spaced between 50 and 90°.

```
 - --- -- ---- ----- ----- --------- ---------
| |   |  |DIRN|    0|    5|      0.0|     40.0|
| |   |  |DIRN|    6|    6|     45.0|         |
| |   |  |DIRN|    0|   11|     50.0|     90.0|
 - --- -- ---- ----- ----- --------- ---------
```

10.5. The MVEF Data Record - Move Existing Frequency Parameters

This Data Record Has Been Withdrawn. The description is retained for backwards compatibility.

This data record is used to move the position of an existing frequency/period and its associated parameters within data read (from a backing file) from a previous run, in order to specify an additional frequency, (with a FREQ/PERD/HRTZ data record), which would otherwise violate rule (d) in The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Hydrodynamic Parameters are Computed (p. 102).

If periods are input, read period for frequency in this section.

Note that the MVEF data record relates only the structure indicated by the data category keyword.

```
   2   5  7   11    16
 - --- -- ---- ----- -----
|X|   |  |MVEF|     |     |
 - --- -- ---- ----- -----
    |  |   |     |     |
    |  |   |     |     |_(2)Number of Destination Position of Frequency and Parameters(I5)
    |  |   |     |
    |  |   |     |
    |  |   |     |_(1)Number of Frequency and Parameters to be Moved(I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The value of the frequency and frequency-dependent parameters associated with this number are moved from their existing position to the position specified in columns 16-20, leaving a position in the range of frequencies whose value of frequency is undefined. An additional frequency may subsequently be input using a FREQ data record to specify the value of the frequency at the position corresponding to this frequency number.

(2) This is the number of the position to which the value of frequency and frequency- dependent parameters (associated with the number specified in columns 11-15) are to be moved.

Rules for Using the MVEF data record

(a) Both frequency numbers must lie in the range 1 through 100 (the maximum number of frequencies) inclusive.

(b) The frequency and parameters to be moved must exist (i.e. they must have been read in from the backing file).

(c) The frequency and parameters must not already exist in the position to which they are to be moved.

(d) When all data records are input for this data category the frequency numbers and values must not violate rules (b) and (d) in The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Hydrodynamic Parameters are Computed (p. 102).

Examples Using the MVEF Data Record

A backing file exists from a previous Aqwa-Line run with:

```
                              ----------------------------------
                             |   Example 1   |    Example 2      |
                             |               |                   |
                             |---------------+-------------------|
                             |  1  2  3  4  5|  1  2  3  4  5  6 |
                             |               |                   |
         --------------------+---------------+-------------------|
        |Existing frequency  | .3 .4 .7 .9   | .3 .5 .8 .9       |
        |values of           |               |                   |
        |--------------------+---------------+-------------------|
        |with parameters     |  D  D  D  D   |  D  D  D  D       |
        |(D=Defined)         |               |                   |
        |--------------------+---------------+-------------------|
        |To insert frequency | .8            |  .6 .7            |
        |value(s) of         |               |                   |
        |--------------------+---------------+-------------------|
        |Use the MVEF data   |           4  5|        3     5    |
        |record with         |               |           4     6 |
        |parameters (1) and  |               |                   |
        |(2), giving         |               |                   |
        |--------------------+---------------+-------------------|
        |frequency values of | .3 .4 .7 UN .9| .3 .4 UN UN .7 .9 |
        |(UN=Undefined)      |               |                   |
        |--------------------+---------------+-------------------|
        |with parameters     |  D  D  D UN  D|  D  D UN UN  D  D |
        |                    |               |                   |
        |--------------------+---------------+-------------------|
        |Then FREQ           |           4   |        3  4       |
        |data record with    |               |                   |
        |parameters(2)/(1)(2)|               |                   |
        |--------------------+---------------+-------------------|
        |with frequency value|          .8   |       .6 .7       |
        |Ex 1 (3)/Ex 2 (3)(4)|               |                   |
        |--------------------+---------------+-------------------|
        |Resulting frequency | .3 .4 .7 .8 .9| .3 .4 .6 .7 .8 .9 |
        |values are          |               |                   |
        |--------------------+---------------+-------------------|
        |with parameters     |  D  D  D UN  D|  D  D UN UN  D  D |
        |                    |               |                   |
         --------------------------------------------------------
```

The parameters indicated as 'UN' (undefined) are then calculated (Aqwa-Line only) or expected as input in Data Categories 7 and 8. Note that if a frequency of 1.0 was required to be input, a FREQ data record with frequency number 5 and this frequency value is valid WITHOUT a preceding MVEF data record.

10.6. The DELF Data Record - Delete Frequency Parameters

This Data Record Has Been Withdrawn. The description is retained for backwards compatibility.

This data record is used to delete an existing frequency/period and its associated parameters, within data read from a backing file, from a previous run, in order to specify an additional frequency (with a FREQ/PERD/HRTZ data record), or to move/copy other parameters to this position (with a MVEF/CPYF/CPYP/CPYH data record), which would otherwise violate rules (c) or (d) in The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Hydrodynamic Parameters are Computed (p. 102).

If periods are input, read period for frequency in this section.

Note:

The DELF data record relates only to the structure indicated by the data category keyword.

```
    2   5  7   11    16
  - --- -- ---- ----- -----
 |X|   |  |DELF|XXXXX|     |
  - --- -- ---- ----- -----
     |  |   |           |
     |  |   |           |
     |  |   |           |_Number of Frequency and Associated
     |  |   |             Parameters which are to be Deleted(I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on Last Data Record in Data Category(A3)
```

Rules for Using the DELF Data Record

(a) The frequency number must lie in the range 1 through 100 (the maximum number of frequencies) inclusive.

(b) The frequency and parameters to be deleted must exist (i.e. they must have been read in from the backing file).

(c) The frequency should not be the ONLY existing frequency, as the directions associated with this frequency and structure then become undefined. The directions must then be redefined using a DIRN data record.

Note:

Redefinition of a different range of directions will cause an ERROR, if Data Category 10 is used to input direction-dependent parameters based on the ORIGINAL range of directions which became undefined. A warning message is therefore output if the only existing frequency is deleted.

10.7. The CSTR Data Record - Copying Existing Hydrodynamic Parameters for a Specific Structure Number

This data record is used to change the structure number from which parameters are to be copied, using a FREQ/PERD/HRTZ or CPYS, CPDB data record (see below). This structure number remains operative until another CSTR data record is input.

```
      2   5  7   11
    - --- -- ---- -----
   |X|   |  |CSTR|     |
    - --- -- ---- -----
       |  |   |     |
       |  |   |     |
       |  |   |     |_Structure number from which the frequency and
       |  |   |       associated parameters are to be copied(I5)
       |  |   |
       |  |   |_Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on Last data record in data category(A3)
```

See Database Import (p. 114) for examples showing the import of data from an existing Aqwa-Line database.

10.8. The FILE Data Record - Copying Existing Hydrodynamic Parameters from an External File

This data record is used to define a file name from which the database is to be copied using a CPDB data record, or to change the file unit from which parameters are to be copied, using a FREQ/PERD/HRTZ or CPYS data record (see below). This file name or unit remains operative until another FILE data record is input.

See Database Import (p. 114) for examples showing the import of data from an existing Aqwa-Line database.

```
      2   5  7   11    16    21
    - --- -- ---- ----- ----- ---------
   |X|   |  |FILE|     |XXXXX|
    - --- -- ---- ----- ----- ---------
       |  |   |     |            |
       |  |   |     |            |_(2)Filename from which the database
       |  |   |     |                 is to be copied
       |  |   |     |
       |  |   |     |
       |  |   |     |_(1)(Optional) Number of file unit from which the
       |  |   |            frequency and associated parameters
       |  |   |            are to be copied(I5)
       |  |   |
       |  |   |_Compulsory data record keyword(A4)
       |  |
       |  |_Optional user identifier(A2)
       |
       |_Compulsory END on last data record in data category(A3)
```

(1) This may be any of the numbers assigned to Aqwa scratch files. See Section 9 entitled “Running the Program” in each of the Aqwa program manuals, for the FORTRAN units which are valid on computer installations.

(2) This is a file name, usually a *.HYD file from a previous Aqwa-Line analysis, whose database is to be copied.

Note:

It is preferable to use option (2) in conjunction with the CSTR data record (The CSTR Data Record - Copying Existing Hydrodynamic Parameters for a Specific Structure Number (p. 109)) and the CPDB data record (The CPDB Data Record - Copy Existing Hydrodynamic Data Base (p. 112)). In this case, option (1), the file unit number, is not required.

10.9. The CPYF/CPYP/CPYH Data Records - Copy Frequency Parameters

The new user is advised to ignore this facility

This data record is used to copy existing frequency dependent parameters within data read from a backing file, from a previous run, in order to duplicate these values in a position in the frequency range for the structure indicated by the data category keyword. If a CSTR and/or FILE data record precedes, then this data record will copy the parameters from a structure and/or file different from the structure indicated on the data category keyword.

```
    2   5  7   11    16    21
  - --- -- ---- ----- ----- ---------
 |X|   |  |CPYF|     |     |         |
  - --- -- ---- ----- ----- ---------
 |X|   |  |CPYP|     |     |         |
  - --- -- ---- ----- ----- ---------
 |X|   |  |CPYH|     |     |         |
  - --- -- ---- ----- ----- ---------
     |  |   |     |     |       |
     |  |   |     |     |       |_(3)Frequency/Period (default=original F/P)
     |  |   |     |     |            CPYF=radians/sec
     |  |   |     |     |            CPYP=seconds
     |  |   |     |     |            CPYH=hertz(6F10.0)
     |  |   |     |     |
     |  |   |     |     |_(2)Number of Destination Position of Parameters(I5)
     |  |   |     |
     |  |   |     |_(1)Number of Frequency and Parameters to be Copied(I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on Last data record in data category(A3)
```

(1) The value of the frequency-dependent parameters associated with this number within the structure and backing file specified on the preceding CSTR and FILE data record, are to be copied to the position specified in columns 16-20, within the structure indicated by the data category keyword. These parameters are referred to as those within the source file. Note that if there is no preceding CSTR or FILE data record then the structure number will default to the structure indicated on the data category keyword and the default file will be the hydrodynamics database (.HYD) file. (See Chapter 9 of the user manuals).

(2) This is the number of the position to which the frequency-dependent parameters (associated with the number specified in columns 11-15) are copied. This position is ALWAYS with reference to the range of frequencies associated with the structure number indicated on the data category keyword. These parameters are referred to as those within the DESTINATION file.

(3) This is value of the frequency/period of the newly created position and parameters (associated with the number specified in columns 16-20) to be copied. If this field is left blank, or zero is input, the default value will be the same as that of the position copied.

Note:

These data records are not valid for a structure with forward speed in multiple wave directions.

Rules for Using the CPYF/CPYP/CPYH Data Records

(a) Both frequency numbers must lie in the range 1 through 100 (the maximum number of frequencies) inclusive.

(b) The frequency and parameters to be copied must exist in the source file (i.e. they must have been read in from the backing file).

(c) The frequency and parameters must NOT already exist in the DESTINATION file.

(d) When all data records are input for this data category, the frequency numbers and values must not violate rules (b) and (d) in The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Hydrodynamic Parameters are Computed (p. 102).

(e) The number and value of the directions in the source file must be the same as those in the DESTINATION file. See also rule (c) in The DELF Data Record - Delete Frequency Parameters (p. 107).

Parameters in the source File on the CPYF/CPYP/CPYH data records

It is important to note that the source file remains unaltered throughout the processing of this data category. Thus frequencies and their corresponding parameters created or deleted by use of the MVEF, DELF, CPYF/P/H or CPYS data records will not be contained in the source file (if this is also the destination file) until the next data category is encountered. In addition, parameters contained in the files specified on the FILE data record remain unaltered throughout the processing of all data categories.

Examples Using the CPYF/CPYP/CPYH Data Records

```
                             ----------------------------
                            |   Example 1    | Example 2  |
                     -------+----------------+------------|
                    |  1  2 |  1  2  3  4  5|  1  2  3    |
                    |       |               |             |
 --------------------+-------+---------------+------------|
|Backing file(s) from| SOURCE|  DESTINATION  | DESTINATION|
|AQWA-LINE exist with|  File |     File      |    File    |
|--------------------+-------+---------------+------------|
|existing frequency  | .6 .7 | .5 .8 .9      | .5 .8 .9   |
|values of           |       |               |            |
|--------------------+-------+---------------+------------|
|with parameters     |  D  D |  D  D  D      |  D  D  D   |
|(D=Defined)         |       |               |            |
|--------------------+-------+---------------+------------|
```

```
        |To copy parameters  |  1  2 |               |            |
        |from positions      |       |               |            |
        |--------------------+-------+---------------+------------|
        |to positions        |       |     2  3      |     2  3   |
        |                    |       |               |            |
        |--------------------+-------+---------------+------------|
        |Use MVEF/DELF data  |       |     2     4   |     2      |
        |record with         |       |        3     5|        3   |
        |parameters for      |       |               |            |
        |Ex 1 (1)(2)/Ex 2 (2)|       | (using MVEF)  |(using DELF)|
        |--------------------+-------+---------------+------------|
        |and frequency values| .6 .7 | .5 UN UN .8 .9| .5 UN UN   |
        |(UN=Undefined), with|       |               |            |
        |--------------------+-------+---------------+------------|
        |resulting parameters|  D  D |  D UN UN  D  D|  D UN UN   |
        |                    |       |               |            |
        |--------------------+-------+---------------+------------|
        |Then CPYF/CPYP/CPYH |  1    |     2         |     2      |
        |data record with    |     2 |        3      |        3   |
        |parameters          |       |               |            |
        |(1) and (2) of      |       |               |            |
        |--------------------+-------+---------------+------------|
        |with corresponding  |       |   left blank  | left blank |
        |frequency value(s)  |       |               |            |
        |--------------------+-------+---------------+------------|
        |Resulting frequency | .6 .7 | .5 .6 .7 .8 .9| .5 .6 .7   |
        |values are          |       |               |            |
        |--------------------+-------+---------------+------------|
        |with parameters     |  D  D |  D  D  D  D  D|  D  D  D   |
        |                    |       |               |            |
         ---------------------------------------------------------
```

10.10. The CPYS Data Record - Copy Stiffness Matrix

The new user is advised to ignore this facility.

This data record is used when copying the stiffness matrix from data read from a backing file from a previous run in order to duplicate these values for the structure indicated by the data category keyword. The preceding CSTR and/or FILE data records define the structure and the source file from which the stiffness matrix is to be copied. See also The CPYF/CPYP/CPYH Data Records - Copy Frequency Parameters (p. 110), Note 2.

```
       2   5  7
     - --- -- ----
    |X|   |  |CPYS|
     - --- -- ----
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last data record in data category(A3)
```

10.11. The CPDB Data Record - Copy Existing Hydrodynamic Data Base

This data record is used when copying the hydrodynamic data from a backing file (*.HYD) from a previous run in order to duplicate the data base for the structure indicated by the data category keyword. The preceding CSTR and/or FILE data records define the structure and the source file from which the data base is to be copied. See also The CPYF/CPYP/CPYH Data Records - Copy Frequency Parameters (p. 110), Note 2.

See Database Import (p. 114) for examples showing the import of data from an existing Aqwa-Line database.

```
    2   5  7
  - --- -- ----
 |X|   |  |CPDB|
  - --- -- ----
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on Last data record in data category(A3)
```

10.12. The FWDS Data Record - Define Forward Speed

This data record is used to define a constant forward speed of the structure indicated by the data category keyword. A positive speed indicates the vessel moving in +x direction, and a negative speed is for the vessel moving in -x direction. The wave direction is defined as the direction in which the waves are travelling in the global axis system, which is the same as for the zero forward speed case.

```
   2   5  7    11   16    21         31
  - --- -- ---- ---- ----- ---------- ------------
 |X|   |  |FWDS|    |XXXXX|          |
  - --- -- ---- ---------- ---------- ------------
     |  |   |     |            |
     |  |   |     |            |_(2) Value of Speed (F10.0)
     |  |   |     |
     |  |   |     |_(1) Max no. of encounter frequencies in diffraction analysis (I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword (A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on Last data record in data category (A3)
```

(1) Only used for the case of multiple wave directions. Cannot exceed 100 (the maximum number of incident wave frequencies, $Maxfrq$), but normally should not be less than the number of incident wave frequencies defined by FREQ/PERD/HRTZ data records (p. 102). If not defined, it will be set to $Maxfrq$.

(2) Speed must be defined in units consistent with those used for gravity and density in Data Category 5.

Note:

Denoting N_{freq}, N_{dirn}, and $Maxenc$ as the number of incident wave frequencies, the number of wave directions, and the maximum number of encounter frequencies in diffraction analysis, respectively, the actual number of encounter frequencies selected in the diffraction analysis for the structure traveling in multiple wave direction, N_{enc}, is determined in the following cases:

- $N_{freq} \times N_{dirn} \leq Maxenc$

All the different magnitudes of the encounter frequencies associated to the pairs of incident wave frequencies and directions will be included.

- $N_{freq} \times N_{dirn} > Maxenc$

  The positive encounter frequencies are selected in the range of $\left[\omega_{\mathrm{emin}}, \omega_{\mathrm{emax}}\right]$, where $\omega_{\mathrm{emin}} = \max\left\{\omega_{e0}, \min\left(\left|\omega_{eij}\right|\right)\right.$ and $\omega_{\mathrm{emax}} = \max\left(\left|\omega_{eij}\right|\right)$ where ω_{e0} is the minimum encounter frequency allowed by the Green function database, and ω_{eij} is calculated by Equation 4.39 in the *Aqwa Theory Manual* for all the pairs of incident wave frequencies and wave directions ($i=1, N_{freq}$, $j=1, N_{dirn}$).

  The actual number of positive encounter frequencies used in the diffraction analysis is:

  $$N_{enc} = \min\left\{\max\left(2 \times N_{peak} + N_{freq}, Maxenc\right), Maxfrq\right\}$$

  in which N_{peak} is the number of peak encounter frequencies ($\omega_{e\_peak}(\beta)$ defined in Equation 4.80 in the *Aqwa Theory Manual*) if their associated incident wave frequencies are within the user-defined frequency range in this data category.

  Three types of encounter frequency points are included:

  1. N_{peak} of the peak encounter frequencies
  2. N_{peak} of the additional frequency points close to the peak encounter frequencies
  3. $N_{enc} - 2 \times N_{peak}$ of the other encounter frequencies distributed over the range $\left[\omega_{\mathrm{emin}}, \omega_{\mathrm{emax}}\right]$, among which the first one is $\omega_e(1) = \omega_{\mathrm{emin}}$, and the last one is $\omega_e\left(N_{enc} - 2 \times N_{peak}\right) = \omega_{\mathrm{emax}}$.

10.13. Database Import

Import for Two Non-Interacting Structures

This example shows import of databases for two non-interacting structures, from two different .HYD files. Note that Structure 1 in the current run, which is identified by the keyword FDR1, uses data from Structure 1 in AL_RUN1.HYD. Structure 2 in the current run, which is identified by the keyword FDR2, uses data from Structure 1 in AL_RUN3.HYD.

```
   06    FDR1
   06FILE          AL_RUN1.HYD
   06CSTR    1
   06CPDB
END
   06    FDR2
   06FILE          AL_RUN3.HYD
   06CSTR    1
   06CPDB
END
```

Import for Interacting Structures

When using the FILE / CSTR / CPDB data records to import a hydrodynamic database from a previous Aqwa-Line run, for a group of hydrodynamically interacting structures, it is only necessary to refer to the 1st structure in the group. Data for the other structures will be imported automatically. In the example below there are 5 structures, of which structures 2,3,4 form an interacting group. The data is imported from three different .HYD files.

```
   06    FDR1
   06FILE          AL_RUN1.HYD
   06CSTR    1
   06CPDB
END
   06    FDR2
   06FILE          AL_RUN2.HYD
   06CSTR    1
   06CPDB
END
   06    FDR5
   06FILE          AL_RUN3.HYD
   06CSTR    1
   06CPDB
END
   06    FINI
```

Note:

A FINI data record is required. This is because the program is expecting to read 5 FDR* data records and there are only three.

Chapter 11: Wave Frequency Dependent Parameters and Stiffness Matrix - WFS* (Data Category 7)

For the WFS data categories, the * indicates the structure number; for example, enter WFS1 for Structure 1, WFS2 for Structure 2, ... WF10 for Structure 10.

11.1. General Description

This data category is used to input or change the wave frequency dependent hydrodynamic parameters and the linear hydrostatic stiffness matrix of one or more structures. All parameters, except the hydrostatic stiffness, are associated with the frequencies and directions input in the previous data category (Data Category 6). Values of added mass, and radiation damping may be input for each frequency. Values of diffraction forces, Froude Krylov forces and response amplitude operators (RAOs) may be input for each frequency and for each direction.

Although this data category is applicable to all programs using the hydrodynamic parameters this data category is only used when:

(a) the backing file produced by a previous Aqwa-Line run, containing the values of the parameters, is not available; in other words, Aqwa-Line has not been run previously, or you wish to input values of the parameters obtained from a source other than Aqwa-Line.

or

(b) you wish to change some of the values or append to some of the values calculated by a previous Aqwa-Line run for the current analysis (Aqwa-Fer/ Drift/Librium/Naut) or within the backing file (Aqwa-Line only).

The normal mode of operation of the programs using the hydrodynamic parameters is to read these values from the backing file of a previous Aqwa-Line run. Therefore, *unless (a) or (b) above apply*, you should omit this data category by entering NONE for the data category keyword (see Compulsory Data Category Keyword (p. 47)).

3. Default Values when Omitting Data Records

With the exception of the specification of frequency and direction, which are required for the input of parameters dependent on these variables, the omission of any data record in this data category will result in the existing values being unchanged. Any data record in this data category whose values are all zero in columns 21-80, and which does not overwrite existing values is redundant and may be omitted.

11.2. Data Category Header

```
                         -(Indicates Structure Number)
                        |
```

```
         5      11  |
    ---- -- ---- ----
   |XXXX|  |XXXX|WFS1|
    ---- -- ---- ----
         |        |
         |        |_Compulsory Data Category Keyword(A4)
         |
         |_Optional User Identifier(A2)
```

11.3. Hydrostatic Stiffness

The following topics are available:

11.3.1. The LSTF Data Record - Linear Hydrostatic Stiffness Matrix

These data records may be used to input a linear hydrostatic stiffness matrix. If the matrix has been read from the backing file, the LSTF data record will replace (i.e. overwrite) the existing values within that matrix. If you wish to add TO the existing values, use the ASTF data record (The ASTF Data Record - Additional Hydrostatic Stiffness Matrix (p. 120)).

Note:

- This data record is ignored if there is any internal tank associated with this structure.
- LSTF data records must be used to define the whole hydrostatic stiffness matrix for a particular structure. If any LSTF data records are used, undefined rows will be re-set to zero.
- The Z coordinate of the center of gravity and the buoyancy force at equilibrium must always be defined when using LSTF data records to specify the stiffness matrix.

See the notes at the end of this section about the effects of the LSTF data record on the calculations.

```
   2   5  7    11    16    21        31        41
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |LSTF|XXXXX|     |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
     |  |   |           |       |         |         |
     |  |   |           |       |---------------------
     |  |   |           |       |
     |  |   |           |       |_(2)-(7)6 Stiffness Values
     |  |   |           |              (6E10.0)(Units for freedoms
     |  |   |           |                       1-3 = force/length,
     |  |   |           |                       4-6 = force*length/RADIAN)
     |  |   |           |
     |  |   |           |_(1)Row Number of Stiffness Matrix(I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
```

```
        |
        |_Compulsory END on Last data record in data category(A3)
```

(1) This number indicates which row of the stiffness matrix the values input in columns 21-80 relate to.

(2)-(7) These are the values which replace the row (1) in the hydrostatic stiffness matrix.

Note:

- **Stiffness related forces acting on the structure**

  The linear hydrostatic stiffness matrix relates to the hydrostatic forces contributing to the equations of static equilibrium of a structure. Specifically, the net linear hydrostatic forces F(s), acting at the center of gravity of a structure, when the structure is at an arbitrary position X, is given by:

  F(s) = K (X(e) - X) + B(e)

  where

  K = stiffness matrix

  X(e) = equilibrium position

  B(e) = buoyancy force at equilibrium

  At equilibrium, all forces act in the Z direction of the Fixed Reference Axis (FRA), where X(e)=X, and B(e) = F(s). Thus, the Z coordinate of the center of gravity and the buoyancy force at equilibrium must always be defined, when using the LSTF data record to specify the stiffness matrix, in order to fully describe the hydrostatic forces acting on the structure. These parameters must be input using the ZCGE and BFEQ data records which are described in The ZCGE Data Record - Z Coordinate of the Center of Gravity at Equilibrium (p. 122) and The BFEQ Data Record - Buoyancy Force at Equilibrium (p. 121).

- **Effect of the LSTF data record when running Aqwa-Line**

  Normally Aqwa-Line calculates the hydrostatic stiffness matrix from the element description in Data Category 2. Input of 1 or more LSTF data records indicates that this calculation is to be omitted for the specified structure, and the hydrostatic stiffness matrix will use the specified values. Data Records must be used in sets of 6 to define the full hydrostatic stiffness matrix; undefined values will default to zero.

  The hydrostatic stiffness matrix is used in the calculation of the 2nd order drift coefficients. For this purpose it should only represent the hydrostatic stiffness of the outer wetted hull itself; LSTF should not be increased to add in the effect of (e.g.) moorings.

11.3.2. The ASTF Data Record - Additional Hydrostatic Stiffness Matrix

The ASTF data record may be used to add TO the existing values within the hydrostatic stiffness matrix.

Note:

If the analysis includes stage 2 any additional stiffness already in the database will be reset to zero and must be re-defined.

See the notes at the end of this section about the effects of this data record when using different programs.

```
  2   5  7    11    16    21        31        41
 - --- -- ---- ----- ----- --------- --------- ------
|X|   |  |ASTF|XXXXX|     |         |         |      ...
 - --- -- ---- ----- ----- --------- --------- ------
    |  |   |          |       |         |         |
    |  |   |          |       |----------------------
    |  |   |          |       |
    |  |   |          |       |_(2)-(7)6 Stiffness Values
    |  |   |          |               (6E10.0)(Units for freedoms
    |  |   |          |                        1-3 = force/length,
    |  |   |          |                        4-6 = force*length/RADIAN)
    |  |   |          |
    |  |   |          |_(1)Row Number of Stiffness Matrix(I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last data record in data category(A3)
```

(1) This number indicates which row of the stiffness matrix the values input in columns 21-80 relate to.

(2)-(7) These are the values which add TO the row (1) in the hydrostatic stiffness matrix.

- **Stiffness related forces acting on the structure**

  The linear stiffness matrix relates to the hydrostatic forces contributing to the equations of static equilibrium of a structure. Specifically, the net linear hydrostatic forces F(s), acting at the center of gravity of a structure, when the structure is at an arbitrary position X, is given by:

  F(s) = K (X(e) - X) + B(e)

  where

  K = stiffness matrix

  X(e) = equilibrium position

  B(e) = buoyancy force at equilibrium

  If the ASTF data record is used, the program will use X(e) and B(e) as calculated by the program. However, it should be checked that the above expression, which is used to calculate the LINEAR hydrostatic forces throughout the Aqwa suite, produces the forces on the structure intended by the user.

- **Effect of the ASTF data record when running Aqwa-Line**

  Additional hydrostatic stiffness is stored in the database and used in the calculation of the RAOs. However, it is not used in the calculation of the 2nd order drift forces.

- **Effect of the ASTF data record when running Aqwa-Librium/Fer/Drift/Naut**

  Note that in the equation above the term X(e) is the Aqwa-Line equilibrium position. If the initial position in a subsequent Librium/Fer/Drift/Naut analysis is not as defined in the Line run then there will be restoring forces which will try to return the structure to the Aqwa-Line equilibrium position.

- **Effect of multiple ASTF data records**

  If additional stiffness is required and stage 2 is run it is always necessary to use the ASTF data record.

11.3.3. The BFEQ Data Record - Buoyancy Force at Equilibrium

This data record is used to specify the vertical buoyancy force when the structure is at its free-floating equilibrium position (i.e. with no articulations and no mooring lines attached), which is used in the calculation of the linear hydrostatic forces.

If a BFEQ data record is used, there must also be a LSTF data record (The LSTF Data Record - Linear Hydrostatic Stiffness Matrix (p. 118)).

```
       2   5  7   11        21
     - --- -- ---- --------- ---------
    |X|   |  |BFEQ|XXXXXXXXX|         |
     - --- -- ---- --------- ---------
        |  |   |                 |
        |  |   |                 |_(2)Vertical Buoyancy Force at Equilibrium(F10.0)
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last data record in data category(A3)
```

11.3.4. The GMXX/GMYY Data Record - User-Specified Metacentric Height

The hydrostatic stiffness in the hydrodynamic database can be modified to a user specified value creating additional stiffness automatically. This is achieved by specifying the required GMX and GMY (about the global X/Y axis) in Data Category 7 as follows:

```
       2   5  7   11    16    21          31        41        51
     - --- -- ---- ----- ----- ----------- --------- ---------
    |X|   |  |GMXX|     |     |           |         |         |
     - --- -- ---- ----- ----- ----------- --------- ---------
    |X|   |  |GMYY|     |     |           |         |         |
     - --- -- ---- ----- ----- ----------- --------- ---------
        |  |   |                   |
        |  |   |                   |_ (1) Required Value
        |  |   |
        |  |   |_ Data Record Name(A4)
        |  |
```

```
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) Aqwa firstly calculates the hydrostatic stiffness matrix based only on the cut water plane and displaced volume properties. It then adjusts the second moments of area IXX, IYY and recalculates its associated properties, PHI (principal axis), GMX/GMY, BMX/BMY etc. to give the required GM values. The associated additional hydrostatic stiffness is calculated automatically and stored in the hydrodynamic database.

Note:

- This data record is ignored if there is any internal tank associated with this structure.
- If the GM value input is less than that based on the geometry alone, the resulting additional stiffness will be negative. This would be the case if ballast tanks were being modeled, making the structure less stable, statically.

11.4. Analysis Position

The following topics are available

11.4.1. The ZCGE Data Record - Z Coordinate of the Center of Gravity at Equilibrium

This data record is used to specify the Z coordinate of the center of gravity when the structure is at its free-floating equilibrium position (i.e. with no articulations and no mooring lines attached), which is used in the calculation of the linear hydrostatic forces (see The LSTF Data Record - Linear Hydrostatic Stiffness Matrix (p. 118)). It is also used in Aqwa-Line to indicate the structure position for the radiation/diffraction analysis.

```
   2   5  7   11        21
 - --- -- ---- --------- ---------
|X|   |  |ZCGE|XXXXXXXXX|         |
 - --- -- ---- --------- ---------
    |  |   |                 |
    |  |   |                 |_(1)Z Coordinate of the Center of Gravity at Equilibrium(F10.0)
    |  |   |
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
```

```
     |_Compulsory END on Last data record in data category(A3)
```

Note:

1. An alternative method of specifying the free-floating equilibrium position is to use the ZLWL data record in Data Category 2 (The ZLWL Data Record - Waterline Height (p. 82)).
2. If the ZCGE and ZLWL data records are both absent, the definition position based on the nodes in Data Category 1 will be used.
3. This position is not USED as the starting position for an analysis using Aqwa-Librium, Fer, Drift or Naut. This must be specified in Data Category 15 or by using the RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)).

11.4.2. The SSTR Data Record - Submerged Structure

When a structure has no panel elements with an edge on the waterline, this data record is used to indicate that there is no waterline integral term in the near field QTF calculation (see equation Equation 5.16 in the *Aqwa Theory Manual*).

```
  2   5  7
- --- -- ----
X|   |  |SSTR|
- --- -- ----
    |  |   |
    |  |   |_(1)Submerged structure(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on Last
      Data Record in Data Category.(A3)
```

11.5. Frequency Dependent Data

The following topics are available:

11.5.1. The FREQ/PERD/HRTZ Data Record - Frequencies/Periods at which the Parameters are Defined

This data record is used to specify the frequency at which following frequency dependent hydrodynamic parameters are input. The frequency/period specified is operative until another FREQ/PERD/HRTZ data record is input.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ---------
  |X|   |  |FREQ|XXXXX|     |         |
   - --- -- ---- ----- ----- ---------
  |X|   |  |PERD|XXXXX|     |         |
   - --- -- ---- ----- ----- ---------
  |X|   |  |HRTZ|XXXXX|     |         |
   - --- -- ---- ----- ----- ---------
      |  |   |           |       |
      |  |   |           |       |
      |  |   |           |       |
      |  |   |           |       |_(2)Frequency/Period Value(F10.0)
      |  |   |           |           (FREQ=radians/sec)
      |  |   |           |           (PERD=seconds)
      |  |   |           |           (HRTZ=hertz)
      |  |   |           |
      |  |   |           |_(1)Frequency/Period Number(I5)
      |  |   |
      |  |   |
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This is the number of the frequency/period which corresponds to the value in columns 21-30. This number must correspond to one of the frequency numbers specified in Data Category 6.

(2) The frequency/period value should be the same as that specified in Data Category 6 and is used only as a check that the frequency number(1) has been input correctly. It does not redefine the frequency value. If the value is not the same as in Data Category 6, an error will occur.

11.5.2. The DIRN Data Record - Directions at which the Parameters are Defined

This data record is used to specify the direction to which the following diffraction forces, Froude Krylov forces or response amplitude operators, relate. The direction specified is operative until another DIRN data record is input. (NB See also the note at the end of this section when using Aqwa-Line.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ---------
  |X|   |  |DIRN|XXXXX|     |         |
   - --- -- ---- ----- ----- ---------
      |  |   |           |       |
      |  |   |           |       |
      |  |   |           |       |
      |  |   |           |       |_(2)Values of Direction (DEGREES)(6F10.0)
      |  |   |           |
      |  |   |           |_(1)Direction Number(I5)
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
```

```
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This is the number of the direction which corresponds to the values input in columns 21-30. This number must be one of the direction numbers specified in Data Category 6.

(2) The direction value should be the same as that specified in Data Category 6 and is used only as a check that the direction number (1) has been input correctly. It does not redefine the direction value. If the value is not the same, an error will occur.

Note:

Effect of the DIRN Data Record when Running Aqwa-Line

Input of the Froude Krylov forces, diffraction forces or RAOs is redundant, when running Aqwa-Line, as the program normally calculates these parameters. The DIRN data record is a precursor to inputting values of these parameters. Therefore, use of a DIRN data record will instruct Aqwa-Line not to perform a radiation/diffraction analysis at this frequency. You must then specify all the other parameters which would otherwise have been calculated by the analysis at this frequency, i.e. the linear damping/added mass matrix, Froude Krylov and diffraction forces.

11.5.3. The WAMS/WDMP Data Record - Wave Frequency Added Mass Matrix and Wave Frequency Damping Matrix

These data records may be used to input the added mass matrix (WAMS) and linear damping matrix (WDMP) at the frequency/period specified on the preceding FREQ/PERD/HRTZ data record. If the matrix has been read from backing file, the WAMS or WDMP data record will replace (i.e. overwrite) the existing values within that matrix. (NB see Note 1 at the end of this section, when using Aqwa-Line.)

```
    2   5  7   11    16    21        31        41
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |WAMS|     |     |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |WDMP|     |     |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
      |  |   |     |     |       |         |         |
      |  |   |     |     |       |----------------------
      |  |   |     |     |       |
      |  |   |     |     |       |_(4) 6 Mass/Inertia or Linear Damping Values(6E10.0)
      |  |   |     |     |
      |  |   |     |     |_(3) Row Number of Added Mass or Damping Matrix(I5)
      |  |   |     |
      |  |   |     |_(2)  Structure Number(I5)
      |  |   |
      |  |   |_(1) Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values (4) refer to the added mass (WAMS) or damping matrix (WDMP).

(2) If the analysis includes hydrodynamically interacting structures, this is the number of the structure which interacts with that defined on the data category keyword (WFS*). The structure must be input even if the coefficients are those giving the effect of the structure on itself (i.e. structure 1 in data category WFS1). Both complete added mass and damping matrices should be input; if part matrices are input the results will likely be inaccurate, or the program may fail. When using Aqwa-Line, see the note 1 below.

(3) This number indicates to which row of the added mass/damping matrix the values in columns 21-80 correspond.

(4) These are the values which REPLACE those in row (3) of the existing added mass/damping matrix.

Note:

1. **Effect of the WAMS/WDMP Data Record when Running Aqwa-Line**

   Input of the added mass/damping matrix is redundant information when running Aqwa-Line, as the program normally calculates these matrices. Therefore, use of one or more WAMS/WDMP data records will instruct Aqwa-Line not to perform a radiation/diffraction analysis at this frequency. You must then import or specify all other parameters which would otherwise be calculated at this frequency; in other words, the linear damping/added mass matrix, Froude Krylov and diffraction forces.

2. These data records are not valid for a structure with forward speed in multiple wave directions.

11.5.4. The AAMS/ADMP Data Record - Additional Added Mass/Damping Matrices

These data records may be used to input an added mass (AAMS) or linear damping (ADMP) matrix additional to that input or calculated at the frequency/ period specified on the preceding FREQ/PERD/HRTZ data record. The values input will add TO any existing values previously input via data records or backing file, or add TO any subsequent values input or calculated by Aqwa-Line.

Note:

If the convolution method is to be used in a time domain analysis, the AAMS and ADMP data records which define the frequency dependent additional added mass and damping matrices should be replaced by the frequency independent additional added mass and damping defined by FIAM, FIDP (for matrices) (The FIAM/FIDP Data Record - Frequency Independent Added Mass/Damping Matrices (p. 129)) or FIDA, FIDD (for diagonal terms) (The FIDA/FIDD Data Record - Frequency Independent Diagonal Added Mass/Damping (p. 131)).

```
     2   5  7   11    16    21        31        41
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |AAMS|XXXXX|     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |ADMP|XXXXX|     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
      |  |   |           |       |         |         |
```

```
       |  |   |           |       |----------------------
       |  |   |           |       |
       |  |   |           |       |_(3)-(8)6 Added Mass/Damping Values(6F10.0)
       |  |   |           |
       |  |   |           |_(2)Row Number of Added Mass/Damping Matrix(I5)
       |  |   |
       |  |   |_(1)Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values (3) and row number (2) refer to the added mass (AAMS) or damping (ADMP) matrix

(2) This number indicates the row of the added mass/damping matrix to which the values in columns 21-80 correspond.

(3)-(8) These are the values which add TO those in the row (2) of the existing added mass/ damping matrix or add TO any subsequent values input or calculated by Aqwa-Line.

Note:

These data records are not valid for a structure with forward speed in multiple wave directions.

11.5.5. The WDGA/WDGD Data Record - Wave Frequency Diagonal Added Mass and Wave Frequency Diagonal Damping

These data records represent a more convenient manner to input the added mass matrix (WDGA) and linear damping matrix (WDGD) at the frequency/period specified on the preceding FREQ/PERD/HRTZ data record, when there are no off diagonal terms coupling the degrees of freedom of motion. They are used instead of the data records WAMS and WDMP respectively, which are used only when these coupling terms exist. If the added mass or damping matrix has been read from backing file, the WDGA or WDGD data record will replace (i.e. overwrite) the existing values within that matrix. See also the note at the end of this section, when using Aqwa-Line.

```
     2   5  7   11        21        31        41
   - --- -- ---- --------- --------- --------- ------
  |X|   |  |WDGA|XXXXXXXXX|         |         |      ...
   - --- -- ---- --------- --------- --------- ------
  |X|   |  |WDGD|XXXXXXXXX|         |         |      ...
   - --- -- ---- --------- --------- --------- ------
       |  |   |                |         |         |
       |  |   |                |----------------------
       |  |   |                |
       |  |   |                |_(2)-(7)6 Mass/Inertia or Linear Damping Values(6E10.0)
       |  |   |
       |  |   |
       |  |   |_(1)Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values (3) refer to the added mass matrix (WDGA) or to the damping matrix (WDGD)

(2)-(7) These are the values which replace those in the leading diagonal of the added mass/damping matrix. All other elements of the matrix are set to zero.

Note:

Effect of the WDGA/WDGD Data Record when Using Aqwa-Line

Input of the wave frequency added mass/damping matrix is redundant information when running Aqwa-Line as the program normally calculates these matrices. Therefore, use of a WDGA/WDGD data record will instruct Aqwa-Line not to perform a radiation/diffraction analysis at this frequency. You must then specify all other parameters which would otherwise be calculated at this frequency, i.e. the linear damping/added mass matrix, Froude Krylov and diffraction forces.

These data records are not valid for a structure with forward speed in multiple wave directions.

11.5.6. The TDIF/RDIF/TFKV/RFKV/TRAO/RRAO Data Records - Wave Frequency Diffraction Forces and Responses

These data records are used to input the vectors of diffraction forces, Froude Krylov forces and RAOs at the frequency/period specified on the preceding FREQ/PERD/HRTZ data record, and at the direction specified on the preceding DIRN data record. If the vectors have been read from backing file, the values input on each data record will replace (i.e. overwrite) the existing values.

```
   2   5  7    11        21          31          41          51         61          71
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
|X|   |  |TDIF|XXXXXXXXX|           |           |           |          |           |           |
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
|X|   |  |RDIF|XXXXXXXXX|           |           |           |          |           |           |
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
|X|   |  |TFKV|XXXXXXXXX|           |           |           |          |           |           |
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
|X|   |  |RFKV|XXXXXXXXX|           |           |           |          |           |           |
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
|X|   |  |TRAO|XXXXXXXXX|           |           |           |          |           |           |
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
|X|   |  |RRAO|XXXXXXXXX|           |           |           |          |           |           |
 - --- -- ---- --------- ----------- ----------- ----------- ---------- ----------- -----------
   |  |   |                 |           |           |           |          |           |
   |  |   |           (2)Surge(X) (3)Surge(X) (4)Sway(Y)   (5)Sway(Y)  (6)Heave(Z) (7)Heave(Z)
   |  |   |              Roll(RX)    Roll(RX)    Pitch(RY)    Pitch(RY)   Yaw(RZ)     Yaw(RZ)
   |  |   |              Amplitude   Phase       Amplitude    Phase       Amplitude   Phase
   |  |   |
   |  |   |
   |  |   |_(1)Compulsory Data Record Keyword(A4)
   |  |
   |  |_Optional User Identifier(A2)
   |
   |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether values in columns 21-80 are diffraction forces, Froude Krylov forces or Response Amplitude Operators (RAOs) and whether the values relate to the translational or rotational degrees of freedom, i.e.:

TDIF - Translation Diffraction Forces

RDIF - Rotational Diffraction Forces

TFKV - Translational Froude Krylov Forces

RFKV - Rotational Froude Krylov Forces

TRAO - Translational RAOs

RRAO - Rotational RAOs

(2)-(7) These are the values of the forces or responses, indicated by the data record keyword(1).

The units for each data record keyword are as follows:

TDIF - Units of Force / Unit Wave Amplitude

RDIF - Units of Force / Length/Unit Wave Amplitude

TFKV - Units of Force / Unit Wave Amplitude

RFKV - Units of Force / Length/Unit Wave Amplitude

TRAO - Units of Length / Unit Wave Amplitude

RRAO - Units of DEGREES / Unit Wave Amplitude

11.6. Frequency Independent Added Mass and Damping

The following topics are available:

11.6.1. The FIAM/FIDP Data Record - Frequency Independent Added Mass/Damping Matrices

These data records may be used to input an added mass (FIAM) or linear damping (FIDP) matrix in addition to the radiation added mass and damping calculated by Aqwa-Line or input via data records.

If two FIAM/FIDP entries are used in the same run or in successive runs (for example, Aqwa-Line followed by Aqwa-Drift), the second entry will overwrite the first.

As these are frequency independent parameters, the values defined in the FIAM and FIDP data records will apply to all the frequencies. Therefore there is no preceding FREQ/PERD/HRTZ data record for FIAM and FIDP.

```
     2   5  7   11    16    21        31        41
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |FIAM|XXXXX|     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |FIDP|XXXXX|     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
```

```
        |  |   |           |       |         |         |
        |  |   |           |       |---------------------
        |  |   |           |       |
        |  |   |           |       |_(3)-(8)6 Added Mass/Damping Values(6F10.0)
        |  |   |           |
        |  |   |           |_(2)Row Number of Added Mass/Damping Matrix(I5)
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values refer to the added mass (FIAM) or damping (FIDP)

(2) This number indicates the row of the added mass/damping matrix to which the values in columns 21-80 correspond.

(3)-(8) These are the values which add to those in the existing added mass/ damping matrix or add to any subsequent added mass/damping values input or calculated by Aqwa-Line.

11.6.2. The AIAM/AIDP Data Record - Additional Frequency Independent Added Mass/Damping Matrices

These data records may be used to input additional frequency independent added mass (AIAM) or linear damping (AIDP) matrices in addition to the radiation added mass and damping calculated by Aqwa-Line or input via data records. These data records should be used after the FIAM (p. 129) and FIDP (p. 129) data records have been input. The values input will ADD to any values previously input via FIAM/FIDP data records or backing file, or ADD to any values input or calculated by Aqwa-Line.

As these are frequency independent parameters, the values defined in the AIAM and AIDP data records will apply to all the frequencies. Therefore there is no preceding FREQ/PERD/HRTZ data record for AIAM and AIDP.

```
     2   5  7   11    16    21        31        41
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |AIAM|XXXXX|     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |AIDP|XXXXX|     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
      |  |   |           |       |         |         |
      |  |   |           |       |---------------------
      |  |   |           |       |
      |  |   |           |       |_(3)-(8)6 Added Mass/Damping Values(6F10.0)
      |  |   |           |
      |  |   |           |_(2)Row Number of Added Mass/Damping Matrix(I5)
      |  |   |
      |  |   |_(1)Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values refer to the added mass (AIAM) or damping (AIDP)

(2) This number indicates the row of the added mass/damping matrix to which the values in columns 21-80 correspond.

(3)-(8) These are the values which add to those in the existing added mass/ damping matrix or add to any subsequent added mass/damping values input or calculated by Aqwa-Line.

11.6.3. The FIDA/FIDD Data Record - Frequency Independent Diagonal Added Mass/Damping

These data records may be used to input a diagonal added mass (FIDA) or diagonal linear damping (FIDD) in addition to the radiation added mass and damping calculated by Aqwa-Line or input via data records.

If two FIDA/FIDD entries are used in the same run or in succesive runs (for example, Aqwa-Line followed by Aqwa-Drift), the second entry will overwrite the first.

As these are frequency independent parameters, the values defined in the FIDA and FIDD data records will apply to all the frequencies. Therefore there is no preceding FREQ/PERD/HRTZ data record for FIDA and FIDD. Also as FIDA and FIDD only define the diagonal terms of the additional added mass and damping matrices, row number is no longer needed.

```
     2   5  7   11          21        31        41
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |FIDA|  XXXXX    |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |FIDD|  XXXXX    |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
      |  |   |                 |         |         |
      |  |   |                 |----------------------
      |  |   |                 |
      |  |   |                 |_(2)-(7)6 Added Mass/Damping Values(6F10.0)
      |  |   |
      |  |   |
      |  |   |
      |  |   |_(1)Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values refer to the added mass (FIDA) or damping (FIDD).

(2)-(7) These are the values which add to the diagonal terms of the existing added mass/ damping matrix or add to any subsequent diagonal added mass/damping values input or calculated by Aqwa-Line.

Note:

Only one FIDA data record is needed for defining the diagonal terms of an additional added mass matrix. If more than one FIDA data record is used for a structure, only those values in the last FIDA data record will be used. This also applies to the FIDD data record.

11.6.4. The AIDA/AIDD Data Record - Additional Frequency Independent Diagonal Added Mass/Damping

These data records may be used to input additional frequency independent diagonal added mass (AIDA) or diagonal linear damping (AIDD) in addition to the radiation added mass and damping calculated by Aqwa-Line or input via data records. These data records should be used after the FIDA (p. 131) and FIDD (p. 131) data records have been input. The values input will ADD to any values previously input via FIDA/FIDD data records or backing file, or add to any subsequent values input or calculated by Aqwa-Line.

As these are frequency independent parameters, the values defined in the AIDA and AIDD data records will apply to all the frequencies. Therefore there is no preceding FREQ/PERD/HRTZ data record for AIDA and AIDD. Also as AIDA and AIDD only define the diagonal terms of the additional added mass and damping matrices, row number is no longer needed.

```
       2   5  7   11         21        31        41
     - --- -- ---- ----- ----- --------- --------- ------
    |X|   |  |AIDA|  XXXXX    |         |         |      ...
     - --- -- ---- ----- ----- --------- --------- ------
    |X|   |  |AIDD|  XXXXX    |         |         |      ...
     - --- -- ---- ----- ----- --------- --------- ------
        |  |   |                  |         |         |
        |  |   |                  |----------------------
        |  |   |                  |
        |  |   |                  |_(2)-(7)6 Added Mass/Damping Values(6F10.0)
        |  |   |
        |  |   |
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates whether the values refer to the added mass (AIDA) or damping (AIDD).

(2)-(7) These are the values which add to the diagonal terms of the existing added mass/ damping matrix or add to any subsequent diagonal added mass/damping values input or calculated by Aqwa-Line.

11.7. Additional Structural Stiffness

The data records described in this section define an additional structural (i.e. not hydrostatic) stiffness, that may act on one structure or may connect two structures. The additional force acting on the structure(s) is defined as

$$F = F(e) - K \cdot (X - X(e))$$

where

X(e) is the equilibrium position, defined on the SPOS data record (p. 133)

F(e) is the force at the equilibrium position, defined on the SFRC data record (p. 134)

K is the stiffness, defined using SSTF data records (p. 132)

11.7.1. The SSTF Data Record - Additional Structural Stiffness Matrix

This data record may be used to input an additional linear structure stiffness matrix in the global fixed frame. *If the analysis includes stage 2 the matrix will be re-set to zero and must be re-defined.* If the

NASF option is used (Administration and Calculation Options for the Aqwa Suite (p. 314)), this matrix will not be included in the analysis.

```
  2   5  7   11    16    21        31        41
 - --- -- ---- ----- ----- --------- --------- ------
|X|   |  |SSTF|     |     |         |         |      ...
 - --- -- ---- ----- ----- --------- --------- ------
    |  |   |     |     |       |         |         |
    |  |   |     |     |       |----------------------
    |  |   |     |     |       |
    |  |   |     |     |       |
    |  |   |     |     |       |_(4)-(9) 6 Stiffness Values (6E10.0)
    |  |   |     |     |
    |  |   |     |     |_(3) Row Number of Stiffness Matrix (I5)
    |  |   |     |
    |  |   |     |_(2) 2nd Structure Number (I5)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(2) The data on this data record defines one row of a stiffness matrix coupling this structure to the one indicated on the WFS* data record in the data category keyword (referred to here as Structure#1). If this is zero or omitted, Structure#2 is set to be the same as Structure#1. Otherwise this number must not be less than Structure#1.

(3) This number indicates which row of the stiffness matrix the values input in columns 21-80 relate to.

(4)-(9) These are the values for the row (3) in the 6x6 additional structure stiffness sub-matrix. The units for angles are radians.

If there are multiple SSTF data records defining the same terms in the stiffness matrix, the values are summed.

11.7.2. The SPOS Data Record - Equilibrium Position

This data record may be used to optionally input the equilibrium position of the structure in the global fixed frame for the additional structure stiffness force calculation only. This data record does not move the structure to this position. Without this data record, the default position will be that position defined by Data Categories 1-2.

```
  2   5  7    11    16    21        31        41
 - --- -- ---- ----- ----- --------- --------- ------
|X|   |  |SPOS|XXXXX|XXXXX|         |         |      ...
 - --- -- ---- ----- ----- --------- --------- ------
    |  |   |                   |         |         |
    |  |   |                   |----------------------
    |  |   |                   |
    |  |   |                   |
    |  |   |                   |_(2)-(7) 6 position coordinates (6E10.0)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(2)-(7) The units for angular positions are degrees.

11.7.3. The SFRC Data Record - Force at Equilibrium Position

This data record may be used to input the force on the structure at the equilibrium position due to the additional structural stiffness, in the global fixed frame, for the additional structure stiffness force calculation only.

```
  2   5  7    11    16    21        31        41
 - --- -- ---- ----- ----- --------- --------- ------
|X|   |  |SFRC|XXXXX|XXXXX|         |         |      ...
 - --- -- ---- ----- ----- --------- --------- ------
    |  |   |                  |         |         |
    |  |   |                  |----------------------
    |  |   |                  |
    |  |   |                  |
    |  |   |                  |_(2)-(7) 6 Force Components (6E10.0)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

11.8. Free Trim Large Angle Stability Calculation

The data records described in this section define the free trim large angle stability calculation settings of a single structure. They are associated with the structure indicated in the WFS* data category (p. 117). The strict sequence required for these data records is as follows:

1. The LASB Data Record (p. 134)
2. The LAAX Data Record (p. 135)
3. The LARG Data Record (p. 136)
4. The LACS Data Record (p. 137)

Note:

The fifth data record (LALM Data Record (p. 137)) is optional. If it is not defined, default values are used.

11.8.1. The LASB Data Record – Large Angle Stability Calculation Indicator

This data record indicates that the large angle stability calculation is requested. It must be the first data record for defining the large angle stability calculation.

```
  2   5  7   11
 - --- -- ---- ----------------------------------------
|X|   |  |LASB|
 - --- -- ---- ----------------------------------------
       |   |
       |   |_Compulsory Data Record Keyword (A4)
```

```
        |
        |_Optional User Identifier (A2)
```

Note:

If there are multiple structures, this data record can be written only once with the first structure in sequence that requests the large angle stability calculation.

11.8.2. The LAAX Data Record – Large Angle Stability Rotation Axis

This data record defines the rotation axis direction for the large angle stability calculation. Rotation Axis is the axis that the structure actively rotates along, during the large angle stability calculation. It is always located on the water plane. Aqwa calculates the large angle stability along rotation axes of different directions.

```
  2   5  7   11    16    21         31         41
 - --- -- ---- ----- ----- ---------- ---------- --------
|X|   |  |LAAX|XXXXX|     |          |          |
 - --- -- ---- ----- ----- ---------- ---------- --------
       |   |          |       |          |
       |   |          |       |          |_(3)End Direction of Rotation Axes (E10.0)
       |   |          |       |
       |   |          |       |_(2)Start Direction of Rotation Axes (E10.0)
       |   |          |
       |   |          |_(1)Number of Rotation Axes (I5)
       |   |
       |   |_Compulsory Data Record Keyword (A4)
       |
       |_Optional User Identifier (A2)
```

(1)-(3) together define a sequence of direction angles with constant angular increment.

(1) is the total number of rotation axes from the start direction set in (2) to the end direction set in (3).

(2)-(3) give the range of the angular directions of rotation axes. (2) is the start direction angle (in degrees) while (3) is the end direction angle (in degrees). Rotation axis direction is defined in the OXY plane of the fixed reference axes (FRA). The direction is defined as the angle between the rotation axis and the positive global X-axis measured anti-clockwise. For example, the rotation axis direction angle is 0 when the rotation axis is along the positive X-axis of the global axes and 90 degrees when along the positive Y-axis of the global axes. The default values of (2) and (3) are both zero degrees.

Note:

- If (1)-(3) are all empty, the rotation axis direction is set to zero degrees.
- If the number of rotation axes is set by (1) and the range set by (2) and (3) are not consistent, the setting is based on the direction range set by (2) and (3).
- Only one LAAX data record is required for each structure. Subsequent ones, starting from the second data record, will be ignored by the program.

11.8.3. The LARG Data Record – Large Angle Stability Rotation Angle Group

This data record defines a group of rotation angles, of which the structure rotates along the rotation axis during the large angle stability calculation.

```
  2   5  7   11    16    21         31         41         51         61         71
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
|X|   |  |LARG|     |     |          |          |          |          |          |          |
 - --- ------------- ----- ---------- ---------- ---------- ---------- ---------- ----------
      |   |     |     |       |          |           |          |         |          |
      |   |     |     |       |          |           |----------------------------------
      |   |     |     |       |          |           |
      |   |     |     |       |          |           |_(5)Special Individual Rotation Angles
      |   |     |     |       |          |                                          (4E10.3)
      |   |     |     |       |          |
      |   |     |     |       |          |_(4)End Rotation Angle (E10.0)
      |   |     |     |       |
      |   |     |     |       |_(3)Start Rotation Angle (E10.0)
      |   |     |     |
      |   |     |     |_(2)Number of Rotation Angles (I5)
      |   |     |
      |   |     |_(1)Rotation Angle Group Index (I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) is the rotation group index number which is used in the LACS data record (p. 137). The default value is 0.

(2)-(4) define a sequence of rotation angles with constant angular increment. The angular increment value can be calculated by ((4)-(3))/((2)-1) when (2) is larger than 1.

Specifically, (2) is the total number of rotation angles from the start rotation angle set in (3) to the end rotation angle set in (4).

(3) is the start rotation angle, defined in degrees. The default value is 0.

(4) is the end rotation angle, defined in degrees. The default value is 0.

(5) refers to special individual rotation angles that can be added as additional angles to the rotation angle group in the case where the sequence of rotation angles defined by (2)-(4) does not include those angles. The default values are 0.

Note:

- Several rotation LARG data records can be defined for each structure, but the total number of rotation angle groups must not exceed the total number of rotation axes defined in the LAAX data record (p. 135).
- If the number of rotation axes set by (2) and the angular range set by (3) and (4) are not consistent, the setting will be based on the rotation angle range set by (3) and (4).

11.8.4. The LACS Data Record – Large Angle Stability Case

The large angle stability calculation in Aqwa is case-based. This data record defines a large angle stability calculation case which includes the information of a rotation axis direction and a rotation angle group.

```
  2   5  7   11    16    21
 - --- -- ---- ----- ----- -----------------------------
|X|   |  |LACS|     |     |
 - --- -- ---- ----- ----- -----------------------------
      |   |     |     |
      |   |     |     |_(2)Rotation Angle Group Index (I5)
      |   |     |
      |   |     |_(1)Rotation Axis Direction Sequence Index (I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) is the sequence index of the rotation axis direction. The sequence index of the rotation axis direction is based on the LAAX data record (p. 135). The sequence indices start from 1 and sequentially increases by 1 for the rotation axis direction sequence from the start direction to the end direction (defined in (1)-(3) of the LAAX data record (p. 135)).

(2) is the rotation angle group index which is defined in (1) of the LARG data record (p. 136).

Note:

For each structure, the total number of LACS data records must not exceed the total number of rotation axis directions.

11.8.5. The LALM Data Record – Large Angle Stability Calculation Iteration Parameters

This data record inputs parameters which are required for the iteration solution during the large angle stability calculation. The iteration parameters find the large angle position which is balanced in a heave and pitch direction in the rotation axis coordinate system. The progression towards this equilibrium state can also be controlled via the input of this data record. If you do not specify particular convergence limits and the likes, the program uses default values.

Note:

A rotation axis coordinate system is a coordinate system with a positive X-axis along the rotation axis direction, a positive Z-axis along the global positive Z-axis direction, and a Y-axis following the right-hand rule.

```
  2   5  7   11    16    21         31         41         51         61
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- --------------------
|X|   |  |LALM|XXXXX|     |          |          |          |          |
 - --- ------------- ----- ---------- ---------- ---------- ---------- --------------------
      |   |           |       |          |           |          |
      |   |           |       |          |           |          |_(5)Maximum Errors for Pitch
      |   |           |       |          |           |      for System to be Considered
```

```
          |   |           |       |          |           |      in Large Angle Stability
          |   |           |       |          |           |      (E10.0)
          |   |           |       |          |           |
          |   |           |       |          |           |_(4)Maximum Errors for Heave
          |   |           |       |          |              for System to be Considered
          |   |           |       |          |       in Large Angle Stability (E10.0)
          |   |           |       |          |
          |   |           |       |          |_(3)Maximum Pitch Movements allowed per Iteration (E10.0)
          |   |           |       |
          |   |           |       |_(2)Maximum Heave Movements allowed per Iteration (E10.0)
          |   |           |
          |   |           |_(1)Maximum Number of Iterations (I5)
          |   |
          |   |_Compulsory Data Record Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

(1) If you do not specify the maximum number of iterations, the default value of 100 is used.

(2) is the maximum heave movements allowed per iteration with respect to the rotation axis coordinate system. The default value is 0.5 (G=9.81).

(3) is the maximum pitch movements allowed per iteration with respect to the rotation axis coordinate system. The input must be in degrees. The default is 0.573 degrees.

(4) refers to the maximum errors allowed in the final balanced position in the heave direction with respect to the rotation axis coordinate system. This means if the calculated heave movement is less than this, the structure is assumed to be balanced in the heave direction. The default value is 0.02 (G=9.81).

(5) refers to the maximum errors allowed in the final balanced position in the pitch direction with respect to the rotation axis coordinate system. This means if the calculated pitch movement is less than this, the structure is assumed to be balanced in the pitch direction. The input must be in degrees. The default value is 0.057 degrees.

To take into account the varying unit systems, Aqwa multiplies the default translation values only by G/9.81, where G is the value of gravity input in Data Category 5 (p. 99). These defaults are overwritten by any values input in this data record, but Aqwa does not apply any additional factors, which means the value on the data record is the value that is used.

Chapter 12: Drift Force Coefficients - DRC* (Data Category 8)

When entering DRC data categories, the * indicates the structure number; for example, enter DRC1 for Structure 1, DRC2 for Structure 2, ... DR10 for Structure 10.

12.1. General Description

This data category is used to input the regular wave drift forces acting on each structure at the frequencies and directions previously defined in Data Category 6.

The drift forces are applicable to the following programs:

Aqwa-Fer: used to calculate the drift frequency motions in the frequency domain.

Aqwa-Drift: used to calculate the drift frequency motions in the time domain.

Aqwa-Line: used only to change the values of the drift forces in the backing file.

Aqwa-Librium: used to calculate the steady drift forces contributing to the equilibrium position and the dynamic stability of drift frequency motions.

Aqwa-Naut: not applicable.

This data category is used when:

(a) the user wishes to input a database of hydrodynamic coefficients obtained from a source other than Aqwa-Line.

or

(b) the user wishes to change some of the values calculated by a previous Aqwa-Line run, for the current analysis (Aqwa-Fer/ Drift/Librium), or within the backing file (Aqwa-Line only).

The normal mode of operation of the programs using the drift forces is to read these values from the backing file of a previous Aqwa-Line run. Therefore, unless (a) or (b) above apply, the user should omit these data categories by entering 'NONE' for the data category keyword (see Compulsory Data Category Keyword (p. 47) and Omission of Data Categories (p. 50)).

WARNING when running Aqwa-Line

Aqwa-Line handles the hydrodynamic coefficients in sets with each set relating to one frequency. It has two ways to obtain these sets of coefficients.

(a) It can import them from a previously calculated database or from the .DAT file or (for the QTFs) a separate ASCII file

or

(b) it can carry out a radiation/diffraction calculation to calculate them.

These two methods cannot be mixed. If the program imports any data for a particular frequency it assumes all the data is to be imported and does NOT do a calculation for that frequency. This means that if you want to change some of the coefficients for a particular frequency (e.g. the surge drift coefficients) you must:

(1) carry out a "standard" Aqwa-Line radiation/diffraction analysis to populate the whole database

and then

(2) carry out a 2nd Aqwa-Line run, reading in the previously calculated database (.HYD file) and using DRFX data records to change the relevant drift coefficients.

12.2. Data Category Header

```
                      -(Indicates Structure Number)
                     |
       5      11   |
     ---- -- ---- ----
    |XXXX|  |XXXX|DRC1|
     ---- -- ---- ----
          |        |
          |        |_Compulsory Data Category Keyword(A4)
          |
          |_Optional User Identifier(A2)
```

12.3. The FREQ/PERD/HRTZ Data Records - Frequencies/Periods at which the Drift Coefficients are defined

Any one of these data records will define the frequency/period number and value at which the following drift coefficients apply. This frequency/period is operative until another FREQ/PERD/HRTZ data record is encountered.

```
      2   5  7   11    16    21
    - --- -- ---- ----- ----- ---------
   |X|   |  |FREQ|XXXXX|     |         |
    - --- -- ---- ----- ----- ---------
   |X|   |  |PERD|XXXXX|     |         |
    - --- -- ---- ----- ----- ---------
   |X|   |  |HRTZ|XXXXX|     |         |
    - --- -- ---- ----- ----- ---------
      |  |   |           |       |
      |  |   |           |       |_(2)Frequency/Period Value
      |  |   |           |            (FREQ=radians/sec)
      |  |   |           |            (PERD=seconds)
      |  |   |           |            (HRTZ=hertz)(F10.0)
      |  |   |           |
      |  |   |           |_(1)Frequency/Period Number(I5)
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
```

```
       |
       |_Compulsory END on last data record in data category(A3)
```

(1) This is the number of the frequency/period, as specified in Data Category 6.

(2) The frequency/period Value should be the same as that specified in Data Category 6 and is used only as a check that the frequency number (1) has been input correctly. It does not re-define the frequency value. If the values are not the same, an error will occur.

12.4. The DRFX/DRFY/DRRZ Data Records - Drift Force Coefficients

The frequency/period to which the values of the following drift coefficients apply are given by the preceding FREQ/PERD/HRTZ data record.

```
     2   5  7   11    16    21        31        41
    - --- -- ---- ----- ----- --------- --------- --------- ---------
   |X|   |  |DRF*|     |     |         |         |         |         ...
    - --- -- ---- ----- ----- --------- --------- --------- ---------
   |X|   |  |DRR*|     |     |         |         |         |         ...
    - --- -- ---- ----- ----- --------- --------- --------- ---------
       |  |   |     |     |       |         |         |         |
       |  |   |     |     |       |------------------------------------
       |  |   |     |     |       |
       |  |   |     |     |       |_(4)-(9)Up to 6 Drift Coefficients(6E10.0)
       |  |   |     |     |
       |  |   |     |     |_(3)Terminal Direction Number(I5)
       |  |   |     |
       |  |   |     |_(2)Initial Direction Number(I5)
       |  |   |
       |  |   |_(1)Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on last data record in data category(A3)
```

(1) The data record keyword indicates the freedom of the structure, as defined in the Fixed Reference Axis system (FRA), to which the drift coefficients apply, where:

DRFX - X translational freedom of motion

DRFY - Y translational freedom of motion

DRFZ - Z translational freedom of motion

DRRX - X rotational freedom of motion

DRRY - Y rotational freedom of motion

DRRZ - Z rotational freedom of motion, i.e. XY plane rotation

(2)-(3) These are the directions, as defined in Data Category 6, to which the values of the drift coefficients in columns 21-80 apply, e.g.

```
     ----------------------------------------------------
    |If the Drift Coefficient(s)  |  Initial  | Terminal  |
    |Correspond(s) to Direction(s)| Direction | Direction |
    |-----------------------------+-----------+-----------|
    |      1,2,3,4,5 and 6        |     1     |     6     |
    |-----------------------------+-----------+-----------|
    |        4,5,6, and 7         |     4     |     7     |
```

```
      |----------------------------+-----------+-----------|
      |             3              |     3     |     3     |
       ---------------------------------------------------- 
```

(4)-(9) These are the values of the drift coefficients which are defined at the directions specified by (2) and (3) and at the frequency/period specified on the preceding FREQ/PERD/HRTZ data record. Note that when less than 6 coefficients are input on one data record, the values in the extra fields on the data record are ignored.

12.5. The CQTF Data Record - Import of QTF Database

The CQTF data record is used to import fully coupled QTF coefficients. Both difference and sum frequency values must be input, even if the sum frequency values are not required. (Use the SQTF option (Administration and Calculation Options for the Aqwa Suite (p. 314)) to include sum frequencies in an analysis).

Note that import of external QTF coefficients is a "post-processing" operation that must be done after the hydrodynamic database has been created. This means that the CQTF data record will normally be used in the same run as a CPDB data record is used to import a previously calculated hydrodynamic database. It cannot be used in a full radiation/diffraction analysis, i.e. with wave frequencies and directions defined in Data Category 6.

The format of the CQTF data record is as follows.

```
       2   5  7   11    16    21
     - --- -- ---- ----- ----- ---------
    |X|   |  |CQTF|     |XXXXX|
     - --- -- ---- ----- ----- ---------
        |  |   |     |            |
        |  |   |     |            |_(2)File containing QTF values in AQWA format(A108)
        |  |   |     |
        |  |   |     |_(1) Structure number from which the QTF values are to be copied(I5)
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last data record in data category(A3)
```

(1) QTFs are copied from this structure in the QTF file to the structure number indicated by the data category keyword (DRC* data record).

(2) The format of the input file is the same as the format of the `.QTF` file written by Aqwa when the AQTF option is used. The `.QTF` file is ASCII with the first line containing the version number of the file itself and optional user title. All files must start with version 1.0 or version 2.0. A simple example using fixed format is shown here and the formatting is explained in detail below.

Version 2.0 of the AQTF format was created to accommodate the increase in maximum number of frequencies from 50 to 100.

```
AQTF-2.0 :Example - Fully-Coupled SUMM/DIFF QTF
  1  4   3          0.00000    30.00000    45.00000    90.00000
                  0.3490659   0.4188791   0.5235988
  1  4   2   3  -1.4695E-03  4.8995E+05 -7.4829E+03 -1.0434E+07  2.9763E-01 -2.1092E+04
                -5.0714E-03  3.1427E+03 -2.0972E+03 -3.4310E+04  5.3036E-02 -2.4030E-01
                 1.3916E-01  1.1357E+06  1.2190E+03 -8.1649E+06  6.3355E-01 -1.9725E+04
                 1.0582E-01  7.0678E+05  1.2178E+03 -4.6883E+06  1.0078E+00 -7.8328E+03
```

The format descriptions below make use of FORTRAN style codes. The meaning of these is:

nX	n spaces
nIw	n integers in columns of w characters
nFw	n floating point numbers in columns of width w characters
nEw	n exponential numbers in columns of width w characters

AQTF-1.0 or AQTF-2.0: User title

A FREE_FORMAT keyword may be input if free format is required. Free format will allow the user to input the data in any columns as long as the correct number of data items is input.

Then for each structure:

(Str no.) (No. of Directions) (No. of Frequencies) (Direction values)

(a) V1.0: the fixed format is (3I2,2X,6F12.4)

(b) V2.0: the fixed format is (2I3,I4,5X,6F12.4)

If there are more than 6 directions, the remaining directions are input in blocks of 6.

(a) V1.0: the fixed format is (8X,6F12.4)

(b) V2.0: the fixed format is (15X,6F12.4)

The frequencies are then input in blocks of 6

(a) V1.0: the fixed format is (8X,6F12.4)

(b) V2.0: the fixed format is (15X,6F12.7)

The QTF data is then input as follows:

(a) V1.0: the fixed format is (4I2,6E12.4), then (8X,6E12.4)

(b) V2.0: the fixed format is (2I3,2I4,1X,6E12.4), then (15X,6E12.4)

(Str no.) (Dirn no.) (Freq#1) (Freq#2) (6* REAL Difference frequency QTF values)

(6* IMAG Difference frequency QTF values)

(6* REAL Sum frequency QTF values)

(6* IMAG Sum frequency QTF values)

This is then repeated until all the frequencies/directions have been input for this structure, a total of (No. of Directions)*(No. of Frequencies)*(No. of Frequencies) logical records.

QTF values for another structure may then follow.

Chapter 13: Drift Motion Parameters - DRM* (Data Category 9)

When entering DRM data categories, the * indicates the structure number; for example, enter DRM1 for Structure 1, DRM2 for Structure 2, ... DR10 for Structure 10.

13.1. General Description

This data category is used to input the added mass and damping at drift frequency, and the non-linear drag forces due to the yaw motion of the structure at drift frequency, for each structure.

The coefficients are applicable to the following programs:

Aqwa-Fer: Used only to calculate the drift frequency motions in the frequency domain. They are not applicable when using Aqwa-Fer for the calculation of wave frequency motions.

Aqwa-Drift: Used to calculate the drift frequency motions in the time domain.

Aqwa-Line: May be input for scaling (see Change Geometric/Mass Characteristics - GMCH (Data Category 16L) (p. 277)).

Aqwa-Librium: Used to calculate the dynamic stability of the drift frequency motions. They are not applicable when using Aqwa-Librium to calculate the static equilibrium position.

Aqwa-Naut: Although Aqwa-Naut does not include any drift forces, frequency independent added mass and damping input using the FIDA and FIDD data records is used.

The Yaw-Rate Drag Forces

In general, a structure with yaw velocity, in the presence of a current, experiences non-linear drag forces additional to those present when the structure is stationary. These forces are referred to as yaw-rate drag forces and are zero when there is no yaw velocity. The forces act only in the surge, sway and yaw (translational X,Y and rotational Z) directions and are a function of the local water velocity and the geometry of the structure, for a fully-developed wake (i.e. they are only applicable at drift frequency).

The user is required to specify an average drag force coefficient, and a length along which the local drag force is integrated, to give the total forces on the structure.

A linearized form of the force equation is used in the calculations of motions (Aqwa-Fer, if LDRG (p. 316) option is on) and, in general, the yaw rate drag forces do not strongly influence the results.

13.2. Data Category Header

```
                     -(Indicates Structure Number)
                    |
        5      11   |
  ---- -- ---- ----
 |XXXX|  |XXXX|DRM1|
  ---- -- ---- ----
       |        |
       |        |_Compulsory Data Category Keyword(A4)
       |
       |_Optional User Identifier(A2)
```

13.3. The DGAM Data Record - Diagonal Added Mass Matrix

This data record is invalid if the convolution method is used, i.e. CONV option is on, in time domain analysis. The values used in the analysis will be calculated within the program.

```
     2   5  7   11         21
  - --- -- ---- ---------- --------- --------- ------
 |X|   |  |DGAM|XXXXXXXXXX|         |         |      ...
  - --- -- ---- ---------- --------- --------- ------
    |  |   |                  |         |         |
    |  |   |                  |------------------------
    |  |   |                  |
    |  |   |                  |_(1)Up to 6 Added Mass
    |  |   |                       Coefficients(6E10.0)
    |  |   |
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data categoy(A3)
```

(1) These 6 values specify the Drift Added Mass of the structure indicated by the Data Category Keyword, at each of the 6 degrees of freedom of motion.

Typical values of drift added mass for a ship structure in the surge, sway direction are 10 to 100 per cent of the mass of displaced water. The rotational inertia in yaw is typically the same as that of the displaced water (i.e. the same as a solid mass of the same density and shape as that of the displaced water).

13.4. The DGDP Data Record - Diagonal Damping Matrix

This data record is invalid if the convolution method is used, i.e. CONV option is on, in a time domain analysis. The drift frequency damping will default to zero. If additional damping is to be added for the drift frequency motion, one should use the frequency independent damping defined by the FIDD data record (The FIDA/FIDD Data Record - Frequency Independent Additional Diagonal Added Mass and Damping (p. 148)).

```
     2   5  7   11         21        31        41
  - --- -- ---- ---------- --------- --------- --------- ---------
 |X|   |  |DGDP|XXXXXXXXXX|         |         |         |         ...
  - --- -- ---- ---------- --------- --------- --------- ---------
    |  |   |                  |         |         |         |
    |  |   |                  |------------------------------------
    |  |   |                  |
    |  |   |                  |_(1)Up to 6 Damping Coefficients(6E10.0)
```

```
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data categoy(A3)
```

(1) These 6 values specify the Drift Damping of the structure indicated by the Data Category Keyword, at each of the 6 degrees of freedom of motion.

Typical values of damping for a ship structure in the surge,sway and yaw direction range between 1 and 10 per cent of critical. For freedoms where there is no mooring stiffness, the critical damping is not defined. In this event, reference should be made to the literature.

Note:

In the present version of the program, only the surge, sway (X and Y translation) and yaw (Z rotation) need to be specified. This also means that there are no off-diagonal terms in the damping matrix.

13.5. The LFAD Data Record - Use Lowest Wave Frequency Added Mass and Damping for Drift Frequency Analysis

The default low frequency added mass is the added mass calculated in Aqwa-Line at the lowest wave frequency.

The default low frequency damping is zero.

```
      2   5  7    11
     - --- -- ----
    |X|   |  |LFAD|
     - --- -- ----
        |  |   |
        |  |   |
        |  |   |
        |  |   |
        |  |   |
        |  |   |_Optional Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data categoy(A3)
```

Note:

- When this data record is on, the DGAM and DGDP data records should be omitted, and the program will use the added mass and damping calculated in Aqwa-Line at lowest wave frequency for drift frequency analysis.

- When the convolution method is used, i.e. CONV option is on, in a time domain analysis, Aqwa automatically calculates the low frequency (asymptotic) added mass and this data record is ignored. Any additional added mass or damping should be frequency-independent, specified using the FIDA, FIDD, FIAM or FIDP data records (The FIDA/FIDD Data Record -

Frequency Independent Diagonal Added Mass/Damping (p. 131) and The FIAM/FIDP Data Record - Frequency Independent Added Mass/Damping Matrices (p. 129)).

13.6. The YRDP Data Record - Yaw-Rate Drag Parameters

```
    2   5  7   11    16    21
  - --- -- ---- ----- ----- ---------
 |X|   |  |YRDP|     |     |         |
  - --- -- ---- ----- ----- ---------
     |  |   |     |     |       |
     |  |   |     |     |       |
     |  |   |     |     |       |_(3)Yaw-Rate Drag Coefficient(E10.0)
     |  |   |     |     |
     |  |   |     |     |_(2)Second Node Number(I5)
     |  |   |     |
     |  |   |     |_(1)First Node Number(I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data categoy(A3)
```

(1)-(2) These node numbers specify the positions defining the 'length' on the geometric center of the structure along which the drag force is integrated.

For ship structures these nodes should be positioned where the longitudinal centerline cuts the water-plane at the bow and stern.

For a structure whose plan section (viewed along the negative Z axis) is more square than a ship, the positions of the nodes (1) and (2) should be at the ends of a horizontal diagonal across the structure.

(3) The yaw-rate drag coefficient is the force per unit length per unit velocity squared where the velocity is that of a side-on current (i.e. a current at right angles to the direction along which its 'length' is defined). A function of this force, together with the local current velocity is integrated along the 'length' of the structure to give the total drag force.

The yaw-rate drag coefficient will depend on the cross sectional shape of the structure which generally varies along the 'length'. As the coefficient is assumed constant it therefore represents an average value.

Note:

For structures where the cross sectional area varies greatly along its length, the choice of node positions and the yaw-rate drag coefficient becomes more complicated and reference should be made to the literature.

13.7. The FIDA/FIDD Data Record - Frequency Independent Additional Diagonal Added Mass and Damping

These data records may be used to input a diagonal added mass (FIDA) or diagonal linear damping (FIDD) in addition to what will be calculated by the program.

Note that these data records can also be used in Data Category 7 in Aqwa-Line. The difference is that when used in Data Category 7, the RAO calculation in Aqwa-Line will include the additional added mass and damping, and when used in Data Category 9, there will be no effect on the Aqwa-Line results. If FIDA or FIDD is used in Data Category 9 in a current Aqwa-Drift or Naut analysis while it is already used in Data Category 7 in a preceding Aqwa-Line analysis, the program will use the values in Data Category 9. In a frequency domain analysis using Aqwa-Fer, the RAOs will be recalculated within the program, and if FIDA/FIDD is defined in Data Category 9, it will be included in the RAO calculation.

```
    2   5  7   11         21        31        41
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |FIDA|  XXXXX    |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |FIDD|  XXXXX    |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
     |  |   |                  |         |         |
     |  |   |                  |---------------------
     |  |   |                  |
     |  |   |                  |_(2)-(7)6 Added Mass/Damping Values(6F10.0)
     |  |   |
     |  |   |
     |  |   |
     |  |   |_(1)Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data categoy(A3)
```

(1) This data record keyword indicates whether the values refer to the added mass (FIDA) or damping (FIDD).

(2)-(7) These are the diagonal values in the 6 X 6 wave drift damping matrix.

13.8. The FIAM/FIDP Data Record - Frequency Independent Additional Added Mass/Damping Matrices

These data records may be used to input an added mass (FIAM) or linear damping (FIDP) matrix additional to that input or calculated. The values input will add to any values previously input via data records or backing file.

As these are frequency independent parameters, the values defined in the FIAM and FIDP data records will apply to all the frequencies. Therefore there is no preceding FREQ/PERD/HRTZ data record for FIAM and FIDP.

```
    2   5  7   11    16    21        31        41
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |FIAM|XXXXX|     |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |FIDP|XXXXX|     |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
     |  |   |           |       |         |         |
     |  |   |           |       |---------------------
     |  |   |           |       |
     |  |   |           |       |_(3)-(8)6 Added Mass/Damping Values(6F10.0)
     |  |   |           |
     |  |   |           |_(2)Row Number of Added Mass/Damping Matrix(I5)
     |  |   |
     |  |   |_(1)Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data categoy(A3)
```

(1) This data record keyword indicates whether the values refer to the added mass (FIAM) or damping (FIDP).

(2) This number indicates the row of the added mass/damping matrix to which the values in columns 21-80 correspond.

(3)-(8) These are the values which add to those in the existing frequency independent added mass or damping matrix.

13.9. The FILE Data Record - Copy from File

This data record is used to define the name of a file from which the directional coupled QTFs can be copied. The file name or unit remains active until another FILE data record is input. If this data record is not present, there is no interaction between waves from different directions.

```
   2   5  7   11    16    21
 - --- -- ---- ----- ----- ---------
|X|   |  |FILE|XXXXX|XXXXX|
 - --- -- ---- ----- ----- ---------
    |  |   |                  |
    |  |   |                  |_(1)Filename
    |  |   |
    |  |   |_Compulsory card header(A4)
    |  |
    |  |_Optional user identifier(A2)
    |
    |_Compulsory END on last card in deck(A3)
```

(1) This is a file name, usually a `.MQT` file from a previous Aqwa-Line analysis when the MQTF (p. 317) option is requested, from which the database is to be copied.

Note:

A CSTR (p. 150) data record is also required to specify which structure's QTFs are to be copied from the specified file.

13.10. The CSTR Data Record - Copy from Structure Number

This data record is used to change the structure number from which the directional coupled QTFs are to be copied. This structure number remains operative until another CSTR data record is input.

```
   2   5  7   11
 - --- -- ---- -----
|X|   |  |CSTR|     |
 - --- -- ---- -----
    |  |   |     |
    |  |   |     |
    |  |   |     |_Structure number
    |  |   |
    |  |   |_Compulsory Card Header(A4)
    |  |
    |  |_Optional User Identifier(A2)
```

```
    |
    |_Compulsory END on Last card in deck(A3)
```

Note:

A FILE (p. 150) data record is also required to specify the file from which the QTFs are to be read.

Chapter 14: Hull Drag Coefficients and Thruster Forces - HLD* (Data Category 10)

When entering HLD data categories, the * indicates the structure number; for example, enter HLD1 for Structure 1, HLD2 for Structure 2, ... HL10 for Structure 10.

14.1. General Description

This data category is used to input the hull drag coefficients and thruster forces, for each structure.

The hull drag coefficients are input for a defined number of wave directions. Coefficients can be input for all 6 degrees of freedom. The coefficients are divided into two distinct categories. The first relates to the forces on the submerged part of the hull, due to current, and the second relates to the forces on the freeboard section of the hull and superstructure, due to wind.

Up to 10 thruster forces and their positions may be specified, for each structure. These forces are assumed to be constant in magnitude throughout the analysis.

The coefficients applicable to the following programs:

Aqwa-Fer: Used only to calculate the drift frequency motions in the frequency domain. N.B. they are NOT applicable for wave frequency motion

Aqwa-Drift: Used to calculate the drift frequency motion in the time domain.

Aqwa-Line: Not applicable

Aqwa-Librium: Used to calculate dynamic stability of drift frequency motion and forces contributing to the static equilibrium position.

Aqwa-Naut: Used to calculate motions in the time domain

14.2. Data Category Header

```
                    -(Indicates Structure Number)
                    |
      5      11  |
 ---- -- ---- ----
|XXXX|  |XXXX|HLD1|
 ---- -- ---- ----
      |        |
      |        |_Compulsory Data Category Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

14.3. The CUFX/CUFY/CURZ Data Record - Current Force Coefficients and the WIFX/WIFY/WIRZ Data Record - Wind Force Coefficients

```
    2   5  7   11    16    21        31        41        51
  - --- -- ---- ----- ----- --------- --------- --------- ---------
 |X|   |  |CUFX|     |     |         |         |         |         ...
  - --- -- ---- ----- ----- --------- --------- --------- ---------
 |X|   |  |CUFY|     |     |         |         |         |         ...
  - --- -- ---- ----- ----- --------- --------- --------- ---------
 |X|   |  |CURZ|     |     |         |         |         |         ...
  - --- -- ---- ----- ----- --------- --------- --------- ---------
 |X|   |  |WIFX|     |     |         |         |         |         ...
  - --- -- ---- ----- ----- --------- --------- --------- ---------
 |X|   |  |WIFY|     |     |         |         |         |         ...
  - --- -- ---- ----- ----- --------- --------- --------- ---------
 |X|   |  |WIRZ|     |     |         |         |         |         ...
  - --- -- ---- ----- ----- --------- --------- --------- ---------
    |  |   |     |     |       |         |         |         |
    |  |   |     |     |       |         |         |         |
    |  |   |     |     |       |-----------------------------------
    |  |   |     |     |       |
    |  |   |     |     |       |_(4)-(9)Up to 6 Force Coefficients(6E10.0)
    |  |   |     |     |
    |  |   |     |     |_(3)Terminal Direction Number(I5)
    |  |   |     |
    |  |   |     |_(2)Initial Direction Number(I5)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1) The data record keyword indicates the freedom of the structure, as defined in the Fixed Reference Axis system (FRA), to which the force coefficients apply where

CUFX/WIFX - X translational freedom of motion (SURGE)

CUFY/WIFY - Y translational freedom of motion (SWAY)

CURZ/WIRZ - Z rotational freedom of motion (YAW), i.e. rotation in the XY plane

Similar conventions apply to forces or moments in heave (CUFZ/WIFZ), roll (CURX,WIRX), and pitch (CURY,WIRY). CUFZ may be utilized to simulate the sinkage effect that can be induced due to forward speed or high current. The RX and RY parameters can be included to account for the distance between the physical center of load application and the position of the center of gravity where the actual load will be applied in the numerical model.

(2)-(3) These are the directions, as defined using the DIRN data records (either within this data category or in the Frequencies and Directions data category), to which the values of the force coefficients in columns 21-80 apply, e.g.

```
 -----------------------------------------------------
|If the Force Coefficient(s)  |  Initial  | Terminal  |
|Correspond(s) to Direction(s)| Direction | Direction |
|-----------------------------+-----------+-----------|
|      1,2,3,4,5 and 6        |     1     |     6     |
|-----------------------------+-----------+-----------|
|        4,5,6, and 7         |     4     |     7     |
|-----------------------------+-----------+-----------|
```

```
          |              3              |     3     |     3     |
           -----------------------------------------------------
```

(4)-(9) These are the values of the force coefficients which are defined at the directions specified by (2) and (3). When less than 6 coefficients are input, the values in the extra fields on the data record are ignored.

Note:

- The current and wind force coefficients are defined as the force or moment per unit velocity squared. The moment is about the center of gravity of the structure or the combined center of gravity of mass of the structure and the liquid in the internal tanks if there are internal tanks associated with the structure.
- These forces are a function of the relative velocity between the structure and current/wind. This means that the current/wind coefficient should still be input even when there is no current/wind present, as the relative velocity is generally non-zero for a dynamic analysis, even when there is no current/wind present.
- When profiled currents are used in conjunction with the CUFX, CUFY, and CURZ commands, the DPOS (p. 162) or DDEP (p. 162) data record must also be specified. If one of these data records is not specified, the current profile is ignored and a warning is issued.

14.4. The THRS Data Record - Thruster Forces

N.B. A maximum of 10 thruster forces may be specified on each structure, i.e. up to 10 thruster data records may be input within a data category.

```
   2   5  7   11    16    21        31        41
  - --- -- ---- ----- ----- --------- --------- ---------
 |X|   |  |THRS|XXXXX|     |         |         |         |
  - --- -- ---- ----- ----- --------- --------- ---------
     |  |   |           |       |         |         |
     |  |   |           |       |         |         |
     |  |   |           |       |-------------------
     |  |   |           |       |
     |  |   |           |       |_(2)-(4)X,Y,Z Components of Force(6E10.0)
     |  |   |           |
     |  |   |           |
     |  |   |           |_(1)Node Number(I5)
     |  |   |
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data category(A3)
```

(1) This node number and its corresponding position (defined in Data Category 1) specifies the position on the structure at which the Thruster Force (2)- (4) acts.

(2)-(4) These are the three components of force in the X,Y, and Z directions (see note below) exerted by the thruster at the position of the node (1) specified.

Note:

The magnitude of the thruster forces is assumed to be constant throughout the analysis. The three components of force define the direction relative to the structure which is also assumed constant. This means that their direction relative to the Fixed Reference Axis system (FRA) will change with the structure position; for example, if the thruster force is defined with a component in the X direction only (i.e. zero for parameters (3) and (4)) and the structure at some stage of the analysis is yawed (Z rotation) by 90 degrees, then the direction of the force will act in the Y direction of the Fixed Reference Axes (FRA).

14.5. The NLRD/BOFF/BASE/BKRD Data Records - Nonlinear Roll Damping

Nonlinear roll damping moment can be calculated in Aqwa time domain and frequency statistical analyses to take into account the effect of vortex shedding from the bilges and bilge keels of a vessel. For frequency domain solutions, the LDRG (p. 316) option should be added.

The method for bilge vortex shedding is based on "An Engineering Assessment of the Role of Non-linearities in Transportation Barge Roll Response", Robinson and Stoddart, Trans. R.I.N.A 1986.

The method for bilge keel roll damping is based on "ITTC recommended procedures 7.5-02-07-04.5 - Numerical estimation of roll damping", 2011.

The following three data records are needed for the program to calculate the bilge vortex moment. Whether vortex shedding is occurring or not is calculated by the program based on the relative flow velocity at the bilge, Keulegan-Carpenter number, roll natural frequency of the vessel, and the radius of the bilge. The roll damping coefficient used in the nonlinear roll damping force calculation is also calculated by the program based on a database stored within the program.

```
   2   5  7   11    16    21        31        41
 - --- -- ---- ----- ----- --------- --------- ---------
|X|   |  |NLRD|   XXXXXXXXXXXXXX
 - --- -- ---- ----- ----- --------- --------- ---------
|X|   |  |BOFF|     |     |         |
 - --- -- ---- ----- ----- --------- --------- ---------
|X|   |  |BASE|     |     |XXXXXXXXX|
 - --- -- ---- ----- ----- --------- --------- ---------
    |  |   |     |     |       |
    |  |   |     |     |       |
    |  |   |     |     |       |_(3)Bilge Radius (only for BOFF data record) (F10.0)
    |  |   |     |     |
    |  |   |     |     |_(2)Node Number Two(I5)
    |  |   |     |
    |  |   |     |_(1)Node Number One(I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
```

```
     |_Compulsory END on last data record in data category(A3)
```

Note:

No parameters are required for the NLRD data record

(1)-(2) On the BOFF data record, these two nodes define the lateral and vertical position of the two bilges. They should be at opposite ends of a line that is perpendicular to the line defined by the nodes on the BASE data record. These define B_b and D_b in Figure 7.2: Ship-Like Cross Section with Bilge in the *Aqwa Theory Manual*.

On the BASE data record, these two nodes define the longitudinal extent of the bilges (two bilges are assumed to have the same longitudinal extent). They should normally be on the centerline of the vessel. Z is unimportant but is normally near the baseline. These define L_b in Equation 7.5 in the *Aqwa Theory Manual*

(3) This value is the bilge radius (assuming the two bilges have the same radius), and is only for BOFF data record. This is r_b in Figure 7.2: Ship-Like Cross Section with Bilge in the *Aqwa Theory Manual*.

If the bilge keel roll damping is involved, an additional data record is required:

```
  2   5  7   11    16    21        31        41        51        61
 - --- -- ---- ----- ----- --------- --------- --------- --------- ---------
|X|   |  |BKRD|     |     |         |         |         |         |
 - --- -- ---- ----- ----- --------- --------- --------- --------- ---------
    |  |   |                  |         |         |         |         |
    |  |   |                  |         |         |         |         |_(5)Bilge keel breadth (F10.0)
    |  |   |                  |         |         |         |
    |  |   |                  |         |         |         |_(4)Bilge keel length (F10.0)
    |  |   |                  |         |         |
    |  |   |                  |         |         |_(3)Mid-ship section coefficient (F10.0)
    |  |   |                  |         |
    |  |   |                  |         |_(2)Breadth of vessel (F10.0)
    |  |   |                  |
    |  |   |                  |_(1)Draft of vessel (F10.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1) d in Figure 7.2: Ship-Like Cross Section with Bilge in the *Aqwa Theory Manual*.

(2) B in Figure 7.2: Ship-Like Cross Section with Bilge in the *Aqwa Theory Manual*.

(3) C_m in Bilge Keel Damping in the *Aqwa Theory Manual*.

(4) L_{BK} in Equation 7.8 in the *Aqwa Theory Manual*.

(5) b_{BK} in Equation 7.7 in the *Aqwa Theory Manual*.

14.6. The MDIN/MDSV Data Records - Morison Hull Drag

These data records provide a facility for the hull drag force on a diffracting structure to be calculated in a similar way to that for Morison element, i.e. the structure motion in six degrees of freedom is taken into account in the drag force calculation.

```
               _           _       _        _
Drag Force = |             |      |Vx.mod(Vx)|
             |   6 x 6     |      |Vy.mod(Vy)|
             |   matrix    |      |Vz.mod(Vz)|
             |     of      |  *   |Rx.mod(Rx)|
             |coefficients|       |Ry.mod(Ry)|
             |_           _|      |Rz.mod(Rz)|
```

14.6.1. The MDIN Data Record

```
     2   5  7   11    16    21        31        41
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |MDIN|     |     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
      |  |   |     |     |        |
      |  |   |     |     |        |_(4)-(9)6 Coefficients (6F10.0)
      |  |   |     |     |
      |  |   |     |     |_(3)Column number in the coefficient matrix (I5)
      |  |   |     |
      |  |   |     |_(2)Row number in the coefficient matrix(I5)
      |  |   |
      |  |   |_(1)Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This data record keyword indicates that the drag force on this structure is to be calculated as Morison hull drag using the coefficients specified.

(2)-(3) Row number and column number of the coefficients. These entries are interpreted as follows:

(a) Row and column number zero or omitted: The 6 values are assigned to the lead diagonal.

(b) Row only specified: The 6 values are assigned to the specified row.

(c) Column only specified: The 6 values are assigned to the specified column.

(d) Row and column specified: The value of C is assigned to the specified row/column. The coefficient C must be in columns 21 - 30.

The default fluid velocity U is relative steady fluid velocity for translational freedoms, i.e:

U(translational) = U(uniform + current profile) - U(structure)

U(rotational) = -U(structure)

These default values can be changed by using the MDSV data record (see below).

The current velocity used is always that at the center of gravity. The DDEP (p. 162) and DPOS (p. 162) data records have no effect on this drag calculation.

14.6.2. The MDSV Data Record

```
    2   5  7   11    16    21        31        41
  - --- -- ---- ----- ----- --------- --------- ------
 |X|   |  |MDSV|     |     |         |         |      ...
  - --- -- ---- ----- ----- --------- --------- ------
     |  |   |     |     |
     |  |   |     |     |
     |  |   |     |     |
     |  |   |     |     |_(3)Finish freedom number(I5)
     |  |   |     |
     |  |   |     |_(2)Start freedom number(I5)
     |  |   |
     |  |   |_(1)Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data category(A3)
```

(1) This data record may (optionally) be used in conjunction with the MDIN (p. 158) data record to change the value of the relative fluid velocity used in the calculation of the Morison hull drag. It specifies that the structure velocity only is to be used for translational freedoms. For example,

```
MDSV     1     2
```

will cause structure velocity only to be used for X and Y freedoms.

14.7. The IUFC/RUFC Data Records - External Forces

Aqwa-Drift and Naut can accept forces calculated in an external routine, at each timestep. This is done by calling a routine called user_force, which is stored in a file called `user_force.dll` in the Aqwa installation directory. See External Force Calculation (p. 323) for a description of how to use this capability. Up to 200 control parameters (100 integers and 100 reals) can be passed to the user_force routine using the IUFC and RUFC data records described below.

Note:

Although these data records can be entered under any structure number (denoted on the HLD* header for this data category), they are not specific to any particular structure. If the same parameter number is entered on two data records, even if they are under different structures, the second entry overwrites the first.

```
    2   5  7   11    16    21        31        41        51        61
  - --- -- ---- ----- ----- --------- --------- --------- --------- ---
 |X|   |  |IUFC|     |     |         |         |         |         |   ...
  - --- -- ---- ----- ----- --------- --------- --------- --------- ---
 |X|   |  |RUFC|     |     |         |         |         |         |   ...
  - --- -- ---- ----- ----- --------- --------- --------- --------- ---
     |  |   |     |     |       |         |         |         |
     |  |   |     |     |       |-----------------------------------------
     |  |   |     |     |       |
```

```
        |  |   |     |     |       |_(3)-(8)Up to 6 integer (IUFC)
        |  |   |     |     |                        or real (RUFC) parameters
        |  |   |     |     |
        |  |   |     |     |_(2)Last parameter number (I5)
        |  |   |     |
        |  |   |     |_(1)1st parameter number(I5)
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category (A3)
```

These data records can be repeated until all the required parameters are defined.

14.8. The DIRN Data Record - Directions at which the Drag Coefficients are Defined

If this data record is not present the directions used for the drag coefficients are those defined on the DIRN data records in Data Category 6.

```
     2   5  7   11    16    21        31        41
   - --- -- ---- ----- ----- --------- --------- ------
  |X|   |  |DIRN|     |     |         |         |      ...
   - --- -- ---- ----- ----- --------- --------- ------
      |  |   |     |     |       |         |         |
      |  |   |     |     |       |----------------------
      |  |   |     |     |       |
      |  |   |     |     |       |_(3)-(8)Up to 6 Values of Direction(6F10.0)(DEGREES)
      |  |   |     |     |
      |  |   |     |     |
      |  |   |     |     |_(2)Terminal Direction Number(I5)
      |  |   |     |
      |  |   |     |_(1)Initial Direction Number(I5)
      |  |   |
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category (A3)
```

(1)-(2) These are the direction numbers associated with the values in columns 21-80. The first number refers to the first value input (columns 21-30) and the second number refers to the last value input.

(3)-(8) These are the values of direction at which the following hull drag coefficients are to be defined. These values are associated with the numbers defined in columns 11-20. The following rules govern input of directions:

(a) Direction numbers must be unique.

(b) There must be no gaps in direction numbers; for example, if five directions are input then these must be numbered 1 through 5.

(c) Directions must be distinct and unique.

(d) If no symmetry is defined, direction values must be input for the directions from -180° to 180°.

If SYMX is specified, direction values must be input for the directions from -180° to 0° or from 0° to -180°.

If SYMY is specified, direction values must be input for the directions from -90° to +90° or from +90° to -90°.

If both SYMX and SYMY are specified, direction values must be input for one 90° quadrant.

(e) When all data records in this data category have been input, ascending numbers must correspond to ascending direction values.

(f) Although more than one direction data record can be used, the total number of directions cannot exceed 41. 41 directions can be input when there is no symmetry, 21 directions can be input when there is one plane of symmetry, and 11 directions when there are two symmetry planes. Symmetry for hull drag coefficients is defined using the SYMX and SYMY data records in Data Category 10.

(g) The directions defined here for drag coefficients are distinct from those used for the wave directions. They do not have to be the same in number or value as those in Data Category 6.

14.9. SYMX and SYMY Data Records - X AND Y Symmetry

These data records may be used to reduce the number of coefficients that have to be written in Data Category 10. SYMX means that the following coefficients are symmetric about the global X-Z plane, and SYMY means that they are symmetric about the global Y-Z plane.

Note:

This data category cannot specify a greater degree of symmetry than is defined for the structure in Data Category 2. In other words, SYMX/SYMY cannot be used here if the structure does not have the corresponding symmetry.

```
    2   5  7
  - --- -- ----
 |X|   |  |SYMX|
  - --- -- ----
 |X|   |  |SYMY|
  - --- -- ----
     |  |   |
     |  |   |_(1)Symmetry Specification(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on Last
       Data Record in Data Category.(A3)
```

1) The same restrictions on directions apply as for the diffraction analysis directions in Data Category 6.

If no symmetry is defined, coefficients must be input for the directions from -180° to 180°.

If SYMX is specified, coefficients must be input for the directions from -180° to 0° or from 0° to -180°.

If SYMY is specified, coefficients must be input for the directions from -90° to +90° or from +90° to -90°.

If both SYMX and SYMY are specified, coefficients must be input for one 90° quadrant.

14.10. The DPOS Data Record - Position for Drag Calculation

When calculating the current hull drag on a structure, this data record defines a position on the structure at which the current is "measured".

```
   2   5  7   11    16    21    26    31         41         51         61
 - --- -- ---- ----- ----- ----- ----- --------- ---------
|X|   |  |DPOS|     |     |     |     |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- ---------
    |  |   |     |
    |  |   |     |_(1) Node number
    |  |   |
    |  |   |_ Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) This is a node on the structure defined by the HLD* data category (Hull Drag Coefficients and Thruster Forces - HLD* (Data Category 10) (p. 153)). When calculating the hull drag force on the structure using coefficients defined on the CU** (p. 154) data records, the current at this point will be used.

Note:

- The drag force is still applied at the center of gravity.
- The node moves with the structure.
- The current used is the total of uniform + profiled current.
- If the node is zero or omitted, the current at the center of gravity of the structure will be used.
- Both current profile and constant current extend above the water surface, so if the node is above the water surface there may still be a drag force. See the CPRF data record (CPRF Data Record - Profiled Current Velocity (p. 166)).
- This data record does not apply to Morison-type hull drag using coefficients specified on the MDIN (p. 158) data record.

14.11. The DDEP Data Record - Depth for Current Measurement

When calculating the current hull drag on a structure, this data record defines the global height at which the current is measured.


```
   2   5  7   11    16    21         31        41        51        61
  - --- -- ---- ----- ----- ---------- --------- ---------
 |X|   |  |DDEP|XXXXX|XXXXX|          |         |         |
  - --- -- ---- ----- ----- ---------- --------- ---------
     |  |   |                   |
     |  |   |                   |_(1) Reference height
     |  |   |
     |  |   |_ Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

(1) This is a vertical position in the FRA. When calculating the hull drag force on the structure using coefficients defined on the CU** (p. 154) data records, the current at this point will be used.

Note:

- The drag force is still applied at the center of gravity.
- This is a fixed height in the FRA.
- The current used is the total of uniform + profiled current.
- This data record does not apply to Morison-type hull drag using coefficients specified on the MDIN (p. 158) data record.

14.12. The QDRD Data Record - User-Defined Quadratic Roll Damping Coefficient

The nonlinear roll damping moment can be calculated in Aqwa time domain and frequency statistical analyses. For frequency domain solutions, the LDRG (p. 316) option should be added.

The following data record is required for the program to calculate this moment:

```
   2   5  7   11    16    21        31
  - --- -- ---- ----- ----- --------- ---------
 |X|   |  |QDRD|     |     |         |
  - --- -- ---- ----- ----- --------- ---------
     |  |   |     |     |       |
     |  |   |     |     |       |
     |  |   |     |     |       |_(3)Quadratic roll coefficient, Cd (F10.0)
     |  |   |     |     |
     |  |   |     |     |_(2)Node Number Two(I5)
     |  |   |     |
     |  |   |     |
     |  |   |     |_(1)Node Number One(I5)
     |  |   |
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data category(A3)
```

(1)-(2) These two nodes define the horizontal direction of the roll axis in the local structure axes (LSA), only the x and y coordinates of these nodes are used. The vertical coordinate utilizes the value associated with the structure center of gravity.

If any node number is less than or equal to zero, or is not defined, the roll axis is assumed to be along the x-axis of the local structure axes (LSA).

(3) The roll damping moment about the roll axis is calculated by $M = Cd \times (\text{roll angular velocity})^2$

Chapter 15: Current/Wind Parameters - ENVR (Data Category 11)

15.1. General Description

This data category is used to input the environmental parameters of current and wind. It is optional and the user may enter NONE for the Data Category Keyword if there is no current or wind.

15.2. Data Category Header

```
        5      11
  ---- -- ---- ----
 |XXXX|  |XXXX|ENVR|
  ---- -- ---- ----
       |        |
       |        |_Compulsory Data Category Keyword(A4)
       |
       |_Optional User Identifier(A2)
```

15.3. CURR/WIND Data Records - Uniform Current/Wind Velocity

```
    2   5  7   11        21
  - --- -- ---- --------- ---------
 |X|   |  |CURR|         |         |
  - --- -- ---- --------- ---------
 |X|   |  |WIND|         |         |
  - --- -- ---- --------- ---------
    |  |   |         |       |
    |  |   |         |       |_(3)Direction of Current/Wind in Degrees(F10.0) (Default 0.0)
    |  |   |         |
    |  |   |         |
    |  |   |         |_(2)Uniform Current/Wind Speed(F10.0)(Default 0.0)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1) Enter CURR or WIND in columns 7-10 as appropriate. Note that both data records may be input if required.

(2) Current/Wind speed is a scalar quantity and must always be a positive value. The current is uniform from the sea bed to the water surface and the wind is uniform from the water surface upwards. Their components in the directions of the Fixed Reference Axes are given by:

X - Component = (Speed)(COS (Direction))

Y - Component = (Speed)(SIN (Direction))

(3) The direction of the current/wind, if left blank or zero is input, is in the positive X direction of the Fixed Reference axes.

15.4. CPRF Data Record - Profiled Current Velocity

```
  2   5  7   11        21        31
 - --- -- ---- --------- --------- ---------
|X|   |  |CPRF|         |         |         |
 - --- -- ---- --------- --------- ---------
    |  |   |        |       |        |
    |  |   |        |       |        |_(3) Direction of Current in Degrees(F10.0)(Default Value 0.0)
    |  |   |        |       |
    |  |   |        |       |_(2) Current Speed(F10.0)(Default Value 0.0)
    |  |   |        |
    |  |   |        |_(1) Z - Position at which the Current is Defined(F10.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1) The Z position at which the current is defined is with reference to the Fixed Reference Axes whose origin is at the water surface. These values will therefore always be negative and must also appear in order i.e. from the sea bed, at Z = - (Water Depth), up to the water surface at Z = 0.0.

(2) Current/Wind speed is a scalar quantity and must always be a positive value. The current components at the Z position in columns 11-20 (1) in the directions of the Fixed Reference Axes are given by

X-component = (Current Speed) * cos(Current Direction)

Y-component = (Current Speed) * sin(Current Direction)

(3) This is the direction of the current at the Z position in columns 11- 20 (1). If this field is left blank or zero is input, it will be the positive X direction of the Fixed Reference axes. As it is common to define a current profile with this value the same on all data records, the user may wish to input a single CDRN (p. 167) data record instead of repeating the current direction on each data record.

Note:

- The maximum number of CPRF data records which may be used to define a current profile is 25.
- The current profile remains constant below the lowest Z position or above the highest; it does not drop to zero outside the defined range.
- If a wave height time-history is imported using the IWHT card it may be necessary to define the current profile with negative velocities. This is because the WHT file must contain a positive constant current in order for the waves to be calculated correctly. The total current velocity will be the sum of the value in the WHT file and the values defined here.

- When profiled currents are used in conjunction with the CUFX, CUFY, and CURZ (p. 154) commands, the DPOS (p. 162) or DDEP (p. 162) data record must also be specified. If one of these data records is not specified, the current profile is ignored and a warning is issued.

15.5. CDRN Data Record - Current Direction

```
    2   5  7   11
  - --- -- ---- ---------
 |X|   |  |CDRN|         |
  - --- -- ---- ---------
     |  |   |       |
     |  |   |       |_(1)Direction of Current in Degrees (F10.0) (Default Value 0.0)
     |  |   |
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data category(A3)
```

(1) This value of the current direction will apply to all CPRF (current profile) data records where the direction is given as zero or left blank. It enables the user to avoid repeating the direction of the current on each or any of the CPRF data records.

Below is an example showing the effect of the CDRN data record.

```
      INPUT IN .DAT FILE                              AS INTERPRETED BY AQWA

*        1         2         3         41
*2345678901234567890123456789012345678901             Depth     Speed   Direction
      CPRF    -800.0       0.1       0.0             -800.0       0.1     180.0
      CPRF    -700.0       0.2       0.0             -700.0       0.2     180.0
      CPRF    -600.0       0.3       0.0             -600.0       0.3     180.0
      CPRF    -500.0       0.4       0.0             -500.0       0.4     180.0
      CPRF    -400.0       0.5      45.0             -400.0       0.5      45.0
      CPRF    -300.0       0.6      45.0             -300.0       0.6      45.0
      CPRF    -200.0       0.7      45.0             -200.0       0.7      45.0
      CPRF    -100.0       0.7      45.0             -100.0       0.7      45.0
      CPRF       0.0       0.9      45.0                0.0       0.9      45.0
      CDRN     180.0
```

15.6. The TOWS Data Record - Tether Tow Speed

This data record should only be input for towed tethers.

```
   2   5  7   11          21         31
  - --- -- ---- ---------- ---------- ---
 |X|XXX|  |TOWS|          |          |
  - --- -- ---- ---------- ---------- ---
        |   |       |          |
        |   |       |          |
        |   |       |          |_(2) Tow Direction (E10.0)
        |   |       |
        |   |       |_(1) Tow Speed (E10.0)
```

```
          |   |
          |   |_Compulsory Data Record Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

(1) The speed at which the tether is towed.

(2) The tow direction relative to the global (FRA) X-axis. Maximum +/- 30°.

15.7. The SBED Data Record - Seabed with Slope

A global seabed with a constant slope can be optionally defined for composite cables, using a reference point and the angle and direction of maximum slope.

```
  2   5  7    11        21        31        41        51        61
 - --- -- ---- ---------- --------- --------- --------- --------- ---
|X|   |  |SBED|          |         |         |         |         |
 - --- -- ---- ---------- --------- --------- --------- --------- ---
    |  |   |        |         |         |         |         |
    |  |   |        |         |         |         |         |_(4) Seabed slope (degrees) (F10.0)
    |  |   |        |         |         |         |
    |  |   |        |         |         |         |_(3) Azimuth of seabed plane (degrees) (F10.0)
    |  |   |        |--------------------
    |  |   |        |
    |  |   |        |_(2) (X,Y,Z) Coordinates of sea bed reference point
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(2) This is a point on the seabed.

(3) This is the direction of greatest slope relative to the global X-axis, using the same convention as for wind and current direction.

(4) Global seabed slope must be not less than zero and not greater than 30°. A positive slope is up in the direction given by (3). The local seabed slope definition for any structure-anchor composite cable using the COMP (p. 217) data record will be ignored if a SBED data record exists.

Chapter 16: Motion Constraints on Structures - CONS (Data Category 12)

16.1. General Description

This data category is used to input the external constraints on the motions of one or more structures. These constraints fall into two distinct categories; elimination of freedoms at the center of gravity, and articulations between structures. The latter are known as constraints.

Elimination of Freedoms at the Center of Gravity

This facility is used to eliminate one or more of the 6 Degrees of Freedom at the Center of Gravity; for example, if the analysis is 1- or 2-dimensional then the user may eliminate the appropriate 5 or 3 Degrees of Freedom respectively.

This facility is extremely useful when data for a full 3-dimensional analysis is unavailable, or when a simple model is being analyzed. This is achieved by use of the DACF (DeACtivate Freedom) data record (see The DACF Data Record - Deactivate Freedom at the Center of Gravity (p. 170)).

Constraints - Articulations Between Structures

This facility is used to physically connect one structure to another structure by means of an articulated joint. These positions are referred to in the documentation as constraints.

Constraints are defined by specifying the number of the first structure and the number of the second structure, together with their respective node numbers corresponding to the position and orientation of the constraint on that structure.

The position of a constraint at any stage of the analysis is UNIQUE. Only rotational freedoms exist at the articulated joint. The 'sliding' of one structure with respect to another (unconstrained translational freedoms) at a joint is therefore not permitted, i.e. there is no relative translational motion, but the constraint position may move with respect to the FRA.

In addition the term 'structure' is used in this context to mean either a floating structure or a fixed position in the fixed Reference Axis System (for example, an anchored plinth on the sea bed).

16.2. Data Category Header

```
          5      11
      ---- -- ---- ----
     |XXXX|  |XXXX|CONS|
      ---- -- ---- ----
          |        |
          |        |_Compulsory Data Category Keyword(A4)
```

```
        |
        |_Optional User Identifier(A2)
```

16.3. The DACF Data Record - Deactivate Freedom at the Center of Gravity

Note:

- The DACF data record has no effect in Aqwa-Fer.
- If all translational freedoms and any (or none) rotational freedoms are required to be 'de-activated' it is preferable to use the DCON data record (see The DCON Data Record - Define Constraint Position (p. 171)). This may require more information but it is a more robust method of preventing movement of the structure.

```
   2   5  7   11    16
 - --- -- ---- ----- -----
|X|   |  |DACF|     |     |
 - --- -- ---- ----- -----
    |  |   |     |     |
    |  |   |     |     |_(2)Freedom Number(I5)
    |  |   |     |
    |  |   |     |_(1)Structure Number(I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2; in other words, if **1** is input, then this will correspond to the structure defined in Data Category ELM1. If **2** is input, then this will correspond to the structure defined in Data Category ELM2, and so on.

(2) Freedom numbers must be from 1 through 6; in other words, 1, 2 and 3 correspond to X, Y, and Z respectively for the translational freedoms and numbers 4, 5 and 6 correspond to X, Y, and Z respectively for the rotational freedoms.

Note:

Axis Systems Associated with the Deactivated Freedoms - if a freedom is deactivated then no motion of the center of gravity will occur in that freedom, where a freedom is defined as motion about an axis system parallel to the fixed reference axes, not the local structure axes.

Example

If translational and rotational motion in the X,Y and Z directions of the structure (as originally defined in Data Category 2) is surge, sway and heave (translational) and roll, pitch and yaw (rotational) respectively, then the following situations are possible:

(i) If the X translational freedom is deactivated, and if the structure is analyzed in a position where its local axes are parallel to the Fixed Reference Axes then surge motion will be eliminated and there will be no restrictions on the sway motion. However, if the structure is yawed by 90 degrees then the local sway motion will be eliminated and there will be no restrictions on the local surge motion.

(ii) If the X rotational freedom is deactivated and if the structure is analyzed in a position where its local axes are parallel to the Fixed Reference Axis then roll motion will be eliminated and there will be no restrictions on the pitch motion. However, if the structure is yawed by 90 degrees then the local pitch motion will be eliminated and there will be no restrictions on the local roll motion.

16.4. The DCON Data Record - Define Constraint Position

Aqwa allows structures to be connected by articulated joints. These do not permit relative translation of the two structures but allow relative rotational movement in a number of ways that can be defined by the user.

The reactions at the articulations can be output in global, structure or local articulation axes; see LSAR and LAAR options (Administration and Calculation Options for the Aqwa Suite (p. 314)).

A maximum of 99 articulations is allowed.

```
  2   5  7   11    16    21    26    31    36    41    46    51
- --- -- ---- ----- ----- ----- ----- ----- ----- ----- ----- -----
X|   |  |DCON|     |     |     |     |XXXXX|     |     |XXXXX|
- --- -- ---- ----- ----- ----- ----- ----- ----- ----- ----- -----
   |  |   |     |     |     |      |          |     |      |
   |  |   |     |     |     |-----            |     |------
   |  |   |     |     |     |                 |     |
   |  |   |     |     |     |                 |     |_(7)-(9)Node Numbers(2I5)
   |  |   |     |     |     |                 |
   |  |   |     |     |     |                 |
   |  |   |     |     |     |                 |_(6)Second Structure Number(I5)
   |  |   |     |     |     |
   |  |   |     |     |     |
   |  |   |     |     |     |_(3)-(5)Node Numbers(2I5)
   |  |   |     |     |
   |  |   |     |     |_(2)First Structure Number(I5)
   |  |   |     |
   |  |   |     |_(1)Number of Locked Rotational Freedoms at the Constraint(I5)
   |  |   |
   |  |   |
   |  |   |_Compulsory Data Record Keyword(A4)
   |  |
   |  |_Optional User Identifier(A2)
   |
   |_Compulsory END on last data record in data category(A3)
```

Constraint Definition

(1) Four types of constraint are valid in the program which are coded as 0, 1, 2 and 3, representing the number of rotational freedoms which are locked at the constraint. Therefore, rotational reactions or moments transmitted through the joint at the constraint, from the first structure to the second structure, and vice versa, also correspond to these numbers. The four types of joint are as follows:

0	Ball and Socket	Free to rotate in all freedoms

1	Universal	Free to rotate in two freedoms transmitting a moment in the third freedom at right angles to the first two
2	Hinged	Transmitting a moment in two freedoms and free to rotate in the third freedom at right angles the first two
3	Locked	Transmitting a moment in all three freedoms and not free to rotate at all. This type of constraint enables the user to find the reactions between two or more parts of the same structure. This type of joint rigidly connects the parts together so that the solution of the equations of motion are the same as if one structure was defined. These parts must be defined as separate structures in Data Category 2 (see also (2))

(2) This is the number of the first structure on which the constraint is defined. If '1' is input then this will correspond to the structure defined in Data Category ELM1. If '2' is input then this will correspond to the structure defined in Data Category ELM2, and so on.

If '0' is input the program will recognize that the constraint is connected to a fixed position in the Fixed Reference Axis System corresponding to the position of the nodes in columns 21-35 as defined in Data Category 1.

See rules concerning how structures may and may not be connected at the end of this section.

(3)-(5) The first node (3) defines the position and the second (4) node defines the orientation of the constraint with respect to the structure specified in (2). Different numbers of nodes must be input to uniquely define each type of constraint, and are tabulated below.

Type	**Joint**	**Mandatory Input**	
		For Structure 1	**For Structure 2**
0	B/Socket	(3)	(7)
1	Universal	(3) (4)	(7) (8)
2	Hinged	(3) (4)	(7) (8)
3	Locked	(3)	(7)

(6) This is the number of the second structure on which the constraint is defined otherwise as in (2) except that '0' structure number is illegal. See rules at the end of this section.

(7)-(9) As for the first node. See (3)-(5).

Function of the Nodal Input on Each Structure

First node: Position of the constraint with respect to the first structure.

Second node: The axis about which the two structures are free to rotate relative to one another is given by the line going from the first node to this node.

Function of the Nodal Input for Each Constraint

0	Ball and Socket Joint	The first node is the position of the joint.

1	Universal Joint	The axis defined on each structure by the second node will give two axes which will always be at right angles to each other. The joint will only allow relative motion about these two axes.
2	Hinged Joint	The axis defined on each structure by the second node will give two axes which will always be coincident. The joint will only allow relative motion about this coincident axis.
3	Locked Joint	The first node is the position of the joint.

Local Axis Systems for the Constraint Reactions Output

FRA = Fixed Reference Axis. X, Y, Z axis are local axes.

0	Ball and Socket Joint	X – Parallel to the FRA Y – Parallel to the FRA Z – Parallel to the FRA
1	Universal Joint	X – Axis defined by the second node on the first structure Y – Axis defined by the second node on the second structure Z – At right angles to X and Y
2	Hinged Joint	X – Axis defined by the second node on the first/second structure Y – At right angles to X and parallel to the XY plane in the FRA Z – At right angles to X and Y with +ve Local Z on the +ve side of the XY plane of the FRA In the special case where the local Z axis lies in the XY plane of the FRA the local Y axis is coincident with the Y axis of the FRA.
3	Locked Joint	X – Parallel to the FRA Y – Parallel to the FRA Z – Parallel to the FRA

Defining the Initial Position with Constraints

When constraints are defined on a structure, the usual specification of initial or starting positions for the analysis (input in Data Category 15) is not treated in the same manner as when there are no constraints. This is because the specification of the 6 degrees of freedom for each center of gravity may not be geometrically compatible with the position of constraints defined within this data category, e.g. it is possible to input the positions of two structures where the position of the common constraint is not coincident.

It is realized that it is tedious for the user to have to calculate the exact positions of the structures so that common constraint positions are coincident. Indeed if a fixed constraint is specified, the position of the structures can be uniquely defined by the rotational Degrees of Freedom only.

The program will take the position of the first structure within any articulated group of structures, and connect the remaining structures to the first structure using only the orientation of these remaining structures (Note that this includes structure '0', a fixed constraint, as the first structure).

If the program is unable to achieve this due to the manner in which the user has modeled a group of structures, the model is invalid.

Note:

Rules for Joining Structures with Constraints

In order to achieve a valid model of a group of structures joined together by constraints (outlined above) the rules below must be followed.

- 'Closed loops' are now permitted, (e.g. Structure 1, to Structure 2, connected to Structure 3 which is connected back to Structure 1, is now legal).
- If a fixed constraint, i.e. Structure '0', is present within a group of articulated structures, then '0' must be the first structure number on a DCON data record.
- Only one fixed constraint, i.e. Structure '0', may be present within any one group of articulated structures.
- Redundant systems of constraints may cause a statically indetermined solution of the reaction force/moments on the joints. A simple example of a redundant system is two structures connected by two locked articulations. As the structures are also rigid, it is impossible to determine how the reactions should be divided between the two joints. A single locked articulation will suffice to fix two structures together.

16.5. The KCON/CCON/FCON Data Records - Define Articulation Stiffness, Damping, and Friction

Articulation stiffness, damping, and friction can be defined for all the articulation types. KCON, CCON and FCON data records for an articulation should be input before the articulation definition data record DCON for this articulation.

16.5.1. KCON and CCON Data Records

```
   2   5  7   11         21         31         41         51
  - --- -- ---- ---------- ---------- ---------- ----------
 |X|   |  |KCON|XXXXXXXXXX|          |          |          |
  - --- -- ---- ---------- ---------- ---------- ----------
 |X|   |  |CCON|XXXXXXXXXX|          |          |          |
  - --- -- ---- ---------- ---------- ---------- ----------
     |  |   |                 |         |         |
     |  |   |                 |         |         |
     |  |   |                 |         |         |_(3) Stiffness(KCON) or Damping(CCON) about
     |  |   |                 |         |              Z axis (F10.0)
     |  |   |                 |         |
     |  |   |                 |         |_(2) Stiffness(KCON) or Damping(CCON) about Y axis (F10.0)
     |  |   |                 |
```

```
      |   |   |                    |_(1) Stiffness(KCON) or Damping(CCON) about X axis (F10.0)
      |   |   |
      |   |   |_Compulsory Data Record Keyword(A4)
      |   |
      |   |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1), (2), (3) As articulations only allow rotational motion (for articulation types 1,2,3), KCON and CCON only define the rotational stiffness and damping. The input values should have the units of moment/radians for stiffness (KCON) and moment/(radians/second) for damping (CCON).

For a ball and socket (type 0), the stiffness and damping defined in the KCON and CCON data records should be in the Aqwa global axis system (i.e. FRA).

For a universal joint (type 1) or hinge (type 2), these values should be in the articulation local axis system (please refer to The DCON Data Record - Define Constraint Position (p. 171) for the definition of local axis system).

The forces due to the articulation stiffness and damping will be output as a part of the articulation reaction force and will be in the Aqwa global system.

16.5.2. The FCON Data Record

```
   2   5  7   11         21         31         41         51         61
  - --- -- ---- ---------- ---------- ---------- ---------- ----------
 |X|   |  |FCON|XXXXXXXXXX|          |          |          |          |
  - --- -- ---- ---------- ---------- ---------- ---------- ----------
      |   |   |                    |         |          |          |
      |   |   |                    |         |          |          |_(4) Constant friction moment (F10.0)
      |   |   |                    |         |          |
      |   |   |                    |         |          |_(3) Friction coefficent for axial force (F10.0)
      |   |   |                    |         |
      |   |   |                    |         |_(2) Friction coefficent for overturning moment (F10.0)
      |   |   |                    |
      |   |   |                    |_(1) Friction coefficient for transverse force (F10.0)
      |   |   |
      |   |   |_Compulsory Data Record Keyword(A4)
      |   |
      |   |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1), (2), (3), (4) Coulomb friction always uses a local axis system for calculation with the X-axis being the axis of the instantaneous relative rotational velocity of the two parts of the articulation. For a hinge this will always be the axis of the hinge; for a ball joint it will vary as the two structures move relative to one another. The frictional moment is given by

$$M = \varepsilon\left(k1\sqrt{Fy^2+Fz^2}+k2\sqrt{My^2+Mz^2}+k3Fx+k4\right)$$

where:

ε = 0 if the relative rotational velocity is less than 0.001 rad/s, 1 otherwise.

k1 - k4 are coefficients. Note that these are not conventional dimensionless friction coefficents, as used in the equation F = μR. These coefficients are factors to be applied to the appropriate forces to give frictional moments, and they must include effects of the bearing diameter etc.

k1, k2 and k3 must not be negative. k1 and k3 have dimensions of length, and the maximum value allowed is $\frac{0.025g}{g_{SI}}$ where g is the acceleration due to gravity expressed in the current unit system and g_{SI} is the acceleration due to gravity expressed in the [kg, meter, second] unit system. k2 is non-dimensional and has a maximum value of 0.025.

This moment is transformed into articulation, structure or global axes as appropriate before output.

Chapter 17: Wind/Wave Spectrum Definition - SPEC (Data Category 13)

17.1. General Description

This Data Category is used to input the parameters which are used to define spectra of wind or waves together with their associated current and wind. At present the wind spectra available are OCIN, APIR, NPD, ISO, or User-Defined, and wave spectra available are JONSWAP, Pierson-Moskowitz, Gaussian, or User-Defined, and are uni-directional (see Irregular Wave and Wind in the *Aqwa User's Manual* for more information concerning wind and wave spectra).

Spectral groups allow the inclusion of multiple wave spectra in a given simulation to model short crested waves.

Applicability to programs in the Aqwa suite is as follows:

Aqwa-Librium - Accepts up to 20 wave spectra or spectral groups, i.e. 20 equilibrium positions are therefore output for each mooring-line combination specified in Data Category 14. This data category may be omitted, i.e. enter NONE for the data category keyword if it is considered that the equilibrium position is not substantially affected by the sea state or if an approximate solution is required. Note that all equilibrium positions are transferred automatically to Aqwa-Fer if requested by the user.

Aqwa-Fer - Accepts up to 20 wave spectra or spectral groups, i.e. 20 spectral response parameters of the model are therefore output for each mooring-line combination specified in Data Category 14.

Aqwa-Drift - Only one wave spectrum or spectral group is permitted, as only one time-history can be executed per run, and each time-history is associated with a single spectrum or spectral group. Additional spectra input are ignored.

Aqwa-Naut - Only one wave spectrum or spectral group is permitted, as only one time-history can be executed per run, and each time-history is associated with a single spectrum or spectral group. Additional spectra input are ignored. The IRRE job option is required and convolution is mandatory.

17.2. Data Category Header

```
        5       11
  ---- -- ---- ----
 |XXXX|  |XXXX|SPEC|
  ---- -- ---- ----
       |        |
       |        |_Compulsory Data Category Keyword(A4)
       |
       |_Optional User Identifier(A2)
```

17.3. Wind Spectra Definition

The user is advised to read the theory in Wind Velocity Profile and Fluctuation in the *Aqwa Theory Manual* before using wind spectra.

Wind spectra in Aqwa are only available in Fer and Drift at present. They are input by specifying the type of wind spectrum and the reference height at which the wind speed is measured. There are currently five types of wind spectra available in Aqwa. The Data Record Keywords are:

- OCIN - Ochi and Shin wind spectrum
- APIR - API wind spectrum
- NPDW - NPD wind spectrum
- ISOW - ISO wind spectrum
- UDWD - User-defined wind spectrum

The format of the input is as follows:

```
    2   5  7   11        21        31        41
  - --- -- ---- --------- --------- --------- ---------
 |X|   |  |OCIN|                                       |
  -- -- -- ---- --------- --------- --------- ---------
 |X|   |  |APIR|                                       |
  -- -- -- ---- --------- --------- --------- ---------
 |X|   |  |NPDW|                                       |
 -- -- -- ---- --------- --------- --------- ---------
 |X|   |  |ISOW|                                       |
  -- -- -- ---- --------- --------- --------- ---------
 |X|   |  |UDWD|  XXXXX  |cf       |cs       |I(z)     |
  -- -- -- ---- --------- --------- --------- ---------
 |X|   |  |WIND|  Seed   |Speed Uz |Direction| Ref Ht  |
  -- -- -- ---- --------- --------- --------- ---------
    |  |   |      |
    |  |   |      |_Optional Wind Random Number Seed (I10)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

The UDWD data record should be followed by UDWS data records defining dimensionless frequencies, f, and spectral ordinates, U(f), (as defined below). A user defined wind spectrum can consist of up to 200 UDWS data records.

```
    2   5  7    11        21        31
  -- -- -- ---- --------- --------- ---------
 |X|   |  |UDWS|  XXXXX  |f        |U(f)     |
  -- -- -- ---- --------- --------- ---------
 |X|   |  |UDWS|  XXXXX  |f        |U(f)     |
  -- -- -- ---- --------- --------- ---------
 |X|   |  |UDWS|  XXXXX  |f        |U(f)     |
  -- -- -- ---- --------- --------- ---------
 |X|   |  |UDWS|  XXXXX  |f        |U(f)     |
  -- -- -- ---- --------- --------- ---------
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
```

```
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

Note:

- The OCIN/APIR/NPDW/ISOW/UDWD/UDWS data records must be input before the WIND data record in each wind spectrum definition.
- The WIND data record must be input BEFORE any wave spectra.
- Wind random number seed in the WIND data record is optional and applicable only for the wind spectrum. The value must be less than 2^{31}.
- If a non-zero height is input and the spectrum type is not defined, the Ochi and Shin spectrum will be used.
- For the Ochi and Shin spectrum a non-zero reference height must be defined; otherwise a uniform wind will be used.
- For the other types of spectrum a default of 10m will be used if the reference height is zero or undefined.
- The speed Uz is the speed at the reference height (NO DEFAULT). (Note: wind speed in Data Category 11 is for uniform wind only.)
- Range of valid mean wind speeds is min-max= 0.01-100.00m/s.
- The wind force is calculated using the wind speed at 10m. If some other reference point is input, then the program will first calculate the corresponding wind speed at 10m.
- For user-defined spectra, the dimensionless frequency is defined as

  f = cf * z/Uz F   where F is the frequency in hertz

  The wind speed spectral density is defined as   S(F)= cs * U(f) * (I(z)*Uz)**2/F

  The default for cf = 1.0

  The default for cs = 1.0

  The default for I(z) = 0.167
- A new wind spectrum may be defined before each WIND data record.
- A WIND data record can also be used to define a constant wind (frequency independent) associated with a wave spectrum (see The CURR / WIND Data Records - Current and Wind Speed and Direction (p. 182)).

17.4. The HRTZ Data Record - Change Units of Frequency to Hertz

```
     2   5  7
   - --- -- ----
  |X|   |  |HRTZ|
   - --- -- ----
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

This data record acts as a switch which changes the units for all following frequencies input to hertz in wave spectra definitions.

If omitted, the program will expect all frequencies to be input in radians/second.

17.5. The RADS Data Record - Change Units of Frequency to Radians/Second

```
     2   5  7
   - --- -- ----
  |X|   |  |RADS|
   - --- -- ----
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

This data record acts as a switch which changes the units for all following frequencies input to radians/second. Note that this data record is needed only if a HRTZ data record has been input, as the default units for frequency are radians/second in wave spectra definitions.

17.6. The SPDN Data Record - Wave Spectral Direction

This data record must be input before any wave spectra. The maximum number of wave spectra is 20.

```
     2   5  7   11    16    21         31    36
   - --- -- ---- ----- ----- ---------- ----- -----
  |X|   |  |SPDN|     |     |          |XXXXX|     |
   - --- -- ---- ----- ----- ---------- ----- -----
      |  |   |     |     |       |              |
      |  |   |     |     |       |              |_(4) No. of Gaussian integral angles (I5)
      |  |   |     |     |       |
      |  |   |     |     |       |_(3)Direction of Spectrum in Degrees (F10.0)
      |  |   |     |     |
      |  |   |     |     |_(2)Total Wave Spreading Angle in Degrees (I5)
      |  |   |     |
      |  |   |     |_(1)Power of Wave Spreading Function (I5)
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in data category(A3)
```

(1) This is only required for a spreading sea. This value defines the power N of the wave spreading function which is in the form of $\cos^N$, where $2 \leq N \leq 250$. If this space is blank and a spreading angle is input in (2) the power defaults to $N=2$.

(2) This value defines the total spreading angle for the case when $N=2$. The maximum permitted angle is 180 degrees. If $N>2$ this space should be left blank as the total spreading angle is set to 180 degrees.

(3) This value is the direction of waves within a wave spectrum (for a spreading sea, this is the direction in which the wave spectra values are the highest). All the following specifications of wave spectra take this value until another SPDN data record is input. The next group of wave spectra will then take the new value as the wave direction. It is therefore a mandatory requirement that this data record is the first data record of the wave spectrum data category, as the wave direction will be undefined until this data record is input.

(4) This value is the number of Gaussian integration angles N_w to represent a spreading sea. The default value is 7 and the maximum allowed value is 28. If (4) is blank or less than the default value, $N_w=7$ is used. If (4) is greater than 28, N_w is set to 28.

For a non-spreading sea, (1), (2), and (4) should be left blank.

The introduction of a SPDN data record thus enables the user to alter the value of the wave direction for a complete group of wave spectra.

Note:

Although there is no limit to the number of SPDN data records that may be input, a wave spectrum can have only one direction. Hence the number of SPDN data records can never exceed the number of wave spectra.

The results output for plotting in the AGS are for the main direction only.

17.7. The SEED Data Record - Wave Spectral Seed

This data record is used to define the random seed for a wave spectrum. It must be before the spectrum to which it applies. Default seed values are defined below.

```
    2   5  7   11        21
  - --- -- ---- ---------
 |X|   |  |SEED|         |
  - --- -- ---- ---------
                |
                |_(1)Seed number n (I10)
```

Within a spectral group, the default values of SEED for each spectrum will be:

- If there is no SEED data record or the SEED number is set to 0:

$$\mathrm{SEED}=1+(I-1)*1{,}000{,}000$$

  where I represents the i-th spectrum.

- If a SEED data record is used for some but not all of the spectra:

$$\mathrm{SEED{=}N\_SEED{+}}J*1{,}000{,}000$$

where

N_SEED is the number of SEED data records defined in this group

J ranges from 1 to the number of spectra which do not have a SEED data record

- The seed number of a Gaussian integral wave direction of $\cos^n$ spread seas:

$$\mathrm{SEED{=}I\_SEED{+}}\left(J-1\right)*100{,}000{,}000$$

where

I_SEED is the starting seed number of the spread seas

J ranges from 1 to the number of Gaussian integral points

- The seed number of a sub-direction of a user-defined carpet wave spectrum:

$$\mathrm{SEED{=}I\_SEED{+}}\left(J-1\right)*100{,}000{,}000$$

where

I_SEED is the starting seed number of the user-defined carpet wave spectrum

J ranges from 1 to the total number of user-defined wave sub-directions

17.8. The CURR / WIND Data Records - Current and Wind Speed and Direction

These data records are optional and their omission indicates that no current or wind is present. A value of zero is then assumed for the wind and current speeds associated with each wave spectrum. In general both data records will be input before each wave spectrum.

```
    2   5  7   11         21        31        41
  - --- -- ---- ---------- --------- --------- ---------
 |X|   |  |CURR|XXXXXXXXXX|         |         |         |
  - --- -- ---- ---------- --------- --------- ---------
 |X|   |  |WIND|XXXXXXXXXX|         |         |         |
  - --- -- ---- ---------- --------- --------- ---------
     |  |   |                  |         |         |
     |  |   |                  |         |         |_(4)Reference Height(F10.0)
     |  |   |                  |         |
     |  |   |                  |         |_(3)Direction in degrees(F10.0)
     |  |   |                  |
     |  |   |                  |_(2)Current/Wind Speed (F10.0)
     |  |   |
     |  |   |_(1)Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data category(A3)
```

(1) The Data Record Keyword indicates whether parameters (2) and (3) apply to current or wind.

(2)-(3) These values are magnitude and direction of the current/wind speed for a wave spectrum. All following specifications of wave spectra (q.v.) take these values until another CURR/WIND data record is input.

(4) The reference height defines the height where wind speed is measured and is only required for wind spectrum definition. If a non-zero height is entered, a wind spectrum will be used even if not specifically requested. The default spectrum is Ochi and Shin. See also Wind Spectra Definition (p. 178).

Although there is no limit to the number of CURR/WIND data records that may be input, a wave spectrum can only be associated with one current magnitude and direction and one wind magnitude and direction. Hence the number of functional CURR or WIND data records can never exceed the number of wave spectra.

17.9. The PSMZ Data Record - Pierson-Moskowitz Spectrum

```
   2   5  7   11         21        31
  - --- -- ---- ---------- --------- --------- --------- ---------
 |X|   |  |PSMZ|XXXXXXXXXX|         |         |         |         |
  - --- -- ---- ---------- --------- --------- --------- ---------
     |  |   |                |         |          |         |
     |  |   |                |         |          |         |
     |  |   |                |         |          |     (4)Zero Crossing Period (F10.0)
     |  |   |                |         |          |
     |  |   |                |         |          |
     |  |   |                |         |          |_(3)Significant Wave Height(F10.0)
     |  |   |                |         |
     |  |   |                |         |
     |  |   |                |         |_(2)Finish Frequency(F10.0)
     |  |   |                |
     |  |   |                |_(1)Start Frequency(F10.0)
     |  |   |
     |  |   |_Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier(A2)
     |
     |_Compulsory END on last data record in data category(A3)
```

(1)-(2) Start/Finish Frequency - The lowest/highest frequency at which the spectrum is defined. The program will assume that the frequencies are in radians/sec, unless a HRTZ data record (see The HRTZ Data Record - Change Units of Frequency to Hertz (p. 180)) has been used to change this to Hertz (cycles/sec).

If these fields are left blank, defaults will be assumed as follows:

Start frequency = Peak frequency * 0.58

Finish frequency is evaluated numerically so that approximately 99% of the spectral energy is included.

(3)-(4) The average (i.e. mean zero-crossing) wave period and the significant wave height are the parameters used by Aqwa to describe the Pierson-Moskowitz wave spectrum, the special case for a fully developed sea.

17.10. The GAUS Data Record - Gaussian Spectrum

The program assumes that all frequencies are in radians/sec, unless a HRTZ (p. 180) data record has been used to change this to Hertz (cycles/sec).

Note:

The standard deviation, sigma (σ), is always in radians/sec.

```
  2   5  7   11         21        31
 - --- -- ---- ---------- --------- --------- --------- --------- ---------
|X|   |  |GAUS|XXXXXXXXXX|         |         |         |         |         |
 - --- -- ---- ---------- --------- --------- --------- --------- ---------
    |  |   |                 |         |         |         |         |
    |  |   |                 |         |         |         |         |
    |  |   |                 |         |         |         |     (5)Peak Frequency
    |  |   |                 |         |         |         |
    |  |   |                 |         |         |         |_(4)Significant Wave Height, Hs
    |  |   |                 |         |         |
    |  |   |                 |         |         |_(3)Standard deviation (σ) (rad/s)
    |  |   |                 |         |
    |  |   |                 |         |_(2)Finish Frequency
    |  |   |                 |
    |  |   |                 |_(1)Start Frequency
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1)-(2) Start/Finish Frequency - The lowest/highest frequency at which the spectrum is defined. Aqwa assumes that there is no wave frequency energy outside this range. If these fields are left blank, defaults will be calculated as follows:

First, the peak frequency (5) is converted to rad/s. Then:

Start frequency: $\omega_s = \omega_p - 3\sigma$, subject to a max of 100 rad/s and min of 0.001 rad/s.

Finish frequency: $\omega_f = \omega_p + 3\sigma$, subject to a max of 100 rad/s and min of 0.001 rad/s.

If $\omega_f - \omega_s < 0.001$ then $\omega_s = 0.1$ rad/s and $\omega_f = 6.0$ rad/s.

(3) Standard deviation, σ. The minimum allowed value of σ is $0.08\omega_p$

17.11. The JONS Data Record - JONSWAP Spectrum

The program assumes that all frequencies are in radians/sec, unless a HRTZ (p. 180) data record has been used to change this to Hertz (cycles/sec).

```
   2   5  7   11         21       31       41       51       61
  - --- -- ---- ---------- -------- -------- -------- -------- --------
 |X|   |  |JONS|XXXXXXXXXX|        |        |        |        |        |
  - --- -- ---- ---------- -------- -------- -------- -------- --------
     |  |   |                 |        |         |       |        |
```

```
        |   |   |                 |        |         |       |        |
        |   |   |                 |        |         |       | (5)Peak Frequency
        |   |   |                 |        |         |       |
        |   |   |                 |        |         |       |
        |   |   |                 |        |         |       |_(4)Alpha(F10.0)
        |   |   |                 |        |         |
        |   |   |                 |        |         |_(3)Gamma(F10.0)
        |   |   |                 |        |
        |   |   |                 |        |_(2)Finish Frequency(F10.0)
        |   |   |                 |
        |   |   |                 |_(1)Start Frequency(F10.0)
        |   |   |
        |   |   |_Compulsory Data Record Keyword(A4)
        |   |
        |   |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

(1)-(2) Start/Finish Frequency - The lowest/highest frequency at which the spectrum is defined.

If these fields are left blank, defaults will be assumed as follows:

Start frequency = Peak frequency * (0.58+(γ-1.0)*0.05/19.0)

Finish frequency is evaluated numerically so that approximately 99% of the spectral energy is included.

(3)-(5) Gamma, Alpha and Peak Frequency. Note that even if Hz is used to define the frequencies, Alpha has units of rad^4.

The JONSWAP wave spectrum can be used to describe a wave system where there is an imbalance of energy flow (i.e. sea not fully developed). This is nearly always the case when there is a high wind speed.

It may be considered as having a higher peak spectral value than the Pierson-Moskowitz spectrum (The PSMZ Data Record - Pierson-Moskowitz Spectrum (p. 183)) but is narrower away from the peak in order to maintain the energy balance.

Parameterization of the classic form of the JONSWAP spectrum (with parameters of fetch and wind speed) was undertaken by Houmb and Overvik (BOSS Trondheim 1976,Vol 1). These parameters are used by Aqwa. These empirical parameters are termed gamma (3), alpha (4) and peak frequency (5) (the frequency at which the spectral energy is a maximum).

17.12. The JONH Data Record - JONSWAP Spectrum

```
     2   5  7   11         21       31       41       51       61
   - --- -- ---- ---------- -------- -------- -------- -------- --------
  |X|   |  |JONH|XXXXXXXXXX|        |        |        |        |        |
   - --- -- ---- ---------- -------- -------- -------- -------- --------
      |   |   |                 |        |         |       |        |
      |   |   |                 |        |         |       |        |
      |   |   |                 |        |         |       | (5)Peak Frequency (F10.0)
      |   |   |                 |        |         |       |
      |   |   |                 |        |         |       |
      |   |   |                 |        |         |       |_(4)Significant Wave Height Hs(F10.0)
      |   |   |                 |        |         |
      |   |   |                 |        |         |_(3)Gamma(F10.0)
      |   |   |                 |        |
      |   |   |                 |        |_(2)Finish Frequency(F10.0)
      |   |   |                 |
      |   |   |                 |_(1)Start Frequency(F10.0)
```

```
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

This data record also defines a JONSWAP spectrum. The only difference from the JONS data record is that significant wave height H_s is used instead of the parameter Alpha.

17.13. The OHBS Data Record – Ochi-Hubble Spectrum

```
    2   5  7   11         21        31        41        51        61
   - --- -- ---- ---------- --------- --------- --------- --------- ---------
  |X|XXX|  |OHBS|XXXXXXXXXX|         |         |         |         |         |
   - --- -- ---- ---------- --------- --------- --------- --------- ---------
         |   |                 |         |          |         |         |
         |   |                 |         |          |         |         |_(5)Modal Frequency #1 (F10.0)
         |   |                 |         |          |         |
         |   |                 |         |          |         |_(4)Shape Parameter #1 (F10.0)
         |   |                 |         |          |
         |   |                 |         |          |_(3)Significant Wave Height #1 (F10.0)
         |   |                 |         |
         |   |                 |         |_(2)Finish Frequency(F10.0)
         |   |                 |
         |   |                 |_(1)Start Frequency(F10.0)
         |   |
         |   |_Compulsory Data Record Keyword(A4)
         |
         |_Optional User Identifier(A2)
```

(1)-(2) Start/Finish Frequency - The lowest/highest frequency at which the spectrum is defined. The program will assume that the frequencies are in radians/sec unless a HRTZ (p. 180) data record has been used to change the units to Hertz (cycles/sec). If these fields are left blank, defaults will be assumed as follows:

Start frequency is evaluated numerically so that approximately 0.25% of the spectral energy from zero frequency to this starting frequency is excluded.

Finish frequency is evaluated numerically so that approximately 99.5% of the spectral energy is included.

(3)-(5) The significant wave height, shape parameter and modal frequency (in Rad/s unless a HRTZ data record has been used) are the parameters for the first Ochi-Hubble sub-spectrum.

The shape parameter must not be less than 0.001.

Modal frequency must not be less than 0.01 rad/s.

A warning message will be issued if the total significant wave height of the spectrum is less than 1.0 mm.

Continuation Data Record for defining the parameters of the second Ochi-Hubble sub-spectrum:

```
     2   5     11         21        31        41        51        61
   - --- -- ---- ---------- --------- --------- --------- --------- ---------
  |X|   |  |CONT|XXXXXXXXXX|XXXXXXXXX|XXXXXXXXX|         |         |         |
   - --- -- ---- ---------- --------- --------- --------- --------- ---------
```

```
        |  |   |                                      |         |         |
        |  |   |                                      |         |         |_(8) Modal Frequency #2 (F10.0)
        |  |   |                                      |         |
        |  |   |                                      |         |_(7)Shape Parameter #2 (F10.0)
        |  |   |                                      |
        |  |   |                                      |_(6)Significant Wave Height #2 (F10.0)
        |  |   |
        |  |   |_Indicates Continuation of above Data Record(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category (A3)
```

(6)-(8) The significant wave height, shape parameter and modal frequency (in Rad/s unless a HRTZ data record has been used) are the parameters for the second Ochi-Hubble sub-spectrum.

The shape parameter must not be less than 0.001.

Modal frequency must not be less than 0.01 rad/s.

A warning message will be issued if the total significant wave height of the spectrum is less than 1.0 mm.

The total significant wave height of Ochi-Hubble spectrum is defined by Equation 2.45 in the *Aqwa Theory Manual*.

Cross-swell spectrum cannot be defined with an Ochi-Hubble spectrum.

Spreading sea cannot be defined by The SPDN Data Record - Wave Spectral Direction (p. 180) with an Ochi-Hubble spectrum.

17.14. The BRET Data Record – Bretschneider Spectrum

```
     2   5  7   11         21        31        41        51
    - --- -- ---- ---------- --------- --------- --------- ---------
   |X|   |  |BRET|XXXXXXXXXX|         |         |         |         |
    - --- -- ---- ---------- --------- --------- --------- ---------
        |  |   |                 |         |         |         |
        |  |   |                 |         |         |         |_(4)Modal Frequency (F10.0)
        |  |   |                 |         |         |
        |  |   |                 |         |         |_(3)Significant Wave Height (F10.0)
        |  |   |                 |         |
        |  |   |                 |         |_(2)Finish Frequency(F10.0)
        |  |   |                 |
        |  |   |                 |_(1)Start Frequency(F10.0)
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category (A3)
```

(1)-(2) Start/Finish Frequency - The lowest/highest frequency at which the spectrum is defined. The program will assume that the frequencies are in radians/sec unless a HRTZ (p. 180) data record has been used to change the units to Hertz (cycles/sec). If these fields are left blank, defaults will be assumed as follows:

Start frequency is evaluated numerically so that approximately 0.25% of the spectral energy from zero frequency to this starting frequency is excluded.

Finish frequency is evaluated numerically so that approximately 99.5% of the spectral energy is included.

(3)-(4) The significant wave height and modal frequency (in Rad/s unless a HRTZ data record has been used) are the parameters for the Bretschneider spectrum.

The modal frequency must not be less than 0.01 rad/s.

A warning message will be issued if significant wave height is less than 1.0 mm.

17.15. The TMAS Data Record - TMA Spectrum

```
   2   5  7   11         21       31       41       51       61
 - --- -- ---- ---------- -------- -------- -------- -------- --------
|X|   |  |TMAS|XXXXXXXXXX|        |        |        |        |        |
 - --- -- ---- ---------- -------- -------- -------- -------- --------
    |  |   |                 |        |         |       |        |
    |  |   |                 |        |         |       |        |_(5)Peak Frequency
    |  |   |                 |        |         |       |
    |  |   |                 |        |         |       |_(4)Alpha(F10.0)
    |  |   |                 |        |         |
    |  |   |                 |        |         |_(3)Gamma(F10.0)
    |  |   |                 |        |
    |  |   |                 |        |_(2)Finish Frequency(F10.0)
    |  |   |                 |
    |  |   |                 |_(1)Start Frequency(F10.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(1)-(2) Start/Finish Frequency - The lowest/highest frequency at which the spectrum is defined. The program assumes that all frequencies are in radians/sec unless a HRTZ (p. 180) data record has been used to change the units to Hertz (cycles/sec).

If these fields are left blank, defaults will be assumed as follows:

Start frequency = Peak frequency * (0.58+(γ-1.0)*0.05/19.0).

Finish frequency is evaluated numerically so that approximately 99% of the spectral energy is included.

(3)-(5) Gamma, Alpha and Peak Frequency.

Note:

Even if Hz is used to define the frequencies, Alpha has units of rad^4.

The water depth used in this spectrum is defined by the DPTH (p. 99) data record in Data Category 5.

17.16. The UDEF Data Record - User-Defined Wave Spectrum and the FINI Data Record - User-Defined Spectrum Separator

This facility may be used to input any spectrum the user wishes. It is normally employed for input of non-deterministic spectra such as tank spectra, recorded full-scale spectra, or simply where the formulated spectrum is not yet available in Aqwa.

The program assumes that all frequencies are in radians/sec, unless a HRTZ (p. 180) data record has been used to change this to Hertz (cycles/sec).

```
      2   5  7   11         21        31
    - --- -- ---- ---------- --------- ---------
   |X|   |  |UDEF|XXXXXXXXXX|         |         |
    - --- -- ---- ---------- --------- ---------
       |  |   |                 |         |
       |  |   |                 |         |
       |  |   |                 | (2)Spectral Ordinate(F10.0)
       |  |   |                 |
       |  |   |                 |
       |  |   |              (1)Frequency Value(F10.0)
       |  |   |
       |  |   |_Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on last data record in data category(A3)
```

(1) The value of frequency at which the value of the spectral ordinate (2) is given.

These frequencies must appear in ascending order (lowest first). The maximum number of frequencies is 200.

(2) Value of the spectral ordinate at the frequency given in columns 21-30.

If more than one spectrum is input, then the FINI data record must be used to separate each set of UDEF data records defining a spectrum. The format is shown below:

```
      2   5  7
    - --- -- ----
   |X|   |  |FINI|
    - --- -- ----
       |  |   |
       |  |   |_Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on last data record in data category(A3)
```

17.17. The NSPL Data Record - Number of Spectral Lines

The new user is strongly advised to ignore this facility. The program will automatically generate the appropriate number of spectral lines for the particular method of analysis, and it is only in unusual circumstances that user input is required.

```
      2   5  7   11   16
    - --- -- ---- ---- -----
   |X|   |  |NSPL|XXXX|     |
    - --- -- ---- ---- -----
       |  |   |          |
```

```
        |  |   |          |
        |  |   |          |
        |  |   |          |
        |  |   |          |
        |  |   |          |_(1)Number of Spectral Lines(I5)(default varies, MAXIMUM of 200)
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

(1) The number of spectral lines is the number of spectral ordinates required to define the spectrum in order to achieve an accuracy comparable to the formulation of the analysis in which it is used. This is necessarily a general definition as the program uses this number in several different ways.

This number of spectral lines will be used for ALL subsequent spectra in all groups, unless a particular spectrum type requires a different number. For example, a spectrum imported using the IWHT data record will always use 200 lines, irrespective of any value input using the NSPL data record.

17.18. Input of a Time History of Wind Speed and Direction

A user created ASCII data file defining a time history of wind speed and direction can be utilized by the Aqwa time domain programs. The name of the wind time history file must be identical to the original input data file for the Aqwa time domain analysis, and the extension must be WVT (stands for Wind Velocity Time history). For example, if the original input data file for Drift is `ADRUN1.DAT`, the wind time history file must be named as `ADRUN1.WVT` .

Note:

- As long as this file exists, the program will automatically read it in and use the wind speed and direction defined in the file at each time step during the analysis. There is no data record needed for implementing this feature.
- The time defined in the WVT file does not need to match the time step defined in the corresponding DAT file as the program will interpolate the wind speed and direction when necessary, using a cubic spline interpolation technique. When modeling periods of constant wind velocity adequate data points must be provided to satisfy the interpolation method.
- There is no limit on the length of the WVT file.

The following is an example showing the format of the WVT file:

```

------------------------------------
*A LINE BEGINNIING WITH * IS A COMMENT LINE
*In the first column is time
*In the second column is wind speed
*In the third column is wind direction (blowing towards) in degrees
*The numbers in this WVT file are in a free format
*data_start is a compulsory line before the data block begins
data_start
      0.0000      8.0000     90.0000
      0.5000      7.8532     88.7310
      1.0000      7.4271     86.0840
```

```
      1.5000      6.7634     82.1170
      2.0000      5.9271     76.9100
      2.5000      5.0000     70.5600
      3.0000      4.0729     63.1800
      3.5000      3.2366     54.9000
      4.0000      2.5729     45.8600
      4.5000      2.1468     36.2130
      5.0000      2.0000     26.1180
      5.5000      2.1468     15.7380
      6.0000      2.5729      5.2407
      ........
```

17.19. Input of a Time History of External Forces on Structures

A user created ASCII data file defining a time history of external forces on structures can be utilized by the Aqwa time domain programs. The name of the force time history file must be identical to the original input data file for the Aqwa time domain analysis, and the extension must be XFT (stands for External Force Time history). For example, if the original input data file for Drift is `ADRUN1.DAT`, the force time history file must be named as `ADRUN1.XFT` .

Note:

- As long as this file exists, the program will automatically read it in and apply the forces defined in the file to the structures at each time step during the analysis. There is no data record needed for implementing this feature.
- The time defined in the XFT file does not need to match the time step defined in the corresponding DAT file as the program will interpolate the forces when necessary, using a cubic spline interpolation technique. For this purpose there must be at least 4 time entries in the XFT file. When modeling periods of constant force adequate data points must be provided to satisfy the interpolation method. A warning message will be issued if the difference between the cubic interpolation and the linear interpolation is big, that is:

$$\sqrt{\frac{\sum_{i=1}^{nSteps}\left\{Force_i(\text{Cubic interpolation})-Force_i(\text{Linear interpolation})\right\}^2}{\sum_{i=1}^{nSteps}\left\{Force_i(\text{Linear interpolation})\right\}^2}}>1$$

  where *n*Steps is the number of time steps in the Aqwa time domain analysis.
- The times included in the XFT file must entirely cover the simulation duration: the first time must not be greater than the start time, and the last time must be greater than or equal to the finish time.
- There is no upper limit on the length of the XFT file.
- The forces defined in the XFT file are in six degrees of freedom for each structure and are in the structure's local axis system.

The following is an example showing the format of the XFT file:

```
------------------------------------
*A LINE BEGINNING WITH * IS A COMMENT LINE
*In the first column is time
*In the second to seventh columns are the forces for the first structure in the local surge,
*sway, heave, roll, pitch, and yaw.
*In the eighth to thirteenth columns (only if  there is a second structure) are the forces
*for the second structure  in the local six degrees of freedom.
*In the fourteenth to nineteenth columns (only if there is a third structure) are the forces
*for the third structure in the local six degrees of freedom.
* When there is only one structure, the line structures=1  can be omitted. If there are more
*than one structures, this line is compulsory, e.g. when there are 3 structures, this line
*should be structures=1 2 3.
*data_start is a compulsory line before the data block begins.
*The numbers in the XFT file are in a free format
structures=1
data_start
      0.0000  4.4800E+05  5.0400E+06  3.1360E+06  5.0400E+07  8.9600E+06  1.5120E+08
      0.5000  4.3978E+05  4.9689E+06  3.0784E+06  4.9689E+07  8.7956E+06  1.4907E+08
      1.0000  4.1592E+05  4.8207E+06  2.9114E+06  4.8207E+07  8.3183E+06  1.4462E+08
      1.5000  3.7875E+05  4.5986E+06  2.6512E+06  4.5986E+07  7.5750E+06  1.3796E+08
      2.0000  3.3192E+05  4.3070E+06  2.3234E+06  4.3070E+07  6.6383E+06  1.2921E+08
      2.5000  2.8000E+05  3.9514E+06  1.9600E+06  3.9514E+07  5.6000E+06  1.1854E+08
      3.0000  2.2808E+05  3.5381E+06  1.5966E+06  3.5381E+07  4.5617E+06  1.0614E+08
      3.5000  1.8125E+05  3.0744E+06  1.2688E+06  3.0744E+07  3.6250E+06  9.2232E+07
      4.0000  1.4408E+05  2.5682E+06  1.0086E+06  2.5682E+07  2.8817E+06  7.7045E+07
      4.5000  1.2022E+05  2.0279E+06  8.4155E+05  2.0279E+07  2.4044E+06  6.0838E+07
      5.0000  1.1200E+05  1.4626E+06  7.8400E+05  1.4626E+07  2.2400E+06  4.3878E+07
      5.5000  1.2022E+05  8.8133E+05  8.4155E+05  8.8133E+06  2.4044E+06  2.6440E+07
      6.0000  1.4408E+05  2.9348E+05  1.0086E+06  2.9348E+06  2.8817E+06  8.8044E+06
      ........
```

17.20. The XSWL/GATP Data Records - Input of Cross Swell

The effects of cross swell are implemented in most of Aqwa. If cross swell is not available for a particular application then a warning message will be issued that it has been ignored, or a fatal error will occur. More details are given below.

The XSWL data record must be used to define the cross swell spectrum before the main wave spectrum definition. If Tp is specified on the XSWL data record, then the GATP data record (Gauss T Peak) must be input before the XSWL data record. For example, for a P-M spectrum with cross swell the order is GATP, XSWL, PSMZ (p. 183).

If the main wave spectrum exists, the number of the cross swell wave spectral lines is the same as that of its corresponding main wave spectrum. The default value is 50.

The program assumes that all frequencies are in radians/sec, unless a HRTZ (p. 180) data record has been used to change this to Hertz (cycles/sec).

Note:

For the Gaussian spectrum the standard deviation (σ) is always in radians/sec.

```
      2   5  7   11         21       31       41       51       61        71
    - --- -- ---- ----- ----- -------- -------- -------- -------- -------- ----------
   |X|   |  |XSWL|X     |XXXXX|XXXXXXXX|XXXXXXXX|        |        |        |         |
    - --- -- ---- ----- ----- -------- -------- -------- -------- -------- ----------
       |  |   |     |                              |        |        |         |
```

```
        |  |  |     |                            |        |        |         |
        |  |  |     |                            |        |        |     Direction of Cross Swell
        |  |  |     |                            |        |        |     (degrees)
        |  |  |     |                            |        |        |
        |  |  |     |                            |_ _ _ _ |_ _ _ _ |_(2)Wave parameters - see below
        |  |  |     |
        |  |  |     |
        |  |  |     |_(1)Spectrum type (JONH, JONS, PSMZ or GAUS)
        |  |  |
        |  |  |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

The parameters used to define the spectra are the same as on the JONH (p. 185), JONS (p. 184), PSMZ (p. 183), and GAUS (p. 184) data records, except that the start and finish frequencies are calculated by the program.

```
-----------------------------------------------------------------
|Spectrum Type     | Parameter 1 | Parameter 2 | Parameter 3    |
-----------------------------------------------------------------
|JONSWAP (JONH)    |    gamma    |     Hs      | peak frequency |
-----------------------------------------------------------------
|JONSWAP (JONS)    |    gamma    |   alpha     | peak frequency |
-----------------------------------------------------------------
|Pierson Moskowitz |     Hs      |     Tz      | not used       |
-----------------------------------------------------------------
|Gaussian          |   sigma     |     Hs      | peak frequency |
-----------------------------------------------------------------
```

For more information about the standard Gaussian spectrum, see Gaussian Spectrum in the *Aqwa Theory Manual*.

Note:

Hydrodynamic interaction between the normal and the cross swell spectrum in the case of coupled Drift Force Coefficients or QTFs has been ignored; in other words, the spectra are considered totally separately and for totally linear systems will give the same results as the sum of the results for each spectrum analyzed separately. Note that results such as significant motions will be the square root of the sum of the squares.

The default cross-swell spectral type is Gaussian spectrum (GAUS) if (1) Spectrum Type is not defined.

17.20.1. The GATP Data Record - Use of Peak Period

The GATP data record acts as a switch enabling the Gaussian spectrum on subsequent XSWL data records to be defined in terms of peak period (Tp) instead of peak frequency (Ω_p). It does not apply to JONSWAP or Pierson-Moskowitz spectra. There are no parameters.

```
   2   5  7   11       21
 - --- -- ---- -------- -------- -------- --------
|X|   |  |GATP|XXXXXXXX|XXXXXXXX|XXX
 - --- -- ---- -------- -------- -------- --------
    |  |   |
```

```
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

17.20.2. Where Cross-Swell is Implemented

The following are INCLUDED in the implementation of Cross-Swell:

Aqwa-GS - Input and display of definition of cross swell parameters.

Aqwa-GS - Wave spectra graph generation of wave height spectral density

Aqwa-Drift - Drift forces, Linear Diffraction and Froude Krylov forces (*1)

Aqwa-Drift/Aqwa-Naut/Aqwa-Fer - Morison Elements

Aqwa-Librium/Aqwa-Drift/Aqwa-Naut/Aqwa-Fer - Cable Dynamics

Aqwa-Fer - Treated as 2 component directional wave spectrum

Aqwa-Librium - Calculation of steady drift force only

(*1) Includes effects on wave drift damping.

17.20.3. Where Cross-Swell is not Implemented

By definition all other uses of cross swell with wave spectra are excluded. Note that the following are specifically excluded, but this list is not necessarily exhaustive.

Aqwa Graphical Supervisor

Wave Surface Display

Calculation of Shear Force and Bending Moment

Graphs of Waves (*1)

Contours

(*1) with the exception of cross swell spectral density and other features which are not direction dependent and are automatically included in the wave kinematics associated with Morison elements. - see also inclusions.

Note:

All of the above and other places where wave spectra are used but cannot use cross swell will cause a fatal error. This failure mechanism will be implemented in as many places as possible where the wave spectra are used, but may not include every occurrence.

17.21. The IWHT Data Record - Import of Wave Height Time History

A time history series of wave elevation may be imported into Aqwa-Drift/Naut, in order to reproduce model test wave conditions as accurately as possible. This facility uses the IWHT data record and an external data file. See the section below for a discussion on the accuracy of the reproduction.

Import of the time series will also generate a user-defined spectrum, using a Fast Fourier Transform, whose frequency range is based on a JONSWAP fit of the wave elevation spectral density. In Aqwa-Librium, Aqwa-Fer and Aqwa-Naut (when the NWHT (p. 319) option is on) this spectrum will be used in the same way as a normal user-defined spectrum.

Note:

As the phases of the spectral wave components are allocated randomly, the input wave elevation time-history will not be reproduced.

The number of spectral lines of 200 is mandatory for this facility.

Note:

The wave elevation time history records in the external data file with the extension `.WHT` must be measured at the reference point traveling on the current, if the current exists.

Current is ignored when calculating the phase wave forces on the structure and the wave kinematics for Morison elements.

This data record is used to define the file from which the wave height time history is to be copied.

```
     2   5  7   11    16    21
   - --- -- ---- ----- ----- ---------
  |X|   |  |IWHT|XXXXX|XXXXX|
   - --- -- ---- ----- ----- ---------
      |  |   |                |
      |  |   |                |_(1)Filename from which the data is to be copied
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on Last data record in data category(A3)
```

(1) This is a file name with a `.WHT` extension. Up to 5 WHT files may be imported in a spectral group.

Imported wave elevations are treated as user-defined spectra, so they must be listed consecutively within a spectral group and the last IWHT data record must be followed by a FINI data record. The format is shown below:

```
     2   5  7
   - --- -- ----
  |X|   |  |FINI|
   - --- -- ----
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
```

```
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

Format of the *.WHT File

The `*.WHT` file is an ASCII file with the wave elevation data in free format with 2 values per line. The first value is the time and the second value is the wave elevation.

Additional mandatory data records describe the units. These are in the form:

DEPTH=value

G=value

These values must correspond to the values in the `*.`RES file. i.e. those input in Data Category 5. If the values differ, this will cause a fatal error.

The following optional data can also be input. If not input the relevant value defaults to zero.

DIRECTION=value(degrees)

X_REF=value

Y_REF=value

NAME=Spectrum Name

CURRENT_SPEED=value

CURRENT_DIRECTION=value(degrees)

These values (whether input or default) will override any corresponding data in Data Category 13.

Note:

- The X_REF and Y_REF values are used in the calculation of the phase of the wave and are the position where the wave elevation was measured. For example (in SI units), if the direction of the wave is zero degrees (i.e. along the positive X-axis in the FRA) then values of X_REF/Y_REF of 100.0/0.0 will indicate that the wave elevation was measured 100 metres downstream of the 0,0 wave reference point. Omission of these data will default the reference point to 0,0. i.e. the wave elevation will be calculated using the origin of the FRA as the point at which the wave elevation will be reproduced.

- The Spectrum Name will be used for graphs and tables where appropriate throughout the program.

- Current speed and direction are needed for calculation of the wavelengths of the wave components used to reproduce the wave elevation. If omitted it is assumed that there is no current. Special treatment is necessary for a profiled current. See CPRF Data Record - Profiled Current Velocity (p. 166) for additional information.

- The duration of the time history in the file should be at least 7200s. This duration is necessary in order to give sufficient resolution of low frequency resonant responses. If the file contains less data than this, the data will be extended automatically up to 7200s, using a process of mirroring and copying.

- The maximum number of timesteps in the .WHT file is 150000.
- Comments (starting with * in Column 1) may be added anywhere in the file.
- When the data is imported a ramp is applied over a short period at the start and end of the time history to ensure that the start and end values are zero. This enables the Fourier transform to be more accurate. When the imported data is plotted in the AGS it is this modified data that is plotted.

An example of a `.WHT` file is shown below.

```
* This is an example of a *.wht file
*
DEPTH=30.0
G=9.81
DIRECTION=0.0
X_REF=100.0
Y_REF=0.0
NAME=EXAMPLE
CURRENT_SPEED=0.6
CURRENT_DIRECTION=90
* TIME  WAVE HT
*  s      m
0.0000 -1.088
0.0000 -1.088
0.2366 -1.188
0.4732 -1.268
0.7098 -1.351
0.9464 -1.427
1.1830 -1.471
1.4196 -1.494
1.6562 -1.476
1.8928 -1.406
2.1294 -1.293
2.3660 -1.149
2.6026 -0.966
ETC.
```

Accuracy of Wave Surface Modeling

In Aqwa-Drift/Naut the wave elevation time-history will be reproduced exactly, within the frequency range of the fitted spectrum and subject to the limitations of roundoff error. This is achieved by multiplying each of the spectral wave components (as in standard Aqwa) by a different Low Frequency Perturbation (LFP) Function, i.e.:

Wave elevation =Sigma(j=1,N) { a(j) cos(-w(j)t+k(j)x+í(j)) * LFP(j)(t) }

Where:

N is the number of spectral lines (normal Aqwa N=NSPL)

j is the wave component number

t is time

w is frequency (as normally output in the .LIS file)

í is phase (as normally output in the .LIS file)

a(j) is the amplitude

k is the wave number

Note that no spurious low frequency waves are generated by the above method. For any wave component, the minimum frequency present in the wave elevation is w(j) - dw, where dw is the highest frequency present in the LFP function. Note also that there is no frequency overlap for each wave component. Each LFP function can be considered as a frequency spreading function over a limited set of contiguous frequency bands. In this case each wave component has a different energy (as opposed to the standard Aqwa wave components which have equal energy).

17.22. The SSDN/UDDS/SSWT Data Records - User-Defined Carpet Spectrum

User-defined spread seas may be input with each wave spectrum defined by the user at a series of directions.

The SSDN data record specifies the number of directions to be input and the direction values in degrees. This must be input before any spectral ordinate values. The format of the input is as follows.

```
  2   5  7    11    16    21         31         41         51         61         71       80
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
|X|XXX|  |SSDN|     |     |XXXXXXXXXX|          |          |          |          |          |
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
       |   |     |     |                  |           |          |          |          |
       |   |     |     |                  |           |          |          |          |
       |   |     |     |                  |_Up to 5 Directions (Degrees) (F10.0)
       |   |     |     |
       |   |     |     |_Finish Direction Number (Maximum = 41) (I5)
       |   |     |
       |   |     |_Start Direction Number (I5)
       |   |
       |   |_Compulsory Data Record Keyword(A4)
       |
       |_Optional User Identifier(A2)
```

This may then optionally be followed by specification of the individual weighting factors for each direction. This uses the SSWT data record and is described in detail below.

This is then followed by specification of the wave spectral density ordinates. The spectrum in each direction can be defined by ordinates at up to 200 frequencies. Note that the same frequencies must be used for each spectrum.

```
  2   5  7    11    16    21         31         41         51         61         71       80
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
|X|   |  |UDDS|XXXXX|XXXXX|          |          |          |          |          |          |
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
    |  |   |                   |          |           |          |          |          |
    |  |   |                   |          |           |          |          |          |
    |  |   |                   |          |_(3)Spectral ordinate values for each direction (F10.0)
```

```
        |  |   |                   |
        |  |   |                   |_(2)Frequency of Spectral Ordinates (F10.0)
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

(2) The frequency at which the following ordinates are defined. The same set of frequencies must be used for each spectrum.

(3) A single UDDS data record gives one frequency and the ordinates for up to five directions at this frequency.

If more than one spectrum is input, the last UDDS data record of this carpet spectrum must be followed by a FINI data record. The format is shown below:

```
       2   5  7
     - --- -- ----
    |X|   |  |FINI|
     - --- -- ----
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in data category(A3)
```

Notes

If you need to enter more than one SSDN card, you must input the first SSDN card with its directions defined, then all the associated UDDS/SSWT cards. After you have input the requirements for the first SSDN card, enter the second SSDN card and all associated UDDS/SSWT cards. The following example shows the correct way to input multiple SSDN cards:

```
13SSDN    1    5            -85.420   -66.738   -36.526     0.000    36.526
13SSWT                     0.1294850 0.2797054 0.3818301 0.4179592 0.3818301
13UDDS              0.3142    0.0000    0.0000    0.0000    0.0000    0.0000
13UDDS              0.3796    0.0006    0.0156    0.0647    0.1002    0.0647
.....
13SSDN    6    7             66.738    85.420
13SSWT                     0.2797054 0.1294850
13UDDS              0.3142    0.0000    0.0000
13UDDS              0.3796    0.0156    0.0006
```

The results output for plotting in the AGS are for the main direction only.

If there is no SSWT data record the weighting factors i.e. the contribution of each sub-direction spectrum of N total directions to the total force or motion are calculated by a simple trapezoidal integral and will add up to unity. In this case, if the sub-directions are not input in ascending order, the index number of the *j*-th direction in ascending order of direction ($i=1,2,...,N$) is defined as $\mathrm{Inx}(i)=j$. For example, the ascending direction index numbers $\mathrm{Inx}(1:7)$ are (6, 4, 2, 1, 3, 5, 7), if 7 sub-directions are input in the sequence $\beta_1=0°,\beta_2=-36.5°,\beta_3=36.5°,\beta_4=-66.7°,\beta_5=66.7°,\beta_6=-85.4°,\beta_7=85.4°$. If all the sub-directions are input in ascending order, the index number of the *j*-th direction is $\mathrm{Inx}(j)=j$. The weighting factors are calculated as:

$$W_t(j)=\frac{1}{2}\left(\frac{\beta_{j2}-\beta_{j1}}{\text{Total direction range}}\right)$$

where

if $i=1$ (minimum wave direction), $j=\text{Inx}(1), j1=\text{Inx}(1), j2=\text{Inx}(2)$

if $i=N$ (maximum wave direction), $j=\text{Inx}(N), j1=\text{Inx}(N-1), j2=\text{Inx}(N)$

if $1<i<N$, $j=\text{Inx}(i), j1=\text{Inx}(i-1), j2=\text{Inx}(i+1)$

In general, it is up to the user to input the spectral ordinates factored so the integral of the spreading function divided by the spread range is unity.

As an example, if a carpet spectrum is defined to model a $\cos^2$ spreading function, then the spectral ordinates must be factored by 2.0, as the integral of $\cos^2$ divided by the direction range is 0.5.

Alternatively the user may exercise total control over the contribution of each spectrum at each direction by specifying the individual weighting factors. This information must be input directly after the SSDN input and has the following format.

```
  2   5  7    11    16    21         31         41         51         61         71        80
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
|X|   |  |SSWT|XXXXX|XXXXX|XXXXXXXXXX|          |          |          |          |          |
 - --- -- ---- ----- ----- ---------- ---------- ---------- ---------- ---------- ----------
       |   |                            |           |          |          |          |
       |   |                            |           |          |          |          |
       |   |                            |_(1)Spectral weights for each direction (F10.0)
       |   |
       |   |_Compulsory Data Record Keyword(A4)
       |
       |_Optional User Identifier(A2)
```

For each direction, a spectral weight of 1.0 will give the same results as a single long-crested wave. This method of input can therefore be used to describe a long crested wave with 2 simultaneous cross swell spectra with 3 direction entries. Note that if columns 31-80 are left blank then the default weighting factor of 1.0 will be used for all directions, otherwise values must be input for ALL directions. The same number of values that was specified on the previous SSDN data record is expected.

17.23. The NAME Data Record - Spectrum Name

This data record optionally defines a name for a wave spectrum. It is associated with the currently defined Wave Spectral Direction (p. 180).

```
   2   5  7    11         21
 - --- -- ---- ---------- ----------
|X|   |  |NAME|XXXXXXXXXX|
 - --- -- ---- ---------- ----------
    |  |   |                 |
    |  |   |                 |_(2) Name for this Spectrum
    |  |   |
    |  |   |_(1) Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

17.24. The NODR Data Record - No Drift Forces

This data record specifies that 2nd order drift forces are not to be calculated for the current spectrum. It is applicable to any program except Aqwa-Naut.

```
    2   5  7   11    16   21       31
  - --- -- ---- ----- ----- -------- --
 |X|   |  |NODR|     |XXXXX|XXXXXXXX|
  - --- -- ---- ----- ----- -------- --
     |  |   |     |
     |  |   |     |_(2) Direction number (I5)
     |  |   |
     |  |   |_(1) Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

(1) NODR specifies that the 2nd order drift forces are not to be calculated for the spectrum being defined. If more than one spectrum is input then a NODR data record is required for every spectrum for which drift forces are to be omitted.

(2) Where a User Defined Spread Seas Spectra (p. 198) is defined, this item specifies a direction for which 2nd order drift forces are to be omitted. For all other spectrum types this data is not required.

17.25. The SPGR Data Record - Spectral Group Keyword

This data record signifies that the following spectra, until the next SPGR data record, form one spectral group.

```
    2   5  7   11    16   21       31
  - --- -- ---- ----- ----- -------- --
 |X|   |  |SPGR|XXXXX|XXXXX|XXXXXXXX|
  - --- -- ---- ----- ----- -------- --
     |  |   |     |
     |  |   |     |_(2) No other data is required (I5)
     |  |   |
     |  |   |_(1) Compulsory Data Record Keyword(A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

LIMITATIONS

1. Program applicability:

   - Aqwa-Line - the SPGR card is recognized, but there can be only one spectral group containing only one spectrum.
   - Aqwa-Librium - up to 20 spectral groups.
   - Aqwa-Fer - up to 20 spectral groups.
   - Aqwa-Drift - only one spectral group is allowed.
   - Aqwa-Naut - only one spectral group is allowed.

2. The overall maximum total number of spectra in all groups is 20.

3. In the following sections the term sub-spectrum is used.

   A user-defined 2D (carpet) spectrum is a single spectrum, but it may consist of up to 41 sub-spectra.

   A spectrum with a spreading function is modeled in Aqwa with a series of sub-spectra at Gauss integration points, the number of which is defined by the SPDN (p. 180) data record.

   A spectrum with cross-swell contains 2 sub-spectra.

4. A spectral group may contain up to 20 spectra, subject to the overall limit above. Therefore, if a group contains 20 spectra, there can be only one group. The spectra can be any of the available types, i.e. JONSWAP, Pierson-Moskowitz, Gaussian, user-defined or imported using the IWHT data record.

5. There may be up to 5 IWHT data records, but these must all be in the same spectral group. Within a group they must be listed consecutively and the list terminated with a FINI data record.

6. A spectral group may contain up to 41 sub-spectra in total.

7. A spectral group may contain only one definition of wind and/or current.

8. If there is no wind or current defined in a spectral group, the values will be taken from the last WIND or CURR data record read. This is consistent with behavior in earlier versions of Aqwa.

An example of a spectral group definition is shown below. This group contains a wind spectrum, a current, a JONSWAP spectrum and a user-defined spectrum. It also makes use of both spectrum and group names.

```
       SPGR
       SGNM            Example of Spectral Group definition
       NPDW
       WIND             12.000    126.00      13.0
       CURR              1.000     30.00
       SPDN               20.0
       NAME            Spectrum 1 - JONSWAP
       JONH                0.2       1.5       2.0   1.00000       0.6
       SPDN             -135.0
       NAME            Spectrum 2 - simple user-defined spectrum
       UDEF              0.100     0.000
       UDEF              0.300     2.000
       UDEF              0.700     2.000
       UDEF              0.900     0.000
       FINI
*
       SPGR  (Next Group begins)
```

17.26. The SGNM Data Record - Spectral Group Name

This data record optionally defines a name for a spectral group. It is associated with the currently defined Spectral Group (p. 201).

```
      2   5  7   11         21
     - --- -- ---- ---------- ----------
    |X|   |  |SGNM|XXXXXXXXXX|          |
     - --- -- ---- ---------- ----------
        |  |   |                 |
        |  |   |                 |_(2) Name for this Spectral Group
```

```
       |  |   |
       |  |   |_(1) Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on last data record in Data Category (A3)
```

17.27. The TOWS Data Record - Tether Tow Speed

This data record should only be input for towed tethers.

```
   2   5  7   11         21         31         41
  - --- -- ---- ---------- ---------- ---------- ----------
 |X|XXX|  |TOWS|XXXXXXXXXX|XXXXXXXXXX|          |          |
  - --- -- ---- ---------- ---------- ---------- ----------
          |   |                            |          |
          |   |                            |          |
          |   |                            |          |_(2) Tow Direction (E10.0)
          |   |                            |
          |   |                            |_(1) Tow Speed (E10.0)
          |   |
          |   |_Compulsory Data Record Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

(1) The speed at which the tether is towed

(2) The tow direction relative to the global (FRA) X-axis. Maximum +/- 30°

17.28. The WRMP Data Record - Wave Ramp

```
   2   5  7   11         21
  - --- -- ---- ---------- --------
 |X|   |  |WRMP|XXXXXXXXXX|        |
  - --- -- ---- ---------- --------
       |  |   |                 |
       |  |   |                 |
       |  |   |                 |_(1) Time (tw) before which the wave ramp is effective (F10.0)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on Last Data Record in Data Category (A3)
```

(1) The wave ramp is introduced to reduce the transient motion of the structure at the beginning of a time domain analysis. When this data record is defined, the wave ramp takes effect from t = 0.0 to t = t_w, during which a wave ramp factor f ($0.0 < f < 1.0$) is calculated and multiplied to the wave frequency forces.

The wave ramp factor f is calculated by

$$f = \sin^2\left(\frac{\pi t}{2t_w}\right)$$

At t = 0, the wave ramp factor is 0.0 and at t = t_w, the factor is 1.0. If t_w is omitted in the WRMP data record, the program will default to t_w = highest period of all the wave components in the spectrum or, for an irregular wave group, the highest period of all the wave components in all the spectra.

Chapter 18: Regular Wave (Aqwa-Naut) - WAVE (Data Category 13N)

18.1. General Description

This data category is used to describe a single regular wave. The wave is described in terms of its amplitude, period and direction.

This data category is applicable only to Aqwa-Naut.

18.2. Data Category Header

```
          5      11
     ---- -- ---- ----
    |XXXX|  |XXXX|WAVE|
     ---- -- ---- ----
          |        |
          |        |
          |        |_Compulsory Data Category Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

18.3. The WAMP Data Record - The Regular Wave Amplitude

```
      2   5  7   11         21
    - --- -- ---- ---------- ---------
   |X|   |  |WAMP|XXXXXXXXXX|         |
    - --- -- ---- ---------- ---------
       |  |   |                 |
       |  |   |                 |
       |  |   |                 |_Wave Amplitude (F10.0)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on Last Data Record in Data Category (A3)
```

18.4. The PERD Data Record - Regular Wave Period

```
      2   5  7   11         21
    - --- -- ---- ---------- ---------
   |X|   |  |PERD|XXXXXXXXXX|         |
    - --- -- ---- ---------- ---------
       |  |   |                 |
       |  |   |                 |
       |  |   |                 |_Wave Period (F10.0)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
```

```
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on Last Data Record in Data Category (A3)
```

18.5. The WDRN & WVDN Data Records - Wave Direction

These two data record keywords mean exactly the same.

```
      2   5  7   11         21
    - --- -- ---- ---------- ---------
   |X|   |  |WDRN|XXXXXXXXXX|         |
    - --- -- ---- ---------- ---------
   |X|   |  |WVDN|XXXXXXXXXX|         |
    - --- -- ---- ---------- ---------
        |  |   |                 |
        |  |   |                 |
        |  |   |                 |_Wave Direction (F10.0)
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on Last Data Record in Data Category (A3)
```

18.6. The AIRY Data Record - Linear Wave

This data record tells the program to use linear wave as incident wave instead of the Stokes second order wave which is used by default in the calculation of the Froude-Krylov forces. Note that if the LSTF option is used in the OPTIONS data category, the linear wave and the Stokes second order wave will give the same results.

This data record is not recommended for big waves.

```
      2   5  7   11
    - --- -- ----
   |X|   |  |AIRY|
    - --- -- ----
        |  |   |
        |  |   |
        |  |   |
        |  |   |
        |  |   |_Optional Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on Last Data Record in Data Category (A3)
```

18.7. The WRMP Data Record - Wave Ramp

```
     2   5  7   11         21
    - --- -- ---- ---------- --------
   |X|   |  |WRMP|XXXXXXXXXX|        |
    - --- -- ---- ---------- --------
        |  |   |                 |
        |  |   |                 |
        |  |   |                 |_(1) Time (tw) before which the wave ramp is effective (F10.0)
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
```

```
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on Last Data Record in Data Category (A3)
```

(1) The wave ramp is introduced to reduce the transient motion of the structure at the beginning of a time domain analysis. When this data record is defined, the wave ramp takes effect from t = 0.0 to t = t_w, during which a wave ramp factor f (0.0 < f < 1.0) is calculated and multiplied to the wave frequency forces.

The wave ramp factor f is calculated by

$$f = \sin^2\left(\frac{\pi t}{2t_w}\right)$$

At t = 0, the wave ramp factor is 0.0 and at t = t_w, the factor is 1.0. If t_w is omitted in the WRMP data record, the program will default to t_w = wave period for regular waves; for irregular waves in Naut, the default value for t_w will be the highest period of all the wave components in the spectrum.

18.8. The STK5 Data Record – Stokes Fifth Order Wave

This data record tells the program to use the Stokes fifth order wave as an incident wave instead of the Stokes second order wave, which is used by default in the calculation of the Froude-Krylov forces. A set of three additional wave parameters is defined in this record.

```
     2   5  7   11    16    21        31        41       51
    - --- -- ---- ----- ----- --------- --------- ---------
   |X|   |  |STK5|     |XXXXX|         |         |        |
    - --- -- ---- ----- ----- --------- --------- ---------
       |  |   |     |             |         |         |
       |  |   |     |             |-----------------
       |  |   |     |             |
       |  |   |     |             |_ (3) values of wave parameters (3F10.0)
       |  |   |     |
       |  |   |     |_(2) Set number of input parameters (I5)
       |  |   |
       |  |   |_(1) Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on Last Data Record in Data Category (A3)
```

1. The data record keyword defines the Stokes fifth order wave.

2. The sequence number of the set of the additional Stokes fifth order wave parameters among five sets of input parameters.

3. Three parameters of the specified set.

Set Number	Parameter 1	Parameter 2	Parameter 3
1	Wavelength	Still water depth	Uniform current
2	Wave period	Still water depth	Uniform current

3	Wavelength	Mean water depth	Uniform current
4	Wavelength	Still water depth	Volume flux
5	Wave period	Still water depth	Volume flux

Chapter 19: Mooring Lines and Attachment Points - MOOR (Data Category 14)

19.1. General Description

This data category is used to input the description of the mooring line/hawser attachment points/cable configurations. The types of mooring lines available at present include both linear and nonlinear cables. The linear cables are made up of linear elastic cables, winch cables and 'constant force' cables. The nonlinear cables are made up of catenary cables, steel wire cables and cables described by a polynomial of up to fifth order.

Up to a maximum of 100 mooring lines may be input, by specifying the structure number and node number (see Node Number and Coordinates (Data Category 1) (p. 59)) of the attachment points at each end of the mooring line, together with their physical characteristics.

Enter NONE for the data category keyword if no mooring lines are present (see Compulsory Data Category Keyword (p. 47)).

Attachment Positions of Mooring Lines

One end of all mooring lines must be attached to a point on a floating (or sinking!) structure. The other end of the mooring line may be attached to either another structure or a fixed point (e.g. the sea bed) with the following exceptions.

The FORC cable is inherently a constant force vector and cannot be attached between two structures. Although presented as a type of cable, this facility is used in practice to represent any external force acting at a point on a structure whose magnitude and direction are constant.

Input of Mooring Lines with Nonlinear Properties

It should be noted that the input format for nonlinear mooring lines is not the same as that for linear mooring lines. Linear mooring lines are input by specifying both the physical properties and the attachment points on one data record. Nonlinear mooring lines are input by specifying the physical properties on one data record followed by one or more data records, each representing a mooring line with the previously defined physical properties.

The maximum number of different types of nonlinear properties accepted by the program is 1000.

19.2. Data Category Header

```
        5      11
  ---- -- ---- ----
 |XXXX|  |XXXX|MOOR|
  ---- -- ---- ----
```

```
          |        |
          |        |_Compulsory Data Category Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

19.3. The LINE/WNCH/FORC Data Records - Linear Cables

The maximum number of mooring lines (linear plus nonlinear) that may be defined is 100.

```
    2   5  7   11    16    21    26    31        41        51        61
  - --- -- ---- ----- ----- ----- ----- --------- --------- --------- ---------
 |X|   |  |LINE|     |     |     |     |         |         |         |         |
  - --- -- ---- ----- ----- ----- ----- --------- --------- --------- ---------
 |X|   |  |WNCH|     |     |     |     |         |         |         |         |
  - --- -- ---- ----- ----- ----- ----- --------- --------- --------- ---------
 |X|   |  |FORC|     |     |XXXXX|     |         |XXXXXXXXX|         |         |
  - --- -- ---- ----- ----- ----- ----- --------- --------- --------- ---------
    |  |   |     |     |     |     |       |         |         |         |
    |  |   |     |     |     |     |       |         |         |         |
    |  |   |     |     |     |     |       |         |         | (9) Paying-out Friction
    |  |   |     |     |     |     |       |         |         |      Factor Fp (WNCH) (F10.0)
    |  |   |     |     |     |     |       |         |         |
    |  |   |     |     |     |     |       |         | (8) Pretension (LINE)
    |  |   |     |     |     |     |       |         |     Winding-in Friction
    |  |   |     |     |     |     |       |         |     Factor Fw (WNCH) (F10.0)
    |  |   |     |     |     |     |       |         |
    |  |   |     |     |     |     |       | (7) Unstretched Length (F10.0)
    |  |   |     |     |     |     |       |
    |  |   |     |     |     |     |   (6) Stiffness (LINE)
    |  |   |     |     |     |     |       Tension   (WNCH)
    |  |   |     |     |     |     |       Force     (FORC) (E10.0)
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |_(5) Node Number (I5)
    |  |   |     |     |     |
    |  |   |     |     |     |_(4) Structure Number (I5)
    |  |   |     |     |
    |  |   |     |     |_(3) Node Number (I5)
    |  |   |     |
    |  |   |     |_(2) Structure Number (I5)
    |  |   |
    |  |   |_(1) Mooring Line Code (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) The mooring line code indicates which type of linear mooring line the user wishes to model. Note that the term 'linear' is used generally to denote that the tension is either constant or linearly proportional to the extension. The cable codes available at present are:

LINE - a conventional linear elastic cable

WNCH - a winch adjusted to constant tension

FORC - a constant force

Note that these mooring lines are assumed to have no mass and are therefore represented geometrically by a straight line. See below for further details.

(2) This is the number of the structure to which the cable is attached and must correspond to one of the structures defined within Data Category 2. If **1** is input, this will correspond to the structure defined in Data Category ELM1. If '2' is input, this will correspond to the structure defined in Data Category

ELM2 etc. Note that Structure 0 (in other words, a fixed node) is an ILLEGAL structure and will produce an error (see (4)).

(3) This is the node number whose position is the attachment point of the end of the mooring line on the structure specified (1). The position of this node on the structure (2) must have been defined in Data Category 1.

(4)-(5) This structure number (4) and its corresponding node number (5) define the attachment position of the other end of the mooring line. This structure number (4) cannot be the same as the first structure (2). The position of this node on the structure (5) must have been defined in Data Category 1 (p. 59).

If '0' is input as the structure number (4), together with a node number (5), the program will recognize that this node number (5) references a fixed position as defined in Data Category 1 in the Fixed Reference Axis System (FRA). Note that a non-zero structure number (4) must be followed by a valid node number (5) on that structure.

(6) This value represents:

WNCH - tension

FORC - constant force

LINE - linear elastic stiffness

(7) The unstretched length is used to indicate the length at which the mooring line is slack. Meaning if the distance between the attachment points at either end of the mooring line is less than this value, then the tension in the mooring line will be zero. Although unusual, it is quite valid to input this value as zero where the 'cable' is never slack. However, in the special case where both ends of the cable are coincident, the direction of the force exerted by the cable is undefined and is automatically set to zero. If this value is zero and the pretension value (8) is positive, the unstretched length will be automatically estimated.

(8) The pretension in the linear elastic mooring (LINE) if the value is greater than zero and the unstretched length is zero or not defined.

(8)-(9) The tension in the winch mooring line when winding-in is given by $T_w=T_s*(1-F_w)$ where T_s is the winch tension specified in (6).

When paying-out, the winch tension is given by $T_p = T_s(1+F_p)$

For example, if the tension specified is 1000 tonnes and F_w and F_p are 0.3 and 0.1 respectively, then the tensions will be 700 and 1100 tonnes respectively.

We note that the initial tension is undefined. The default initial tension is the winding-in tension i.e. 700 tonnes in the example above. The winding-in friction coefficient should be specified as negative if the paying-out value of tension is required as the initial tension.

Note also that for Aqwa-Librium and Aqwa-Fer, this tension value will not change unless the line goes slack. (Range is less than the initial length specified.)

Aqwa-Drift and Aqwa-Naut will vary the tension according to whether the range (distance between the anchor and vessel attachment point) is increasing or decreasing. If the range is less than the initial length specified the line becomes slack and the tension is zero.

19.3.1. The LINE Data Record - A Conventional Linear Elastic Cable

A 'LINE' cable (linear elastic cable) is the conventional type of cable where the tension is proportional to its extension, and the constant of proportionality is termed the STIFFNESS. This type of cable can be attached between a structure and a fixed point or attached between two structures. As the extension may vary during the analysis, the structure(s) to which the cable is attached will experience a force of varying magnitude and direction. The magnitude of this force, which is equal to the cable tension is given by

Force = (Stiffness(6))(Cable Extension)

Note that when the cable is slack, the cable extension, as defined below, is negative and the cable tension is set to zero.

(A) For a cable attached between a structure and a fixed point:

The extension, at any stage of the analysis, is calculated by subtracting the unstretched length (7) from the distance between the position of the attachment node (3) and the position of the fixed node (5) as defined in Data Category 1 in the Fixed Reference Axis System (FRA).

The direction of this force is given by the vector going from the position of the attachment node (3) to that of the fixed node (5)

(B) For a cable attached to two structures:

The extension, at any stage of the analysis, is calculated by subtracting the unstretched length (7) from the distance between the position of the attachment node (3) on one structure and the position of the attachment node (5) on the other structure.

The direction of the force on a structure is given by the vector going from the position of the attachment node (3) on that structure, to the position of the attachment node (5) on the other structure. The forces on each structure will therefore always be equal and opposite. Note that the interchange of parameters (2) and (3) with (4) and (5) has no effect.

19.3.2. The WNCH Data Record - A Winch Adjusted to Constant Tension

The 'WNCH' cable may be thought of as attached to a winch providing constant tension in that mooring line. This type of cable can be attached between a structure and a fixed point or attached between two structures. This model of a cable therefore represents a force of constant magnitude but with varying direction.

The magnitude of this force is given by the value of parameter (6) input in columns 31-40 and is constant throughout the analysis.

(A) For a cable attached between a structure and a fixed point:

The direction of this force is given by the vector going from the position of the attachment node (3), at any stage in the analysis, to that of the fixed node (5) as defined in Data Category 1 in the Fixed Reference Axis system (FRA).

(B) For a cable attached to two structures:

The direction of the force on one structure, at any stage of the analysis, is given by the vector from the position of the attachment node (3) on that structure, to the position of the attachment node (5) on the other structure. The forces on each structure will therefore always be equal and opposite. Note that the interchange of parameters (2) and (3) with (4) and (5) has no effect.

19.3.3. The FORC Data Record - Constant Force

The 'FORC' cable represents a mooring line whose anchor point (parameters (4) and (5)) is automatically adjusted so that the force vector acting on the structure is constant. Although the attachment point moves with the structure during the analysis, the magnitude and direction of the force acting at that point remains constant. This model of a cable therefore represents a force of constant magnitude and direction throughout the analysis.

The magnitude of the force is given by the value of parameter (6) input in columns 31-40.

The direction of the force is given by the vector going from the position of the attachment node (3) to the position of the node (5) where both nodes are as originally defined in Data Category 1 in the Fixed Reference Axis system (FRA).

Although presented as a type of cable, in practice this facility may be used to represent any external force acting at a point on a structure whose magnitude and direction is constant, e.g. the force exerted by wind on a superstructure.

19.4. The POLY Data Record - Polynomial Nonlinear Properties

This data record defines a nonlinear property of a mooring line. In order to use these defined values, one or more NLIN or FLIN data records must follow. The maximum number of nonlinear properties that may be defined is 50.

```
   2   5  7    11                31        41        51        61
 - --- -- ---- ---------------- --------- --------- --------- -----
|X|   |  |POLY|XXXXXXXXXXXXXXXX|         |         |         |     ...
 - --- -- ---- ---------------- --------- --------- ---------------
    |  |   |                        |         |         |        |
    |  |   |                        |--------------------------------
    |  |   |                        |
    |  |   |                        |
    |  |   |              (1)-(5) 5 Coefficients of the Polynomial (5E10.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1)-(5) These values represent the coefficients of the polynomial which defines the force in the mooring as a function of extension or compression.

The Tension as a Polynomial Function of Extension. For application to Fenders see note below.

This facility enables the user to approximate the force/extension curve of any mooring line with known characteristics. Note that this data record does not define a mooring line.

The mooring line properties defined on this data record will apply to all NLIN or FLIN data records that follow until another nonlinear property data record is input. (Note that SWIR is also a nonlinear property data record.)

Tension in a mooring line with this property is given by:

Tension = P1.E + P2.E^2 + P3.E^3 + P4.E^4 + P5.E^5

P1, P2, P3, P4, P5 = Parameters input on the POLY data record

E = Extension of the mooring line

Note:

When used to define the stiffness properties of a fender the force and displacement used are compressive instead of tensile. For a fender with linear stiffness P1 will still be positive.

19.5. The NLIN Data Record - Nonlinear Cables

When an NLIN data record is input, the program assumes that the nonlinear properties correspond to those specified by the most recently input nonlinear properties data record. Failure to input these properties before a NLIN data record means that they are undefined and will result in an error. Note that one nonlinear properties data record will normally apply to several NLIN data records. This not only avoids repeating the same properties for several similar mooring lines, but also enables the user to make a single change to apply to all those properties.

Parameters (6), (8), (9) are only applicable when a POLY nonlinear line is used as a winch line.

The maximum number of mooring lines that may be defined is 100.

```
  2   5  7    11    16    21    26    31        41        51        61        71
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
|X|   |  |NLIN|     |     |     |     |         |         |         |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
    |  |   |     |     |     |     |       |         |         |         |
    |  |   |     |     |     |     |       |         |         |         |
    |  |   |     |     |     |     |       |         |         | (9) Paying-out Friction
    |  |   |     |     |     |     |       |         |         |      Factor Fp (F10.0)
    |  |   |     |     |     |     |       |         |         |
    |  |   |     |     |     |     |       |         | (8) Winding-in Friction
    |  |   |     |     |     |     |       |         |     Factor Fw (F10.0)
    |  |   |     |     |     |     |       |         |
    |  |   |     |     |     |     |       |         |
    |  |   |     |     |     |     |       | (7) Unstretched Length (F10.0)
    |  |   |     |     |     |     |       |
    |  |   |     |     |     |     |   (6) Winch Tension Ts (F10.0)
    |  |   |     |     |     |     |       Pretension Tension (F10.0)
    |  |   |     |     |     |     |
```

```
       |  |   |     |     |     |     |_(5) Node Number (I5)
       |  |   |     |     |     |
       |  |   |     |     |     |_(4) Structure Number (I5)
       |  |   |     |     |
       |  |   |     |     |_(3) Node Number (I5)
       |  |   |     |
       |  |   |     |_(2) Structure Number (I5)
       |  |   |
       |  |   |_(1) Nonlinear Mooring Line Code (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on last data record in Data Category (A3)
```

(6) The pretension on a steel wire or polynomial cable can be defined if the unstretched length (7) is not defined or its value is zero. For the quasi-static composite cable, the pretension can be defined if the pretension calculation required data has been defined in either the first or last section of the ECAT (p. 220) data record.

19.5.1. Parameters Applied to a Polynomial (POLY) Mooring Line

This type of mooring line is a more general case of the linear elastic mooring line (described in detail in The LINE/WNCH/FORC Data Records - Linear Cables (p. 210)) and with the exception of the manner in which the cable tension is calculated, the POLY data record (The POLY Data Record - Polynomial Nonlinear Properties (p. 213)) is identical in all respects. Note that these mooring lines are assumed to have no mass and are therefore represented geometrically by a straight line.

Parameters on the NLIN data record are:

(1) Mooring line code NLIN indicates a nonlinear cable whose properties are specified by the preceding POLY nonlinear properties data record.

(2)-(5) As linear mooring lines in The LINE/WNCH/FORC Data Records - Linear Cables (p. 210).

(6) This field is used to specify the winch tension T_s when the POLY nonlinear line is used as a winch line. Otherwise it is not applicable.

(7) As linear mooring lines in The LINE/WNCH/FORC Data Records - Linear Cables (p. 210).

(8),(9) F_w and F_p are applicable only when the POLY nonlinear line is used as a winch line. The tension in the POLY winch line when winding-in is given by $T_w = T_s(1-|F_w|)$ and when paying-out, the tension is given by $T_p = T_s(1+|F_p|)$.

For example, if the tension specified is 1000 tonnes and F_w and F_p are 0.3 and 0.1 respectively, then the tensions will be 700 (Tmin) and 1100 (Tmax) tonnes respectively.

The default initial tension is calculated as follows:

F_w	F_p	Description	Calculation	Value in example above
>0.0	>0.0	Mean tension	$(T_{min}+T_{max})/2$	900t
>0.0	< 0.0	Winding-in tension	T_{min}	700t
< 0.0	>0.0	Paying-out tension	T_{max}	1100t

< 0.0	< 0.0	Winch tension		1000t

For Aqwa-Librium and Aqwa-Fer, this tension value will not change unless the line goes slack. (Range is less than the initial length specified.)

Aqwa-Drift and Aqwa-Naut will vary the tension according to whether the range (distance between the anchor and vessel attachment point) is increasing or decreasing. If the range is less than the initial length specified the line becomes slack and the tension is zero.

The initial paid-out length is initialized to give the specified tension in the initial position specified in Data Category 15 at the beginning of the time history.

* If the range is increasing and the tension is at T_{max} then the winch is paying out and the tension remains at T_{max}.

* If the range is decreasing and the tension is at T_{min} then the winch is winding in and the tension remains at T_{min} as long as the range is greater than the initial length specified.

* At all other times the line acts as a normal NLIN(POLY) line.

19.5.2. Parameters Applied to a Composite Catenary (COMP/ECAT) Mooring Line

For a description of the elastic catenary mooring line see The COMP/ECAT/SSCB Data Records - Composite Catenary Mooring Line (p. 217). Parameters on the NLIN data record are:

(1) The mooring line code NLIN indicates a catenary mooring line whose properties are specified by the preceding COMP/ECAT nonlinear properties data records.

(2)-(5) As linear mooring lines in The LINE/WNCH/FORC Data Records - Linear Cables (p. 210).

Note that if 0 is specified as the 2nd structure number (parameter 4), it is assumed that this is the seabed and the cable will not hang any lower than the node specified in parameter 5.

19.5.3. Parameters Applied to a Steel Wire (SWIR) Nonlinearity

For a description of the steel wire mooring line see The SWIR Data Record - Steel Wire Nonlinear Properties (p. 242). Parameters on the NLIN data record are:

(1) The mooring line code NLIN indicates a steel wire mooring line whose properties are specified by the preceding SWIR nonlinear properties data record.

(2)-(5) As linear mooring lines in The LINE/WNCH/FORC Data Records - Linear Cables (p. 210).

(6) This field is not applicable as the tension is not fixed but is calculated at each step of the analysis.

(7) This is simply the unstretched length of the steel wire.

19.6. The COMP/ECAT/SSCB Data Records - Composite Catenary Mooring Line

These data records define a nonlinear composite mooring line, in terms of one or more elastic catenaries. In order to use this composite line, one or more NLIN data records must follow.

A composite mooring line can be defined to link a structure to an anchor, or to link two structures.

Limits on the numbers of components in a mooring system are given at the end of this section.

The data requirements for quasi-static composite cables depend upon the mooring line configuration, as summarized below:

Description	Definition Requirement
Structure-anchor cable with horizontal seabed	Omit SBED (p. 168) or use zero slope. Omit SSCB (p. 221).
Structure-structure cable in deep water where the cable will not make contact with the seabed during the analysis	Omit SBED (p. 168) and SSCB (p. 221).
Structure-anchor cable with sloped seabed	Define local slope on COMP (p. 217) data record **OR** Define global slope using SBED (p. 168). Omit SSCB (p. 221).
Structure-structure cable with horizontal seabed	Omit SBED (p. 168) or use zero slope. Include SSCB (p. 221).
Structure-structure cable with sloped seabed	Define slope using SBED (p. 168). Include SSCB (p. 221).

19.6.1. The COMP Data Record

The COMP data record describes a composite mooring line consisting of one or more elastic catenaries. Internally Aqwa converts all composite mooring lines to a multi-dimensional load/extension database. You are strongly advised to read this section before using this facility.

```
  2   5  7    11    16    21          31        41        51
 - --- -- ---- ----- ----- ----- ----- --------- --------- -----------
|X|   |  |COMP|    3|   10|11112|    2|         |         |          |
 - --- -- ---- ----- ----- ----- ----- --------- --------- -----------
    |  |   |     |     |     |     |      |       |            |_(7) Sea bed slope (F10.0)
    |  |   |     |     |     |     |      |       |
    |  |   |     |     |     |     |      |       |_(6) Z Maximum Value of 1st attachment (F10.0)
    |  |   |     |     |     |     |      |
    |  |   |     |     |     |     |      |_(5) Z Minimum Value of 1st attachment (F10.0)
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |_(4) Number of lines in the cable
    |  |   |     |     |     |          composite (I5) (NO DEFAULT) (Max=10)
    |  |   |     |     |     |
    |  |   |     |     |     |_(3) Warning flags and Symmetry forcing (I5)
    |  |   |     |     |            (Def = all warnings issued)
```

```
        |  |   |     |     |
        |  |   |     |     |_(2) Number of X coordinates (I5) (Def =40,Max = 40) or 600 divided by (1),
        |  |   |     |          whichever is less
        |  |   |     |
        |  |   |     |_(1) Number of Z coordinates (I5) (Def =15, Max = 20) or 600 divided by (2),
        |  |   |          whichever is less
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The number of Z values to be used in creating the multi-dimensional load extension database for this composite mooring line

(2) The number of X values to be used in creating the multi-dimensional load/extension database for this composite mooring line.

For composite catenaries linking two structures in deep water (configuration type 2 (p. 217)), it is strongly recommended that the full two-dimensional database size (600 points) be used. The default numbers, when these fields are left blank, for Z and X are 15 and 40 respectively. Also the Z becomes the angular coordinate and the X the radial coordinate, and the program will ignore user specifications for the Z range and use the default values (-90 to + 90 degrees). The seabed slope will also be ignored for catenaries between structures as they are not allowed to touch the seabed.

(3) This parameter indicates whether warnings should be issued when the position of the attachment point of the mooring line relative to the anchor point is outside the range of the database created for this mooring line characteristic. Warnings about the degree of symmetry are not issued, as the stiffness matrix is automatically symmetric for composite cables. See The LE2D Data Record (p. 238) for further details on stiffness matrix asymmetry.

It is used for configuration types 1-2 (p. 217) only.

This parameter should be thought of as five separate flags, which indicate the following:

Flag	Column	Meaning
1	21	0 = Warnings are issued when the X position exceeds the range specified
2	22	0 = Warnings are issued when the X position is below the range specified
3	23	0 = Warnings are issued when the Z position exceeds the range specified
4	24	0 = Warnings are issued when the Z position is below the range specified
5	25	0 = Symmetry Forcing

If a value is set to non-zero then the corresponding warning will be suppressed.

The Z range warnings during the analysis correspond directly to the relative Z position of the attachment point on the vessel in the database axis system being outside the values specified in (5)(6).

The X range (horizontal distance between the attachment point on the vessel and the anchor) will depend on the position of the anchor and the maximum tension specified on the ECAT (p. 220) data record. Warnings during the analysis relating to values below the X range correspond to slack condition when the mooring line is hanging vertically. Warnings during the analysis relating to values exceeding the X range correspond to tensions in excess of the lowest value of maximum tension specified on the ECAT (p. 220) data records following this data record.

The 5th number (column 25) relates to the symmetry forcing. The calculation of the stiffness matrix from the database is not exact and normally leads to small errors (in the order of 1 or 2%). The exact solution is always symmetrical. In theory symmetry forcing should therefore give a slightly more accurate stiffness matrix. The database of 600 values minimises this error. A value of 1 should be used to switch off the warning of asymmetry and a value of 2 should be entered to make the matrix symmetrical.

(4) The number of lines of different properties in the composite cable i.e. for a line made from one section of wire and one of chain, the value would be 2, indicating that two ECAT (p. 220) data records will follow the COMP data record.

(5)-(6) These values have different meanings for a line between a structure and the seabed or between two structures.

Configuration Types 1 and 3: Structure-Anchor Line

These values define the expected range of the vertical distance between the anchor and the attachment point on the structure. These values will normally be the Z distance between the attachment point on the vessel and the anchor plus or minus the expected amplitude of motion of the attachment point. For example:

if the sea bed is at Z = -100;

the Z position of the attachment point when the vessel is in equilibrium is at -10;

the expected amplitude of the vessel motion is 10;

ZMIN and ZMAX would be 80 and 100 respectively.

ZMAX must be greater than ZMIN.

Configuration Type 2: Structure-Structure Line in Deep Water

These values are not used for a line between two structures. However, at the point when the COMP data record is read it is not known if the line will be connected to an anchor or not. Therefore two positive values must be input, with ZMAX > ZMIN. The local seabed slope is ignored for catenaries between structures, as they are not allowed to touch the seabed.

Configuration Types 4 and 5: Structure-Structure Line with Seabed Effect

These values define the expected range of the vertical position of the first attachment point in the fixed reference axis (FRA).

(7) This value is the seabed slope (in degrees) for this COMP mooring line if the global seabed definition (SBED (p. 168)) is not provided (database type 1 (p. 217)). A positive slope is for the seabed to slope up from the anchor towards the attachment point, and a negative slope is for the seabed to slope down from the anchor towards the attachment point. Seabed slope is ignored if cable dynamics is being used for this line (or lines).

This data is ignored if the global seabed is defined by the SBED (p. 168) data record.

19.6.2. The ECAT Data Record

The ECAT data record specifies the properties of each of the sections of the composite line. Although the data record title implies that only properties of elastic catenaries are expected, clump weights may be modeled by specifying a very large mass per unit length and a specification of unit length (Aqwa will not accept lengths less than 1). It is also possible to specify buoys and clump weights explicitly; see the BUOY data record (The BUOY/CLMP Data Records - Intermediate Buoys and Clump Weights (p. 223)).

```
   2   5  7    11      26     31        41        51        61        71
 - --- -- ---- ------- ------ --------- --------- --------- --------- ---------
|X|   |  |ECAT|XXXXXXX|      |         |         |         |         |         |
 - --- -- ---- ------- ------ --------- --------- --------- --------- ---------
    |  |   |            |        |         |        |         |         |
    |  |   |            |        |         |        |         |         |_(6) Unstretched Length
    |  |   |            |        |         |        |         |              of Mooring Line Section
    |  |   |            |        |         |        |         |
    |  |   |            |        |         |        |         |_(5) Maximum Expected Tension at the
    |  |   |            |        |         |        |              the Attachment Point (E10.0)
    |  |   |            |        |         |        |              (default = 5.0E4 * mass/unit length)
    |  |   |            |        |         |        |
    |  |   |            |        |         |        |
    |  |   |            |        |         |        |_(4) EA Value (E10.0)
    |  |   |            |        |         |             (default = 5.0E6 * mass/unit length)
    |  |   |            |        |         |
    |  |   |            |        |         |_(3) Equivalent Cross-Sectional
    |  |   |            |        |              Area (F10.0)
    |  |   |            |        |
    |  |   |            |        |_(2) Mass/Unit Length (E10.0)
    |  |   |            |
    |  |   |            |_(1) Indicator of attachment point at which the pretension is defined
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) This data is optional. If the length of the mooring line (6) is not defined or its value is zero, this data gives an indicator of the attachment. For example, =1 means the pretension is defined at the first attachment point of the composite cable, =2 means the pretension is define at the second attachment.

(2) Mass per unit length of the section of the composite mooring line.

(3) The equivalent cross sectional area of the mooring line. It is often more convenient, especially with wire lines, to specify this parameter so the buoyancy of the line may be calculated and subtracted from the structural weight to give the 'weight in water'. This parameter may also be specified as zero if the mass per unit length (1) is input as the mass of the line less the mass of the displaced water per unit length (this does not apply to the cases when cable dynamic analysis is required, for which a non-zero equivalent cross section area must be defined).

(4) The stiffness of the line is specified in terms of EA, where E is Youngs modulus and A is the cross sectional area of the line. The default value is chosen to give a typical value based on the mass/unit length. Clearly this may be in error if the mass per unit length specified (1) includes buoyancy effects.

(5) The maximum expected tension is the highest value of tension that should used in the database created for this composite mooring line.

(6) The length of the composite mooring line section. Note that, in either the first section or last section of the composite cable's ECAT data record, this value could be undefined or set as zero to indicate that the pretension will be defined by the following NLIN (p. 214) or NLID (p. 225) data record together with Indicator of the pretension definition at the attachment point (1).

N.B. For a composite mooring line containing more than one ECAT data record, the definition of ECATs should start from the anchor point. If a composite mooring line links two structures the ECAT data records can start from either end, but the start must correspond to the second structure on the NLIN data record.

Limits on Mooring Systems

The maximum number of mooring combinations is 25.

The maximum number of mooring lines is 100.

The maximum number of nonlinear properties (i.e. POLY, SWIR, LE2D, COMP and ECAT data records) is 1000.

The maximum number of separate stiffness databases (i.e sets of data headed by COMP or LE2D data records) is 100.

The maximum number of ECAT data records in one COMP mooring line is 10.

19.6.3. The SSCB Data Record - Structure-Structure Composite Cable Database

For a structure-structure composite mooring line, this data record should be defined if the seabed effect is included. It should follow the COMP (p. 217) data record.

```
  2   5  7    11                  31        41        51        61
 - --- -- ---- -------------------- --------- --------- --------- ---
|XXXX |  |SSCB|                    |         |         |         |
 - --- -- ---- -------------------- --------- --------- --------- ---
      |   |                         |         |         |
      |   |                         |         |         |_(3) Maximum radius of horizontal
      |   |                         |         |              movement of 2nd attachment (F10.0)
      |   |                         |----------
      |   |                         |
      |   |                         |_(2) Z range (Z2min, Z2max) of 2nd attachment (F10.0)
      |   |
      |   |_(1)Compulsory Data Record Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

(2) These two values define the variation range of the vertical position of the 2nd attachment in the fixed reference axis (FRA).

(3) This data is ignored if the seabed slope defined by the SBED (p. 168) data record is zero.

The seabed effect on a structure-structure composite cable is not included without this data record. If a structure-structure composite cable never touches the seabed during your analysis, this data record is not recommended for use.

19.7. The ECAX Data Record - Nonlinear Axial Stiffness Polynomial

This data record is used to define nonlinear axial stiffness and should be input after an ECAT data record (The ECAT Data Record (p. 220)). If this data record is omitted for a particular section of a mooring line the axial stiffness will be constant, using the value of EA from the ECAT data record.

```
   2   5  7   11    16    21    26    31         41         51         61
 - --- -- ---- ----- ----- ----- ----- ---------- ---------- ---------- -
|X|   |  |ECAX|XXXXX|XXXXX|XXXXX|XXXXX|          |          |          |
 - --- -- ---- ----- ----- ----- ----- ---------- ---------- ------------
    |  |   |                              |__________|__________|
    |  |   |                              |
    |  |   |                              |_(2)-(4) Coefficients of the polynomial (E10.0)
    |  |   |
    |  |   |_(1) Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(2)-(4) These coefficients define a nonlinear variation in axial stiffness. The stiffness is calculated using the formula

$$EA(\varepsilon) = EA(const) + k1.\varepsilon + k2.\varepsilon^2 + k3.\varepsilon^3 \qquad (0 \leq \varepsilon \leq \varepsilon_{tmax})$$

$$EA(\varepsilon) = EA(\varepsilon_{tmax}) + \{k1 + 2.k2.\varepsilon_{tmax} + 3.k3.\varepsilon_{tmax}{}^2\}.(\varepsilon-\varepsilon_{tmax}) \qquad (\varepsilon > \varepsilon_{tmax})$$

where

$EA(\varepsilon)$ = EA as a function of strain

EA(const) = the EA value on the ECAT data record (The ECAT Data Record (p. 220))

k1, k2, k3 = coefficients input on the ECAX data record (The ECAX Data Record - Nonlinear Axial Stiffness Polynomial (p. 222))

ε = linear strain $\delta L/L$

ε_{tmax} = strain at T_{max}

T_{max} = maximum tension specified on the preceding ECAT

Note:

- The stiffness must increase monotonically over a tension range from zero to the maximum tension specified on the preceding ECAT data record (T_{max}).
- For tension greater than T_{max}, the stiffness is assumed to increase linearly with strain, with slope equal to the slope at T_{max}.

19.8. The BUOY/CLMP Data Records - Intermediate Buoys and Clump Weights

These data records define the properties of intermediate buoys and clump weights. The data records must be input between ECAT data records describing the properties of the lines either side of the buoy. The last ECAT data record must not be followed by a BUOY/CLMP data record as this will be on the attachment point on a structure.

Intermediate buoys always have the same buoyancy and do not "know" where the surface is. Therefore they may float above the water surface.

```
    2   5  7   11       21       31       41       51       61       71       81
   - --- -- ---- -------- -------- -------- -------- -------- -------- -------- -
  |X|   |  |BUOY|XXXXXXXX|XXXXXXXX|        |        |        |        |        |
   - --- -- ---- -------- -------- -------- -------- -------- -------- -------- -
  |X|   |  |CLMP|XXXXXXXX|XXXXXXXX|        |        |        |        |        |
   - --- -- ---- -------- -------- -------- -------- -------- -------- -------- -
      |  |   |                        |        |        |         |         |
      |  |   |                        |        |        |         |         |_(6) Time at which to break
      |  |   |                        |        |        |         |              the buoy/clump weight
      |  |   |                        |        |        |         |              (AQWA-DRIFT/NAUT)
      |  |   |                        |        |        |         |
      |  |   |                        |        |        |         |_(5) Drag Coefficient x Area;
      |  |   |                        |        |        |                CDA (F10.0)
      |  |   |                        |        |        |
      |  |   |                        |        |        |_(4) Added Mass (F10.0)
      |  |   |                        |        |
      |  |   |                        |        |_(3) Displaced Mass of Water
      |  |   |                        |
      |  |   |                        |_(2) Structural Mass (F10.0)
      |  |   |
      |  |   |_(1) Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(2) This is the structural mass of the buoy or clump weight. This must be smaller than the mass of displaced water (3) for a buoy, or larger for a clump weight. This can be positive, zero or negative.

(3) The mass of water displaced, i.e. the buoyancy/gravity. This can be positive, zero or negative.

(4) Total (constant) added mass, i.e. not added mass coefficient. Applicable to Cable Dynamics only.

(5) The drag force (cable dynamics only) will be in the direction of the relative velocity of the fluid, V_R. The magnitude of the force is given by

$$F_D = 0.5\, \rho\, (CDA)(V_R)(|V_R|)$$

where CDA = Drag coefficient $*$ projected area.

(6) The intermediate buoy/clump weight will break at this time if the input value is positive. This field can only be used for a dynamic cable in a time domain analysis.

19.9. Cable Dynamics - Additional Data Requirements

An introduction to cable dynamics is described in this section, in addition to the data records in Data Category 14 for cable dynamics analysis.

NLID is the only data record that is necessary to define a composite catenary line as dynamic; the other data records are optional to allow the input of additional data.

19.9.1. Introduction to Cable Dynamics

When the dynamics of a cable are included in the analysis of cable motion, the effects of the cable mass and drag forces are considered, and tensions are no longer quasi static, i.e. forces on the cable are time varying and have 'memory'. The cable will, in general, respond in a nonlinear manner. The solution during a time history and the solution in the frequency domain are fully coupled, i.e. the cable tensions and motions of the vessel are considered to be mutually interactive where cables affect vessel motion and vice versa.

The following key points should be noted:

- Cable dynamics can only be associated with non-linear composite catenary lines.
- Cables are semi-taut/taut during the analysis i.e. they have a minimum tension.
- The sea bed is considered horizontal at the anchor.
- The cable is modeled with a fixed number of elements.
- Inline dynamics (along the line of the cable) is included.
- Inline stiffness i.e. AE/DL (DL = segment length) is limited.
- Morison Drag forces are included (wave particle velocity ignored).
- Wave kinematics is ignored although current is included.
- Full animation of cable dynamics is not included.
- Sea bed friction is ignored.
- The AGS Model Visualisation is based on the quasi-static configuration and tensions for any particular position of the fairlead.

19.9.2. The NLID Data Record - Non-linear Dynamic Cable

This data record defines a nonlinear mooring line in the same way as a NLIN data record except that NLID will flag the mooring line as dynamic so that dynamic analysis will be performed for this line unless cable dynamics is switched off by a DOFF data record (see The DYNM/DOFF Data Records - Cable Dynamics ON/OFF Switch (p. 227)).

NLID data records can only be used for elastic catenaries.

Line dynamics is available in all Aqwa programs (except Aqwa-Line), but it has little value in Librium static analysis except to take into account the current drag on mooring lines.

The NLID Data Record

```
   2   5  7   11    16    21    26    31        41        51        61        71
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
|X|   |  |NLID|     |     |     |     |         |         |         |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
    |  |   |     |     |     |     |      |
    |  |   |     |     |     |     |      |
    |  |   |     |     |     |     |      |_(6) Pretension Tension (F10.0)
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |_(5) Node Number (I5)
    |  |   |     |     |     |
    |  |   |     |     |     |_(4) Structure Number (I5)
    |  |   |     |     |
    |  |   |     |     |_(3) Node Number (I5)
    |  |   |     |
    |  |   |     |_(2) Structure Number (I5)
    |  |   |
    |  |   |_(1) Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(6) The pretension on the composite cable. The pretension can be defined if either the first or last section of the ECAT (p. 220) data record has defined the required pretension calculation data. Note that the unstretched sectional length is estimated by the quasi-static cable solution excluding the current drag force effect on the cable.

19.9.3. The ECAH Data Record - Elastic Catenary Hydrodynamic Properties

This data record is for defining the hydrodynamic properties for cable dynamic analysis and should be input after an ECAT data record (elastic catenary). If an ECAT data record is not followed by an ECAH data record, the program will use the coefficients defined in the previous ECAH data record. If there is no previous ECAH data record, the program will then use the default values for the coefficients.

```
   2   5  7   11    16    21    26    31         41         51         61         71         81
 - --- -- ---- ----- ----- ----- ----- ---------- ---------- ---------- ---------- ----------
|X|   |  |ECAH|XXXXX|XXXXX|XXXXX|XXXXX|          |XXXXXXXXXX|          |          |          |
 - --- -- ---- ----- ----- ----- ----- ---------- ---------- ---------- ---------- ----------
    |  |   |                             |         |         |         |         |
    |  |   |                             |         |         |         |         |_(6)Inline Drag
    |  |   |                             |         |         |         |              Coefficient Cx (F10.0)
    |  |   |                             |         |         |         |
    |  |   |                             |         |         |         |_(5) Equivalent Diameter
    |  |   |                             |         |         |              for Drag De (F10.0)
```

```
    |  |   |                                |         |         |
    |  |   |                                |         |         |_(4) Transverse Drag Coefficient Cd (F10.0)
    |  |   |                                |         |
    |  |   |                                |         |_(3) Leave Blank (for future use)
    |  |   |                                |
    |  |   |                                |_(2) Added Mass Coefficient Ca (F10.0)
    |  |   |
    |  |   |_(1) Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(2) Added mass is calculated by RHO*Ca*A per unit length in which RHO is the water density and A is the equivalent cross section area of the ECAT The COMP/ECAT/SSCB Data Records - Composite Catenary Mooring Line (p. 217). In other words, the added mass is equal to the displaced mass of water multiplied by Ca. *For cable dynamic analysis, the equivalent cross section area A must not be omitted in the ECAT definition.* The default is 1.0.

(4) Transverse drag force is calculated by 0.5*RHO*Cd*V^2*De per unit length where V is the relative transverse velocity. The default is 1.0.

(5) Equivalent diameter for drag. This allows the drag to be based on a different diameter from the added mass. The default is $\sqrt{\left(4 \times A / \pi\right)}$

(6) Inline drag force is calculated by 0.5*RHO*Cx*V^2*De per unit length where V is the relative inline velocity. The default is 0.025.

19.9.4. The ECAB Data Record - Elastic Catenary Bending Stiffness

This data record is used to define the bending stiffness for a cable dynamic analysis and should be input after an ECAT data record (elastic catenary). If this data record is omitted for a particular section of a mooring line the bending stiffness will be zero.

```
   2   5  7   11    16    21    26    31         41
 - --- -- ---- ----- ----- ----- ----- ---------- -------
|X|   |  |ECAB|XXXXX|XXXXX|XXXXX|XXXXX|          |
 - --- -- ---- ----- ----- ----- ----- ---------- -------
    |  |   |                                |
    |  |   |                                |_(2) Bending Stiffness EI (E10.0)
    |  |   |
    |  |   |_(1) Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(2) For a prismatic section the bending stiffness is the product of the elastic modulus and the 2nd moment of area. For a chain or laid hawser an equivalent value must be defined.

Note:

It is not possible to input a very high stiffness to create a straight rod. The maximum bending stiffness is related to the axial stiffness as follows.

$EI_{max} = (EA)(L^2/30)$

This check is carried out for the individual elements into which the cable is split, so the length (L) is the length of the element. This is not available to the user but is approximately the total length of the line divided by the total number of elements. See the NCEL (p. 227) data record.

19.9.5. The NCEL Data Record - Number of Cable Elements

The number of elements for each line in the calculation of full cable dynamics may be increased from the default value of 50 to a maximum of 250. Computing times will increase by a factor of approximately 5 when 250 elements are used.

```
   2   5  7   11    16    21    26    31        41        51        61        71
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
|X|   |  |NCEL|     |     |     |     |         |         |         |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
    |  |   |     |
    |  |   |     |
    |  |   |     |_(2) Number of elements required for each line (I5)
    |  |   |
    |  |   |_(1) Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

Each NLID data record that follows this specification will have the required number of elements.

19.9.6. The DYNM/DOFF Data Records - Cable Dynamics ON/OFF Switch

These two data records switch the cable dynamics analysis on or off for the dynamic cables defined by NLID data records.

```
   2   5  7   11    16    21    26    31        41        51
 - --- -- ---- ----- ----- ----- ----- --------- ---------
|X|   |  |DYNM|     |     |     |     |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- ---------
|X|   |  |DOFF|     |     |     |     |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- ---------
    |  |   |
    |  |   |_(1) Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

The DYNM data record is in fact not necessary as the NLID data record will automatically switch the cable dynamics on.

The DOFF data record will switch the cable dynamics off so that NLID data records will effectively be the same as NLIN data records and no cable dynamic analysis will be performed. A DOFF data record can be input anywhere in Data Category 14 and it applies to all the NLID data records.

19.9.7. The SBFC Data Record - Seabed Friction Coefficients

The seabed inline and lateral friction coefficients on dynamic cables can be defined using this data record. This data is applied to all the dynamic cables during a time domain analysis.

```
  2   5  7    11                  31        41        51
 - --- -- ---- ------------------- --------- --------- ---
|X|   |  |SBFC|                    |         |         |
 - --- -- ---- ------------------- --------- --------- ---
    |  |   |                            |         |
    |  |   |                            |         |_(3) Seabed lateral friction coefficient (F10.0)
    |  |   |                            |
    |  |   |                            |_(2) Seabed inline friction coefficient (F10.0)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

19.9.8. The SMUD Data Record - Seabed Mud Layer Depth

The seabed mud layer depth used in the cable dynamics is defined using this data record. This data is applied to all the dynamic cables.

```
  2   5  7    11                  31        41
 - --- -- ---- ------------------- ---------
|X|   |  |SMUD|                    |         |
 - --- -- ---- ------------------- ---------
    |  |   |                            |
    |  |   |                            |
    |  |   |                            |
    |  |   |                            |_(2) Seabed Mud Layer Depth(F10.0)
    |  |   |
    |  |   |_(1)Compulsory Data Record Keyword(A4)
    |  |
    |  |_Optional User Identifier(A2)
    |
    |_Compulsory END on last data record in data category(A3)
```

(2) The seabed mud layer depth must be in the region of [0.02, 2.0] *g/g_si, where *g* is the acceleration due to gravity in the analysis units and *g_si* is the acceleration due to gravity in the SI units of {kg, m, sec}. The default value is 2.0*g/g_si.

19.10. The LBRK Data Record - Mooring Line Break

The LBRK data record allows you to specify that one or more mooring lines should be broken (de-activated) during an analysis. The format of the LBRK data record is as follows:

```
  2    7    11   16   21        31        41        51
 - ---- ---- ---- ---- --------- --------- --------- ---------
|X|    |LBRK|    |    |XXXXXXXXX|         |         |         |
 - ---- ---- ---- ---- --------- --------- --------- ---------
        |     |    |                |          |        |
        |     |    |                |          |        |_(4) Breaking tension at 2nd structure
        |     |    |                |          |             (AQWA-DRIFT/NAUT)
        |     |    |                |          |
        |     |    |                |          |_(3) Breaking tension at 1st structure
        |     |    |                |               (AQWA-DRIFT/NAUT)
```

```
              |     |    |                |
              |     |    |                |_(2) Time at which to break the mooring line (AQWA-DRIFT/NAUT)
              |     |    |
              |     |    |_(1) Mooring line number to break (I5)
              |     |
              |     |_Spectrum number (AQWA-LIBRIUM/FER) (max 20)
              |
              |_LBRK Data Record Keyword
```

(1) The mooring line number is taken from the order in which the lines are defined.

(2) The time has two meanings.

If no tension is defined the line will break at this time.

If a tension is also defined, the line will break the 1st time the tension exceeds the specified value, after this time.

(3) The mooring line will break when the tension at the 1st structure on the LINE/NLIN/NLID data record is greater than this value, if the time is greater than the specified breaking time (2).

(4) The mooring line will break when the tension at the 2nd structure on the LINE/NLIN/NLID data record is greater than this value, if the time is greater than the specified breaking time (2).

Note:

- Logic for breaking lines.

```
   TIME              TENSION 1         TENSION 2        RESULT
not given or 0     not given or 0    not given or 0    Always broken
not given or 0           F1          not given or 0    Breaks when tension 1 > F1
not given or 0     not given or 0          F2          Breaks when tension 2 > F2
not given or 0           F1                F2          Breaks when tension 1 > F1 or tension 2 > F2
    t1             not given or 0    not given or 0    Breaks at time=t1
    t1                   F1          not given or 0    Breaks when tension 1 > F1, after time t1
    t1                   F1                F2          Breaks when tension 1 > F1 or tension 2 > F2, after
```

- In Aqwa-Fer and Librium the line is always broken; the time and tension values are ignored.
- The normal usage of the LBRK data record for Aqwa-Fer/Librium is for a specified spectrum rose (e.g. N,NW,W,SW,S etc). An initial run is performed to determine the worst line tensions and then a second run is performed with identical data apart from the LBRK data record. Thus for, say, 8 spectra, the equilibrium and significant motions can be determined in two runs (each) for all 8 spectra.

19.11. The PULY Data Record - Linear Cables

The maximum number of pulleys per pulley set is 2.

```
   2   5  7   11    16    21    26    31        41        51        61
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- ---------
|X|   |  |PULY|     |     |     |     |         |         |         |         |
 - --- -- ---- ----- ----- ----- ----- --------- --------- --------- ---------
    |  |   |     |     |     |     |       |         |         |         |
```

```
        |  |   |     |     |     |     |       |         |         |         |_(9) Sliding Friction (T2/T1)
        |  |   |     |     |     |     |       |         |         |               (F10.0)
        |  |   |     |     |     |     |       |         |         |
        |  |   |     |     |     |     |       |         |         |_(8) Bearing Friction (T2/T1) (F10.0)
        |  |   |     |     |     |     |       |         |
        |  |   |     |     |     |     |       |         |_(7) radius (F10.0)
        |  |   |     |     |     |     |       |
        |  |   |     |     |     |     |       |_(6) angle (E10.0)
        |  |   |     |     |     |     |
        |  |   |     |     |     |     |_(5) Node Number (I5)
        |  |   |     |     |     |
        |  |   |     |     |     |_(4) Structure Number (I5)
        |  |   |     |     |
        |  |   |     |     |_(3) Node Number (I5)
        |  |   |     |
        |  |   |     |_(2) Structure Number (I5)
        |  |   |
        |  |   |_(1) Mooring Line Code (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

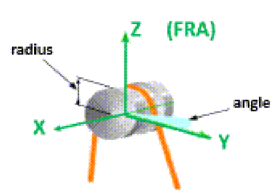
(1) The PULY data record indicates that a pulley is positioned on a line. A maximum of 2 pulleys is allowed for each pulley set (i.e. two pulleys per LINE), with the first PULY data record following a LINE data record, i.e. applying to the most recently defined LINE. In the case of a 2 pulley set the second PULY data record will follow the first PULY data record. A PULY has the effect of intersecting a LINE and will effectively extend the LINE from the LINE's node to the second PULY node.

(2) This is the structure number to which the pulley is attached and must correspond to one of the structures defined in Data Category 2. If '1' is input, this will correspond to the structure defined in Data Category ELM1. If '2' is input, this will correspond to the structure defined in Data Category ELM2 etc. Note that Structure '0' (i.e. a fixed node) is an ILLEGAL structure and will produce an error (see (4)).

(3) This is the node number whose position is the attachment point of the pulley on the structure specified (1). The position of this node on the structure (2) must have been defined in Data Category 1. Items (2) & (3) must appear on the previous LINE data record (see examples).

(4)-(5) This structure number (4) and its corresponding node number (5) define the attachment position of the other end of the mooring line. The position of this node on the structure (4) must have been defined in Data Category 1.

If '0' is input as the structure number (4), together with a node number (5), the program will recognize that this node number (5) references a fixed position as defined in Data Category 1 in the Fixed Reference Axis System (FRA). Note that a non-zero structure number (4) must be followed by a valid node number (5) on that structure.



Pully Visualisation

(6) This value represents the angle at which the pulley lies about the Z axis (FRA). The default angle (0°) places the pulley in the orientation shown in the diagram.

(7) The radius is used to indicate the radius of the pulley, but is not used for the purpose of the calculation. The radius of the pulley will be displayed in the Aqwa Graphical Supervisor.

(8)-(9) There are two possible formulations for the friction. In each case the friction of the pulley is represented by T_2/T_1, where T_2 is the larger tension and T_1 the smaller. T_2/T_1 should be defined for the situation where the line turns through 180° around the pulley.

- T_2/T_1 in columns 51-60 represents bearing friction of a pulley rotating around an axle
- T_2/T_1 in columns 61-70 represents sliding between the rope and the pulley, for example if the pulley represents a fairlead.

If values are entered in both fields the first definition (bearing friction) overrides the second (sliding friction).

Pulley with bearing friction: a friction factor μ is calculated such that $\mu = (T_2-T_1) / (T_2+T_1)$. The friction is then varied depending on how far around the pulley the line passes.

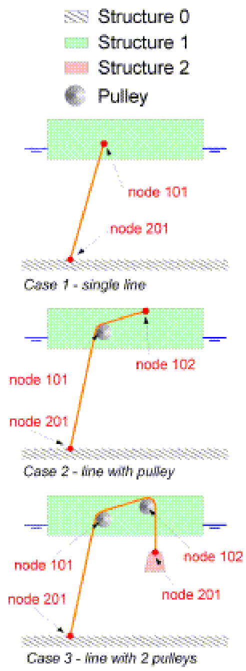
Pulley with sliding friction: a friction factor μ is calculated such that $(T_2/T_1) = \exp(\mu\pi)$. The friction is then varied depending on how far around the pulley the line passes.

In each case T_2/T_1 must be in the range $1 \leq T_2/T_1 \leq 2$.

Pulleys - Assumptions and Restrictions

- A PULY data record must be preceded by a LINE data record.
- Maximum of 2 pulleys per pulley set.
- The radius of the pulley is ignored for the purpose of the calculations.
- If distance from start of pulley mooring line to end point is less than the total length, then the whole line is slack.
- The pulley lines are assumed to be in contact with the pulleys at all times.
- Distances between pulley points are assumed to be scalar quantities. For example, a structure may be 'drawn through' a pulley to appear on the other side.

Examples of Connectivity



The following three cases demonstrate the required input of connectivity for systems including pulleys.

CASE 1 Is a standard LINE connected between a single structure and earth. The typical connectivity input for this system would be:

```
LINE  1  101  0  201   ...
```

CASE 2 Is a LINE connected between a single structure and earth. A pulley is inserted on the line and extends the line to node 102. The typical connectivity input for this system would be:

```
LINE  1  101  0  201   ...
PULY  1  101  1  102   ...
```

CASE 3 Is a LINE connected between a two structures and earth, with a 2 pulley set on the LINE. The typical connectivity input for this system would be:

```
LINE  1  101  0  201   ...
PULY  1  101  1  102   ...
PULY  1  102  2  201   ...
```

19.12. The DWT0/LNDW/DWAL Data Records - Linear Drum Winches

These data records are used to model a winch or drum which winds in or pays out a linear elastic line starting at a user specified time. The line has a start length, a final length and a winch speed.

This is considered a time-history feature, and therefore is only available in Aqwa-Drift and Aqwa-Naut. All other programs will treat this as a normal linear elastic line.

19.12.1. The DWT0 Data Record

This data record specifies the time when the winching action starts and must be input before the LNDW data record.

```
  2   5  7   11    16    21    26    31        41        51        61
- --- -- ---- ----- ----- ----- ----- --------- --------- ---------
X|   |  |DWT0|     |     |     |     |         |         |
- --- -- ---- ----- ----- ----- ----- --------- --------- ---------
      |   |                               |
      |   |                               |
      |   |                               |
      |   |                               |_ (2) Starting Time of the Winching Action
      |   |
      |   |_(1) Compulsory Data Record Keyword(A4)
      |
      |_Optional User Identifier (A2)
```

(2) The line will will be treated as a standard linear elastic line until this time is reached or exceeded at any particular timestep.

19.12.2. The LNDW Data Record

The format of the LNDW data record is the same as that for a LINE mooring line but with three additional parameters.

```
  2   5  7   11    16    21    26    31        41        51        61        71        81
- --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
X|   |  |LNDW|     |     |     |     |         |         |         |         |         |
- --- -- ---- ----- ----- ----- ----- --------- --------- --------- --------- ---------
   |  |   |     |     |     |     |       |         |         |         |         |
   |  |   |     |     |     |     |       |         |         |         |         |_(10)T_Max.
   |  |   |     |     |     |     |       |         |         |         |               Maximum Tension (F10.
   |  |   |     |     |     |     |       |         |         |         |
   |  |   |     |     |     |     |       |         |         |         |_(9) Speed. Non-zero positive
   |  |   |     |     |     |     |       |         |         |             or negative winch speed (F10.0)
   |  |   |     |     |     |     |       |         |         |
   |  |   |     |     |     |     |       |         |         |_(8) L_End. Final Length (F10.0)
   |  |   |     |     |     |     |       |         |
   |  |   |     |     |     |     |       |         |_(7) L_Beg. Initial Length (F10.0)
   |  |   |     |     |     |     |       |
   |  |   |     |     |     |     |       |_(6) K_Beg. Initial Stiffness (E10.0)
   |  |   |     |     |     |     |
   |  |   |     |     |     |     |_(5) 2nd Node Number (I5)
   |  |   |     |     |     |
   |  |   |     |     |     |_(4) 2nd Structure Number (I5)
   |  |   |     |     |
   |  |   |     |     |_(3) 1st Node Number (I5)
   |  |   |     |
   |  |   |     |_(2) 1st Structure Number (I5)
   |  |   |
   |  |   |_(1) Compulsory Data Record Keyword (A4)
   |  |
   |  |_Optional User Identifier (A2)
   |
   |_Compulsory END on last data record in Data Category (A3)
```

(6) K_Beg: stiffness at the beginning of the winch action.

This is equal to EA/L_Beg for the line (E=Youngs' modulus, A = cross sectional area). The stiffness of the line during the winch action will change as the length changes; i.e. the stiffness during the simulation, assuming that the length varies from L_Beg to L_End, will be EA/L_Beg to EA/L_End; where EA = K0*L_Beg.

(7) L_Beg: unstretched length at the beginning of the winching action.

This can also be considered as the initial length and will be the length used if there is no winch action. This value must greater than 0.1m (in S.I. units) or 0.3ft (in Imperial units). Values less than this will be set to the minimum values.

(8) L_End: unstretched length at the end of the winch action.

If the drum speed is positive (i.e. paying out) this is the maximum length of the line and can at no time be exceeded. If this length is reached, or L_Beg is greater than L_End, then all winching action will cease for the rest of the simulation.

If the drum speed is negative (i.e. winding in) this is the minimum length of the line and it can at no time be less than this. If this length is reached, or L_Beg is less than L_End, all winching action will cease for the rest of the simulation.

(9) Speed: paying out (positive speed) or winding in (negative) speed.

In mathematical terms the speed is dl/dt, where l is the unstretched length of line and t is time. For lines which have significant strain(ε) (this precludes steel which yields at about 0.001), the user may wish to consider the speed of the drum in terms of stretched length.

When winding in, the line wound onto the drum will have the same tension as the free line itself at any particular time. This means that in order to wind a length of unstretched line the effective speed must be increased by a factor of $(1+\varepsilon)$. This is done automatically. If the user wishes to simulate a stretched line speed for winding in, then the speed specified should be input with a speed reduction factor of $1/(1+\varepsilon)$, where ε is the average strain.

When paying out, the adjustment of speed is not straightforward. The elastic energy of the line on the drum will depend on exactly how the line was wound on the drum originally. This 'energy' stored on the drum is unknown and is assumed to be zero. i.e. the line on the drum when paying out is assumed to be unstretched. The effective winch speed, (effectively with only 1 side of the line stretched) is $(1+\varepsilon/2)$. If the user wishes to simulate a stretched line speed for paying out, then the speed specified should be input with a reduction factor of $1/(1+\varepsilon/2)$, where ε is the average strain.

(10) T_Max:The maximum tension causing the winch to lock.

If at any time the tension exceeds this value, all winching action of the drum will cease until the tension reduces below this value.

CAVEATS/ASSUMPTIONS

Note:

- The exact length of the line at any time will depend on the previous motions which have been encountered by the structure connected to this line. This in turn means that the length of the line has 'memory'. The implication of this is that in situations where initial or specific positions are used in Aqwa, the line length cannot be determined and will be assumed to be the initial length. An example of this is the hot start. A warning message to this effect will be issued in these cases.

- The resolution of switching on and off the drum winch can only be the same as the time step. This means that the winch drum can only be switched at the beginning or the end of a time step and not in the middle. In order to conserve energy/momentum in the equations of motion, the length of the line can only be changed in steps of (time step)(speed of the winch). The tension resolution will therefore be (stiffness)(time step)(speed). Large stiffnesses or drum speed should therefore be specified with appropriately small time steps.

- Drum winches are not available with PULY lines.

19.12.3. The DWAL Data Record - Drum Winch Additional Length

This data record specifies an additional length of line to be used when calculating the line stiffness. It has no effect on the distance between the start and end points of the line. The stiffness is calculated as AE/(additional length + actual length) and therefore the maximum stiffness is AE/(additional length). This data record must be input before the LNDW data record and each LNDW data record that follows this data record will have the specified additional length.

```
  2   5  7   11    16    21    26    31        41        51        61
- --- -- ---- ----- ----- ----- ----- --------- --------- ---------
X|   |  |DWAL|     |     |     |     |         |         |
- --- -- ---- ----- ----- ----- ----- --------- --------- ---------
      |   |                               |
      |   |                               |
      |   |                               |
      |   |                               |_ (2) Additional length required.
      |   |
      |   |_(1) Compulsory Data Record Keyword(A4)
      |
      |_Optional User Identifier (A2)
```

19.13. The FEND/FLIN Data Records - Fenders

These data records are used to define a fender mooring element between two structures or between a floating structure and a fixed point. They are included in the total number of moorings in the input data.

These data records must be preceded by a POLY data record to define the stiffness properties of the fender (see The POLY Data Record - Polynomial Nonlinear Properties (p. 213)).

19.13.1. The FEND Data Record - Fender properties

```
  2   5  7                        31        41
- --- -- ---- -------------------- --------- ---------
|X|   |  |FEND|XXXXXXXXXXXXXXXXXXXX|         |         |
```

```
     - --- -- ---- -------------------- --------- ---------
        |  |   |                            |         |
        |  |   |                            |         |
        |  |   |                            |     (2) Pretension (E10.0)
        |  |   |                            |
        |  |   |                      (1) Size (E10.0)
        |  |   |
        |  |   |
        |  |   |       51        61        71
        |  |   |        --------- --------- ---------
        |  |   |       |         |XXXXXXXXX|         |
        |  |   |        --------- --------- ---------
        |  |   |            |                   |
        |  |   |            |                   |
        |  |   |            |            (4) Damping coefficient (E10.0)
        |  |   |            |
        |  |   |    (3) Friction coefficient (E10.0)
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The size of the fender is the distance between the contact planes at which the fender just touches both of them.

(2) The pretension of the fender. This is optional and only needed for a fixed fender when the fender size (1) is not defined or its value is zero.

(3) This is the friction coefficient μ. The friction force is given by F = μR, where R is the normal reaction. See note below.

(4) Material (or structural) damping coefficient β. Damping is modeled as linear material damping, where the damping coefficient is (β)(stiffness). Damping is only applied in the direction perpendicular to the contact points.

Note:

Fender friction works best in situations where the friction force is smaller than other forces in the same direction. Friction will slow down relative motion between two structures, but is not suitable for keeping them fixed together - there is no "stiction". When the relative velocity changes sign the friction force must also change sign, but to avoid an instantaneous change in force (and therefore an instantaneous change in acceleration) a smoothing function is applied. This means that when the relative velocity is very small the friction force is also small, and the structures can move relative to each other.

19.13.2. The FLIN Data Record - Fender connections

```
       2   5  7   11    16    21    26    31    36    41    46    51    55
     - --- -- ---- ----- ----- ----- ----- ----- ----- ----- ----- ----- ---------------
    |X|   |  |FLIN|     |XXXXX|     |     |     |XXXXX|     |     |     |
     - --- -- ---- ----- ----- ----- ----- ----- ----- ----- ----- ----- ---------------
        |  |   |     |           |     |     |           |     |     |
        |  |   |     |           |     |     |           |     |     |
        |  |   |     |           |     |     |           |     |     |_(8) Node Number (I5)
        |  |   |     |           |     |     |           |     |
        |  |   |     |           |     |     |           |     |_(7) Node Number (I5)
```

```
|  |   |     |           |     |     |           |
|  |   |     |           |     |     |           |_(6) Structure Number (I5)
|  |   |     |           |     |     |
|  |   |     |           |     |     |_(5) Node Number (I5)
|  |   |     |           |     |
|  |   |     |           |     |_(4) Node Number (I5)
|  |   |     |           |
|  |   |     |           |_(3) Structure Number (I5)
|  |   |     |
|  |   |     |_(2) Type (I5)
|  |   |
|  |   |_(1) Fender Mooring Code (A4)
|  |
|  |_Optional User Identifier (A2)
|
|_Compulsory END on last data record in Data Category (A3)
```

When an FLIN data record is input, the program assumes that the nonlinear properties correspond to those specified by the most recently input nonlinear properties (POLY and FEND) data records. Failure to input these properties before a FLIN data record means that they are undefined and will result in an error. Note that one nonlinear properties data record may apply to several FLIN data records. This not only avoids repeating the same properties for several similar fenders, but also enables the user to make a single change to apply to all those properties.

Parameters on the FLIN data record are:

(1) Mooring line code FLIN indicates a fender whose properties are specified by the preceding POLY and FEND nonlinear properties data records.

(2) Fender type 1 is a fixed fender, type 2 is a floating fender.

(3) The number of the structure to which the fender is attached. A fixed fender is fixed to a specified node on this structure. A floating fender is associated with a specified node on this structure.

(4) The 1st node on structure 1 which the fender is fixed to or associated with. For a fixed fender this is the contact point on structure 1.

(5) 2nd node on structure 1 which defines the direction of the normal to the contact plane on structure 1. The direction from node 1 to node 2 points outwards from the structure, through the fender. For a fixed fender this node is optional for structure 1; if omitted the fender will act uniformly in every direction. This node is mandatory for a floating fender.

(6) The number of the structure that the fender will make contact with.

(7)-(8) Two nodes on structure 2 which define the contact plane. The plane passes through node 1 with its normal in the direction from node 1 to node 2. As for structure 1, the direction from node 1 to node 2 points outwards from the structure, through the fender.

19.14. The LE2D/*RNG Data Records - 2-Dimensional Load Extension Database

N.B. These data records are used to define a set of load extension characteristics of a nonlinear mooring line in 2 dimensions. In order to use these values, one or more NLIN data records must follow the set.

The maximum number of 2D load/extension characteristics/composite lines is 100. Note also that the total number of all nonlinear data records (including POLY, etc) may not exceed 1000.

The first data record of the set after the LE2D data record must be a ZRNG data record.

19.14.1. The LE2D Data Record

```
   2   5  7   11     16   21
 - --- -- ---- ----- ----- -----
|X|   |  |LE2D|    3|   12|11112|
 - --- -- ---- ----- ----- -----
    |  |   |     |     |     |
    |  |   |     |     |     |
    |  |   |     |     |     |
    |  |   |     |     |     |_(3) Warning flags and Symmetry forcing (I5)
    |  |   |     |     |           (Default = all warnings issued)
    |  |   |     |     |
    |  |   |     |     |_(2) Number of X/H/V values (I5)
    |  |   |     |           (Default = 12, Maximum = 40 or 600 divided by (1), whichever is less)
    |  |   |     |
    |  |   |     |_(1) Number of Z coordinates (I5)
    |  |   |           (Default = 5, Maximum = 20 or 600 divided by (2), whichever is less)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) The number of values of Z to be input on the ZRNG data record and hence the number of values on each XRNG, HRNG and VRNG data records.

(2) The number of values XRNG, HRNG and VRNG data records making up the load extension curves. This data record together with (1) form a database which is represented by a matrix of values, e.g. for the default size of the database Z(5), X(12,5), H(12,5), V(12,5) would be created.

(Further details may be found in The 2 Dimensional Load Extension Characteristics (p. 240).)

(3) This parameter indicates whether warnings should be issued when the position of the attachment point of the mooring line relative to the anchor point is outside of the range specified in the ZNRG and XRNG data records. In addition, warnings about the degree of symmetry of the resulting stiffness matrix can also be issued, omitted or the matrix can be forced to be symmetrical. This is explained further below.

The parameter should be thought of as five separate flags which indicate the following:

If flag 1 = 0 or is blank, Warnings are issued when the X position exceeds the range specified

If flag 2 = 0 or is blank, Warnings are issued when the X position is below the range specified

If flag 3 = 0 or is blank, Warnings are issued when the Z position exceeds the range specified

If flag 4 = 0 or is blank, Warnings are issued when the Z position is below the range specified

If flag 5 = 0 or is blank, Warnings are issued when the degree of asymmetry of the stiffness matrix formed from the database is considered unacceptable.

If any flag value is non-zero then warnings are not issued for that flag's conditions.

For the stiffness asymmetry, if the value is greater than unity, symmetry of the stiffness matrix will be imposed. Clearly in this case no warning asymmetry warning message will be issued. Note that in time history programs (Aqwa-Naut/Drift) the stiffness matrix is not used except for output of information to the user.

Stiffness Matrix Asymmetry

The stiffness matrix which can be formed from the 2-D load/extension is evaluated as follows:

```
            K =  DH         DH
                 --    0    --
                 DX         DZ
                       H
                 0     -     0
                       X
                 DV         DV
                 --    0    --
                 DX         DZ
```

where

H = the horizontal force

V = the vertical force

D/DX, D/DZ = differential operators

The values of DH/DZ and DV/DX for a completely elastic mooring line must be equal. It is the responsibility of the user to input values of z, x, H and V which obey this condition. Failure to do so will result in a mooring system which will generate or absorb energy - impossible for a real mooring system.

19.14.2. The ZRNG/XRNG/HRNG/VRNG Data Records

```
     2   5  7    11   16    21        31        41        51        61        71
    - --- -- ---- ---- ----- --------- --------- --------- --------- --------- ---------
   |X|   |  |ZRNG| 6  |  10 |XXXXXXXXX|         |         |         |         |         |
    - --- -- ---- ------------------- --------- --------- --------- --------- ---------
   |X|   |  |XRNG|XXXXXXXXXXXXXXXXXXXX|         |         |         |         |         |
    - --- -- ---- ------------------- --------- --------- --------- --------- ---------
   |X|   |  |HRNG|XXXXXXXXXXXXXXXXXXXX|         |         |         |         |         |
    - --- -- ---- ------------- ------ --------- --------- --------- --------- ---------
   |X|   |  |VRNG|XXXXXXXXXXXXXXXXXXXX|         |         |         |         |         |
    - --- -- ---- ------------------- --------- --------- --------- --------- ---------
       |  |   |    |       |               |_________|_________|_________|_________|
       |  |   |    |       |               |
       |  |   |    |       |           (1)-(5) Up to 5 Values of Z Coordinates     (5F10.0)
       |  |   |    |       |                                     X Coordinates     (5F10.0)
       |  |   |    |       |                                     Horizontal forces (5F10.0)
       |  |   |    |       |                                     Vertical   forces (5F10.0)
       |  |   |    |       |
       |  |   |    |       |_Terminal Z Coordinate number (I5)
       |  |   |    |
       |  |   |    |_Initial Z Coordinate Number (I5)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on Last Data Record in Data Category (A3)
```

(1)-(5) ZRNG-Values on this data record represent values of Z in the Fixed Reference axis at which the load extension characteristics are defined on the XRNG, HRNG, VRNG data records. This value is the expected range of the attachment points in the analysis. These values will normally be the Z distance between the attachment point on the vessel and the anchor plus or minus the expected amplitude of motion of the NLIN line using this composite; that is, if the sea bed and anchor are at -100 and the Z position of the attachment point when the vessel is in equilibrium is at -10, ZMIN and ZMAX would be 80 and 100 respectively assuming a maximum amplitude of motion of 10.

XRNG-Values on this data record represent values of X (horizontal distance in the fixed reference axis FRA) between the attachment and anchor position axis at which the horizontal and vertical forces are defined on the HRNG, VRNG data records.

HRNG/VRNG-Values on these data records represent values of the horizontal/vertical forces at the previously specified X and Z values.

The 2 Dimensional Load Extension Characteristics

This facility enables the user to input the tension/extension curve of any mooring lines with known characteristics in 2 dimensions. Note that these data records do not define a mooring line per se but define a property which may be referred to by NLIN data records which follow. Note also that although a 2-D characteristic has been input, as the structure moves the plane in which the database has been defined rotates with the attachment point in the FRA.

The mooring line properties defined on this set of data records will apply to all NLIN data records that follow until another set of nonlinear property data records is input. (Note that SWIR and POLY data records are also nonlinear property data records.) The difference between this and the other nonlinear property data records is that this facility requires a GROUP of data records to define the characteristics of a mooring line.

This facility is particularly useful for defining elastic catenaries or composite mooring lines whose modeling characteristics are not otherwise available in the Aqwa suite. (See also the COMP data record The COMP/ECAT/SSCB Data Records - Composite Catenary Mooring Line (p. 217))

Each of the above Z-coordinate may be thought of as the "Values at which a 1 dimensional load/extension curve for 2 orthogonal forces is specified",

i.e. at Z range = Z value 1:

```
      HORIZONTAL^                    *   VERTICAL ^
        FORCES  |                         FORCE   |
          IN    |                          IN     |
      COLUMN 1  |                  *     COLUMN 1 |                    *
                |                                 |                  *
                |                                 |               *
                |               *                 |            *
                |                                 |        *
                |           *                     |*   *
                |* *    *                         |
                |____________________>            |____________________>
                 X-VALUES IN COLUMN 1              X-VALUES IN COLUMN 1
```

i.e. at Z range = Z value 2

```
      HORIZONTAL^                        VERTICAL ^
        FORCES  |                         FORCE   |
          IN    |                          IN     |
      COLUMN 2  |                    *   COLUMN 2 |                    *
```

```
                |                                |                  *
                |                  *             |               *
                |                                |            *
                |               *                |        *
                |           *                    |*   *
                |*  *  *                         |
                |____________________>           |____________________>
                 X-VALUES IN COLUMN 2             X-VALUES IN COLUMN 2
```

i.e. at Z range = Z value 3

```
      HORIZONTAL^                         VERTICAL ^
        FORCE   |                           FORCE   |
         IN     |                            IN     |
      COULMN 3  |                         COULMN 3  |                    *
                |                    *              |                  *
                |                                   |               *
                |                  *                |            *
                |               *                   |        *
                |           *                       | *   *
                |*  *  *                            |
                |____________________>              |____________________>
                 X-VALUES IN COLUMN 3                X-VALUES IN COLUMN 3
```

If the above graphs represent a complete set of values to define the 2-D load extension characteristics of a mooring line then the ZRNG data record will contain three values (there is only 1 ZRNG data record in each set). If the number of values of X, H and V are 7 (as shown above) then the complete set of data record required to define the 2-D load/extension curve is as follows:

```
                                          Values of Z, X, H, V

      1-Data Record                     LE2D   3   7 . . . .      .      .

      1-Data Record  (3 values)         ZRNG . . . . . . . xxx    xxx    xxx

      7-Data Records (3 values on each) XRNG . . . . . . . xxx    xxx    xxx
      7-Data Records (3 values on each) HRNG . . . . . . . xxx    xxx    xxx
      7-Data Records (3 values on each) VRNG . . . . . . . xxx    xxx    xxx
```

19.15. The PRIC Data Record - Print Initial Condition of Mooring Lines

This data record causes details of the mooring lines to be printed in the initial position at the start of the analysis.

```
      2   5  7
    - --- -- ---- ---
    X|   |  |PRIC|
    - --- -- ---- ---
              |
              |
              |
              |_Compulsory Data Record Keyword (A4)
```

19.16. The FINI Data Record - Mooring Configuration Separator

This facility is used to separate different mooring configurations defined in Data Category 14. The mooring lines defined before a FINI data record and after the data record will be regarded as different mooring configurations and will be analyzed separately.

```
  2   5  7
- --- -- ---- --
X|   |  |FINI|
- --- -- ---- --
   |  |   |
   |  |   |
   |  |   |_Compulsory Data Record Keyword(A4)
   |  |
   |  |_Optional User Identifier (A2)
   |
   |_Compulsory END on last data record in data category (A3)
```

19.17. The FILE Data Record - Mooring Description

The FILE data record allows the user to specify that a data set normally input in Data Category 14 should be read from a file. This is particularly useful in parametric studies where the user may have some 100 data files to test a particular mooring configuration. This might include Aqwa-Drift/Fer/ Librium runs. If the effect of changing, say, the chain size is required for all 100 runs, then a single change can be made to 1 file, and the runs performed again.

The FILE data record specifies that normal mooring line (Data Category 14) data is to be read from another file, e.g. AQCONF1.MOR (the extension MOR is recommended). The file AQCONF1.MOR will contain data in identical format to the input in Data Category 14. When all the data in AQCONF1.MOR is read the program will revert to reading from the .DAT file.

All programs which accept data from Data Category 14 can use the FILE data record.

The format of the FILE data record is as follows:

```
  2   5  7   11         21
- --- -- ---- ---------- ------------------
X|   |  |FILE|XXXXXXXXXX|
- --- -- ---- ---------- ------------------
          |                   |
          |                   |
          |                   |_(1)Name of the file containing mooring data
          |
          |_FILE Data Record Keyword
```

(1) The name can include the path of the file. If no path is specified, the local directory will be assumed.

19.18. The SWIR Data Record - Steel Wire Nonlinear Properties

The steel wire SWIR facility allows modeling of the nonlinear properties of a new steel wire rope. However it is possible to model steel wire using linear (LINE) or nonlinear (NLIN) lines.

This data record defines a nonlinear property of a mooring line. In order to use these defined values, one or more NLIN data records must follow. The maximum number of nonlinear properties that may be defined is 50.

```
  2   5  7                         31        41
 - --- -- ---- -------------------- --------- ---------
|X|   |  |SWIR|XXXXXXXXXXXXXXXXXXXX|         |         |
 - --- -- ---- -------------------- --------- ---------
    |  |   |                            |         |
    |  |   |                            |         |
    |  |   |                            |         |_(2) Asymptotic Offset (F10.0)
    |  |   |                            |
    |  |   |                            |_(1) Asymptotic Stiffness (E10.0)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1)-(2) These fields contain the values of the two constants in the equation defining the tension of the line as a function of the extension (see below). Values must be specified for both fields.

This facility enables the user to input the physical properties (constants defining the tension/extension curve) of a steel wire mooring line. Note that this data record does not define any mooring lines having these properties. This information must be supplied on following NLIN data records.

The mooring line properties defined on the SWIR data record will apply to all NLIN data records that follow until another nonlinear property data record is input. (Note that POLY is also a nonlinear property data record.)

Tension in a steel wire mooring line is given by:

$T = k (x - d (\tanh(x/d)))$

where

x = extension of mooring line

k = asymptotic stiffness (constant)

d = asymptotic offset (constant)

The names of the constants k and d arise from the fact that, at large values of extension, tanh(x/d) tends to unity and the equation tends to the asymptotic form:

$T = k (x - d)$

19.19. Tether Additional Data Requirements

This section describes the additional data requirements for the input of tethers for Aqwa-Librium, Aqwa-Drift and Aqwa-Naut (not valid in Aqwa-Fer).

The Tether Local Axis system (TLA) referred to in this section is described in detail in Mass and Stiffness Matrices in the *Aqwa Theory Manual*.

The maximum number of tethers is 200.

The mechanical properties of a tether can be modeled by either:

- Section-based information using the composite tether configuration approach, consisting of TECP/TSEG/TSGH (p. 252) data records (this is the recommended approach since it provides more flexibility in tether discretization) .

  Each tether can consist of up to 24 tether sections and will be automatically discretised by up to 250 elements if the section-based modeling is used.

- Element-based information using the TELM (p. 244) data record combined with the material and geometric definitions in the data categories 3 and 4.

  Each tether can consist of up to 24 elements if the element-based modeling is used.

19.19.1. The TELM Data Record - Tether Element

The composite tether configuration approach consisting of TECP/TSEG/TSGH (p. 252) data records is recommended to model tethers.

The maximum number of tether elements for a single tether is 24 if using the TELM configuration approach.

Tether elements must be contiguous; on all but the first TELM data record, the first node input must be the same as the second node of the previous TELM data record.

```
   2   5  7   11    16    21    26
 - --- -- ---- ----- ----- ----- -----
|X|   |  |TELM|     |     |     |     |
 - --- -- ---- ----- ----- ----- -----
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |_(4) Geometric Group Number (I5)
    |  |   |     |     |     |
    |  |   |     |     |     |_(3) Material Group Number (I5)
    |  |   |     |     |
    |  |   |     |     |_(2) Node Number 2 (I5)
    |  |   |     |
    |  |   |     |_(1) Node Number 1 (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1)-(2) These are the nodes input in Data Category 1 and define the length of the tether element only. The first element is considered to have Node 1 attached to the anchor, for installed tethers. It is the trailing node for towed tethers.

(3) The material group number (input in Data Category 3) for this element. There are two parameters input for the material properties of tether elements. These are density and Young's Modulus of elasticity, i.e.

```
      2   5  7         16    21         31
```

```
 - --- -- --------- ----- ---------- ----------
|X|   |  |XXXXXXXXX|     |          |          |
 - --- -- --------- ----- ---------- ----------
      |              |       |           |
      |              |       |           |
      |              |       |           |_(3) Young's Modulus (E10.0)
      |              |       |
      |              |       |
      |              |       |_(2) Material Density or Mass (E10.0)
      |              |
      |              |
      |              |_(1) Material Group Number (I5)
      |
      |
      |_Optional User Identifier (A2)
```

(4) The Geometric Group for this element. Geometric properties for tether elements are the same as for TUBE elements, except that tether elements cannot be free flooding or have end cuts, i.e. they have diameter, wall thickness, drag and added mass coefficients specified.

19.19.2. The TSPA/TSPV Data Records - Tether Anchor and Vessel Springs

Only one TSPA and one TSPV data record may be input for each tether.

```
  2   5  7   11         31         41         51
 - --- -- ---- -----  ...  ---------- ---------- ----------
|X|XXX|  |TSPA|    1|     |          |          |          |
 - --- -- ---- -----  ...  ---------- ---------- ----------
|X|XXX|  |TSPV|    1|     |          |          |          |
 - --- -- ---- -----  ...  ---------- ---------- ----------
      |   |     |            |          |         |
      |   |     |            |----------------------
      |   |     |            |
      |   |     |            |_(2) 3 Spring stiffnesses (3E10.0)
      |   |     |
      |   |     |
      |   |     |_(1) Non-tension element flag (I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) For installed tethers, this should be left blank. For towed tethers, a '1' should be entered in Column 15.

(2) The values of the stiffnesses of the springs at the anchor end should be specified on the TSPA data record. The stiffnesses of the springs at the vessel end should be specified on the TSPV data record.

For installed tethers, the spring stiffnesses are the inline/vertical stiffness and the two rotational stiffnesses (about the local tether Y- and Z-axes) at the ends of the tether. Default values of 1.0E15 are used, if this data record is omitted. A default value of 1.0E15 for the inline stiffness is used if the 1st field is left blank or a negative or zero values is input. For the rotational fields, any value may be entered (except negative values which will be set to zero).

For towed tethers, the stiffnesses are assumed to represent soft mooring line stiffness and are the three stiffnesses in the translational directions. Note that the higher the stiffnesses input here, the smaller the time steps will need to be in Data Category 16. This data record should always be present for towed tethers.

19.19.3. The TEIG Data Record - Tether Eigensolution

This data record should be input for all preliminary runs.

The TEIG data record request that an eigenvalue analysis of the tether at zero displacement from the TLA axis system should be performed.

```
  2   5  7   11    16
 - --- -- ---- -----
|X|XXX|  |TEIG|     |
 - --- -- ---- -----
      |   |     |
      |   |     |
      |   |     |
      |   |     |_(1) Number of Modes (I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) The number of modes to be output for the pre-processing eigensolution. The maximum number of modes available is 60.

19.19.4. The TFAT Data Record - Tether Fatigue Parameters (Aqwa-Drift only)

This data record may be omitted, in which case the default values shown below will be used.

```
  2   5  7   11         31         41         51         61
 - --- -- ----    ...     ---------- ---------- ---------- ----------
|X|XXX|  |TFAT|          |          |          |          |          |
 - --- -- ----    ...     ---------- ---------- ---------- ----------
      |   |                   |          |         |           |
      |   |                   |--------------------------------
      |   |                   |
      |   |                   |_(1) 4 Fatigue parameters( 4E10.0)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) The four fatigue parameters are:

1. Reserved (leave blank)
2. Stress concentration factor (default value 1.24)
3. SN Curve intercept coefficient (default value 1.3367E24) (Units are consistent with stress in kN/m^2)
4. SN Curve slope m (default value 3.5)

Fatigue life (days) = 1/(damage per day)

The formula used to calculate the fatigue life is

$$\text{Damage per day} = \sum_{i=1}^{NBIN} \frac{R(i)SCF^{m}}{A} N(i)$$

where

R(i) = stress range (computed from rainflow count of time history stresses)

N(i) = number of cycles per day for this stress range (from probability distribution by rainflow count)

SCF = stress concentration factor

m = SN curve slope

A = SN curve intercept coefficient

NBIN = number of bins in the stress probability distribution

19.19.5. The TPSH Data Record - Tether Peak Stress Hours (Aqwa-Drift only)

This data record may be omitted, in which case the default value of 3 hours will be used.

```
      2   5  7   11    16
    - --- -- ---- -----
   |X|XXX|  |TPSH|     |
    - --- -- ---- -----
          |   |     |
          |   |     |
          |   |     |
          |   |     |_(1) Number of Hours (I5)
          |   |
          |   |_Compulsory Data Record Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

(1) The number of hours for which the expected peak stress is calculated

The extreme values of stress are based on the assumption that stress has a Rayleigh distribution. The peak stress is given by

$$\text{Peak stress in N hours} = ABS(\text{mean stress}) + (RMS\ \text{stress})\ln\left(\frac{\sqrt{(N)(n)}}{2}\right)$$

where

n = the number of cycles/hour, based on the stress time history calculation of the mean of the number of positive and negative peaks

19.19.6. The TSLK Data Record - Tether Printing when Slack

This data record should only be input for installed tethers which are expected to go slack.

```
  2   5  7   11         21         31
 - --- -- ---- ---------- ---------- ----------
|X|XXX|  |TSLK|XXXXXXXXXX|XXXXXXXXXX|          |
 - --- -- ---- ---------- ---------- ----------
      |   |                             |
      |   |                             |
      |   |                             |_(1) Time (F10.0)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) Duration of time for which the user requires listing file output of the tether motions, forces and stress after the tether goes slack.

This data record controls the listing file time history output for installed tethers. It should be used when the user ONLY wants tether time history output when the tether goes slack. The TPRV data record in Data Category 18, which requests listing file output at specified time intervals, should be omitted as it OVERRIDES this data record.

The user specifies the time for which the time history of tether motion, forces and stresses should be output to the listing file when the tether goes slack; for example, if 20 secs is input, then printing starts when the tether goes slack and continues every time step for 20 seconds. It is then switched off until the tether goes slack again.

This data record does not affect the output to the graphics backing file or statistics post-processing.

19.19.7. The TEGR Data Record - Tether Group Factor

This data record should only be input for installed tethers.

The TEGR data record specifies that a single tether should be considered as a group of tethers.

```
  2   5  7   11
 - --- -- ---- -----
|X|XXX|  |TEGR|     |
 - --- -- ---- -----
      |   |     |
      |   |     |
      |   |     |_(1) Tether group factor (I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) Number of tethers in this group.

This enables a group of tethers to be calculated as a single tether by the program and has the effect of multiplying the forces exerted on the vessel by the tether by a specified factor. It has no other effect.

19.19.8. The TCAP Data Record - Tether End Cap Areas

This data record should only be input for installed tethers.

```
  2   5  7   11          21         31         41
 - --- -- ---- ---------- ---------- ---------- ----------
|X|XXX|  |TCAP|XXXXXXXXXX|XXXXXXXXXX|          |          |
 - --- -- ---- ---------- ---------- ---------- ----------
       |   |                            |          |
       |   |                            |          |
       |   |                            |          |_(2) Vessel Cap Area (E10.0)
       |   |                            |
       |   |                            |_(1) Anchor Cap Area (E10.0)
       |   |
       |   |_Compulsory Data Record Keyword (A4)
       |
       |_Optional User Identifier (A2)
```

(1)-(2)The area which is not subject to external pressure by the water at the anchor and vessel ends. These values are used to calculate the tether effective/wall tensions.

19.19.9. The TIFL Data Record - Tether Internal Fluid Properties

This data record should only be input for installed tethers.

```
  2   5  7   11          21         31         41
 - --- -- ---- ---------- ---------- ---------- ----------
|X|XXX|  |TIFL|XXXXXXXXXX|XXXXXXXXXX|          |          |
 - --- -- ---- ---------- ---------- ---------- ----------
       |   |                            |          |
       |   |                            |          |
       |   |                            |          |_(2) Density (E10.0)
       |   |                            |
       |   |                            |_(1) Pressure (E10.0)
       |   |
       |   |_Compulsory Data Record Keyword (A4)
       |
       |_Optional User Identifier (A2)
```

(1) The internal pressure of the tether at sea level

(2) The density of the internal fluid of the tether

These values are used to calculate the tether effective/wall tensions.

19.19.10. The TIMP Data Record - Tether Impact Parameters

This data record should only be input for installed tethers.

```
  2   5  7   11          21         31         41
 - --- -- ---- ---------- ---------- ---------- ----------
|X|XXX|  |TIFL|XXXXXXXXXX|XXXXXXXXXX|          |          |
 - --- -- ---- ---------- ---------- ---------- ----------
       |   |                            |          |
```

```
        |    |                             |          |
        |    |                             |          |_(2) Half Life (E10.0)
        |    |                             |
        |    |                             |_(1) Impact Factors (E10.0)
        |    |
        |    |_Compulsory Data Record Keyword (A4)
        |
        |_Optional User Identifier (A2)
```

(1) The stress impact factor.

The initial stress caused by tether impact is assumed to be proportional to the velocity of impact. The stress impact factor is the constant of proportionality, in other words.

initial axial stress = (stress impact factor)(impact velocity)

(2) The half life duration of the impact.

As the shock wave is reflected at the vessel and anchor ends it is assumed that the decay is exponential.

If the half life input above is t2, the axial stress due to the impact at a time t after impact is given by:

axial stress = initial axial stress * exp (-0.69315 t/t2)

19.19.11. The TLOW Data Record - Tether Lower Stop Position

This data record should only be input for installed tethers.

```
  2   5  7   11          21         31
 - --- -- ---- ---------- ---------- ----------
|X|XXX|  |TLOW|XXXXXXXXXX|XXXXXXXXXX|          |
 - --- -- ---- ---------- ---------- ----------
       |   |                             |
       |   |                             |
       |   |                             |_(1) Lower Stop Position (E10.0)
       |   |
       |   |_Compulsory Data Record Keyword (A4)
       |
       |_Optional User Identifier (A2)
```

(1) The distance of the lower stop below the anchor. If the end of the tether is below this point, a warning will be issued. Note that, if the lower stop distance is input as zero, the tether can never be free hanging.

19.19.12. The TETH Data Record - Tether Vessel and Anchor/Trailing End Position

This data record should be input after the tether has been fully described i.e. all the previous data records have been input.

For towed tethers this should be the *last* and *only* TETH data record in Data Category 14.

For installed tethers, where in general there is more than one tether, a complete tether description may be duplicated by inputting a TETH data record immediately following another. In this case, the previous tether will be duplicated at the positions specified by the structure/node numbers.

```
  2   5  7   11     16    21     26
 - --- -- ---- ----- ----- ----- -----
|X|XXX|  |TETH|     |     |    0|     |
 - --- -- ---- ----- ----- ----- -----
      |   |     |     |     |     |
      |   |     |     |     |     |
      |   |     |     |     |     |_(4) Node 2 (I5)
      |   |     |     |     |
      |   |     |     |     |_(3) Fixed position specification (I5)
      |   |     |     |
      |   |     |     |_(2) Node 1 (I5)
      |   |     |
      |   |     |_(1) Structure Number (I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) The number of the structure/vessel to which the tether is attached. This must correspond to one of the structures defined in Data Category 2. If '1' is input, this will correspond to the structure defined in Data Category 'ELM1'. If '2' is input, this will correspond to the structure defined in Data Category 'ELM2', etc. Structure number '0' (i.e. a fixed node) is an illegal structure (in this position) and will produce an error.

For towed tethers, the structure number must be 1.

(2) This is the node number of the attachment point at the vessel end of the tether line on the structure specified (1). The position of this node on the vessel must have been defined in Data Category 1.

(3)-(4) Specify structure number 0 (i.e. fixed in the FRA) and its corresponding node number (4) to define the anchor/trailing end of the tether. The position of this node (4) must have been defined in Data Category 1.

19.19.13. The TLAC/TROC/TLAV/TROV Data Records -Tether Constraint Data Records

The user may specify up to four constraints on an installed tether. The constraints may be fixed:

TLAC - Tether fixed LAteral Constraint

TROC - Tether fixed ROtational Constraint

or attached to the vessel:

TLAV - Tether LAteral Vessel constraint (passes though 'gap' in structure)

TROV - Tether ROtational Vessel constraint (encastre condition on vessel)

The format of the input is as follows:

```
    5  7    11        21        31
---- -- ---- --------- --------- --------- ----
XXXX|  |TROC|XXXXXXXXX|XXXXXXXXX|XXXXXXXXX|XXXX
---- -- ---- --------- --------- --------- ----
XXXX|  |TROV|XXXXXXXXX|XXXXXXXXX|XXXXXXXXX|XXXX
---- -- ---- --------- --------- --------- ----
XXXX|  |TLAC|XXXXXXXXX|XXXXXXXXX|XXXXXXXXX|XXXX
---- -- ---- --------- --------- --------- ----
XXXX|  |TLAV|XXXXXXXXX|XXXXXXXXX|    0.100|XXXX
---- -- ---- --------- --------- --------- ----
      |   |                          |
      |   |                          |_(3) Gap between tether and structure
      |   |
      |   |_(2) Mandatory Data Record Keyword
      |
      |_(1) Optional 2 letter user identifier
```

(2) Note that the rotational constraints, TROC and TROV, are rarely used, as this will cause large bending moments at the attachment points. Weak/zero stiffness spring are normally used (see The TSPA/TSPV Data Records - Tether Anchor and Vessel Springs (p. 245)).

(3) For a lateral constraint on the vessel, a gap can be specified, representing an opening which is wider than the tether. It is assumed to be a frictionless circular gap in the structure, vertically below the tether attachment point. If the total lateral movement relative to the center of the gap is greater than the gap distance specified, the program will assume that the node at the gap is constrained laterally by the structure.

As forces on the tether are by definition in the XY plane of the tether axis system (TLA), the reaction on the structure must be at right angles to the TLA, i.e. for a vertical tether, the reactive force will be in the horizontal plane of the FRA. For a sloping tether, i.e. when the TLP is offset, there will be a small vertical (in the Z FRA) component equal to the total reaction multiplied by the sine of the slope of the Z axis of the TLA.

19.19.14. The TECP/TSEG/TSGH Data Records - Composite Tether Configuration

These data records define a composite tether, in terms of one or more tether segments. To use this composite tether configuration, one or more TETH (p. 250) data records must follow.

A composite tether can be defined to link a structure to an anchor (or trailing end).

19.19.14.1. The TECP Data Record

The TECP data record describes a composite tether consisting of one or more sections.

```
  2   5  7    11    16    21
 - --- -- ---- ----- -----
|X|   |  |TECP|     |     |
 - --- -- ---- ----- -----
      |   |     |     |
      |   |     |     |_(2) Number of elements of a tether (I5). (Def =50, if less than (1))
      |   |     |
      |   |     |_(1) Number of sections in the tether(I5)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
```

```
          |
          |_Optional User Identifier (A2)
```

(1) The number of sections of different properties in the tether, indicating that no. of TSEG (p. 253) data records will follow the TECP data record. The maximum number of tether sections in a composite tether is 24.

(2) The number of elements for each tether in the calculation cannot exceed 250. If it is less than the number of sections (1), the default value of 50 is used.

19.19.14.2. The TSEG Data Record

The TSEG data record specifies the properties of each of the sections of the composite tether. Each section is considered as a flexible cylinder tube. Although the data record title implies that only properties of tether sections are expected, constraints may be modeled with the TLAC/TROC/TLAV/TROV (p. 251) data records. If constraints are defined, they act on the ends of sections.

```
    2   5  7        21        31        41        51        61        71
  - --- -- ---- ---- --------- --------- --------- --------- --------- ---------
 |X|   |  |TSEG|XXXX|         |         |XXXXXXXXX|         |         |         |
  - --- -- ---- ---- --------- --------- --------- --------- --------- ---------
      |   |             |        |                  |         |         |
      |   |             |        |                  |         |         |_(6) Tether section
      |   |             |        |                  |         |                length (E10.0)
      |   |             |        |                  |         |
      |   |             |        |                  |         |_(5)Wall thickness(E10.0)
      |   |             |        |                  |
      |   |             |        |                  |_(4) External diameter(E10.0)
      |   |             |        |
      |   |             |        |_(2) Young’s modulus (E10.0)
      |   |             |
      |   |             |_(1) Material density (E10.0)
      |   |
      |   |_Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

(1) Material density of the section of the composite tether.

(2) Young's modulus. The default value is chosen to give a typical value based on the material density, for example: 5×10^6 * material density.

(4) External diameter. Must be greater than 0.

(5) Wall thickness. Must be greater than 0.

(6) Length of tether section. Must be greater than 0.

For a composite tether containing more than one TSEG data records, the definition of TSEGs must be contiguous from the anchor (trailing) point to the vessel attachment point.

19.19.14.3. The TSGH Data Record

The TSGH data record is for defining the hydrodynamic properties of tether sections and should be input after a TSEG (p. 253) data record. If a TSEG (p. 253) data record is not followed by a TSGH data record, Aqwa will use the default coefficients.

```
     2   5  7        21        31        41
   - --- -- ---- ---- --------- ---------
  |X|   |  |TSGH|XXXX|         |         |
   - --- -- ---- ---- --------- ---------
         |   |             |        |
         |   |             |        |_(2) Cross-sectional added mass coefficient (E10.0)
         |   |             |
         |   |             |_(1) Cross-sectional drag coefficient (E10.0)
         |   |
         |   |_Compulsory Data Record Keyword (A4)
         |
         |_Optional User Identifier (A2)
```

(1) Cross-sectional drag coefficient of the section. The default value is 0.75.

(2) Cross-sectional added mass coefficient of the section. The default value is 1.0.

19.20. The CBAZ Data Record - Number of Composite Cable Plane Azimuth Angles

This data record is optional for composite cables if the global seabed slope defined with the SBED (p. 168) data record is non-trivial.

```
  2   5  7    11    16
 - --- -- ---- ----- ---
|XXXX |  |CBAZ|     |
 - --- -- ---- ----- ---
      |   |     |
      |   |     |_(2)No. of azimuths of cable plane (I5)
      |   |
      |   |_(1)Compulsory Data Record Keyword (A4)
      |
      |_Optional User Identifier (A2)
```

Note:

A default value of 21 is used if this data record does not exist, or if the defined value is less than the default. The maximum value should not be greater than 41. The range of azimuth angles is from 0 to 180° relative to the sloped seabed direction.

Chapter 20: Starting Conditions Definition - STRT (Data Category 15)

20.1. General Description

Data Category 15 is used in all programs in the Aqwa suite, except Aqwa-Line, to input the 'starting conditions' for the analysis. Although data categories for each type of analysis are similar, they are documented separately as each requires information appropriate to the type of analysis. This description of Data Category 15 is appropriate to Aqwa-Fer and Aqwa-Librium only.

The programs Aqwa-Fer and Aqwa-Librium solve equations of motion that are in the frequency domain or quasi-static respectively. The programs therefore require the initial position of the body/bodies globally. These initial conditions or initial positions are referred to as starting conditions.

Starting Conditions - Defaults

Aqwa-Librium

The equations to be solved require only the specification of initial positions. These positions are given for each body and for each of the 6 body degrees of freedom. Default starting conditions will be assumed by Aqwa-Librium if the user omits any, or all (the latter by entering NONE for the Data Category Keyword) of the data records in this data category.

The default starting position is the position of the structure(s) as originally defined by the user in Data Categories 1 to 4. (See Motion Constraints on Structures - CONS (Data Category 12) (p. 169) if constraints are present.)

Aqwa-Fer

The equations to be solved require the specification of initial positions and articulation reactions (if there are any articulations in the model). The positions are given for each body and for each of the 6 body degrees of freedom. Default starting conditions will be assumed by Aqwa-Fer if the user omits any, or all (the latter by entering NONE for the Data Category Keyword) of the data records in this data category.

The default initial position is the position of the structure(s) as originally defined by the user in Data Categories 1 to 4.

The default initial articulation reactions are zero. Incorrect articulation reactions can affect the stiffness matrix and lead to inaccurate results. Therefore it is strongly recommended that the reactions are specified on the REA* data record, or read in from an EQP file created by Aqwa-Librium.

Starting Conditions with the RDEP Option

If the RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)) is used with a filename given on the RESTART data record (e.g., FILE01), then the positions and reactions in the file `FILE01.EQP` will override the default positions and reactions. However, if starting positions or reactions are defined in Data Category 15 these will in turn override the data in the `.EQP` file.

Starting Conditions specified in Data Category 15

If the POS*, VEL* or REA* data records are used in Data Category 15 the values on these data records will override the defaults or the values in the `.EQP` file. Note that blank fields on these data records are treated as zero values.

Slow velocity and position are not used in Aqwa-Librium or Fer. If the SLP* or SLV* data records are used they will be ignored.

20.2. Data Category Header

```
       5      11
 ---- -- ---- ----
|XXXX|  |XXXX|STRT|
 ---- -- ---- ----
      |        |
      |        |_Compulsory Data Category Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

20.3. The POS* Data Record - Starting Positions

* denotes structure number (see (1) below)

See Starting Conditions Definition - STRT (Data Category 15) (p. 255) for a discussion of the interaction between the RDEP option and the POS* and REA* data records.

```
  2   5  7   11    16    21         31         41         51
 - --- -- ---- ----- ----- ---------- ---------- ---------- ----------
|X|   |  |POS1|     |     |          |          |          |...
 - --- -- ---- ----- ----- ---------- ---------- ---------- ----------
   |  |   |     |     |        |          |          |         |
   |  |   |     |     |        |------------------------------------
   |  |   |     |     |        |
   |  |   |     |     |        |_(4)-(9)6 Starting Positions (default as
   |  |   |     |     |           defined in Data Categories 1-4)(6F10.0)
   |  |   |     |     |
   |  |   |     |     |______(3) Mooring Configuration number (I5)  (default =1)
   |  |   |     |
   |  |   |     |_______(2) Spectrum number (I5) (default=1)
   |  |   |
   |  |   |_(1)Compulsory Data Record Keyword(A4)
   |  |
   |  |_Optional User Identifier(A2)
   |
   |_Compulsory END on Last Data Record in Data Category.(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter POS1 for Structure 1, POS2 for Structure 2, ... PO10 for Structure 10.

(2)-(3) This is to indicate which spectrum and mooring configuration the structure position is defined for, only needed for multiple spectra/mooring configuration cases.

(4)-(9) This is the position of the structure indicated by the data record keyword (1) at the start of the analysis. The position is defined by three translations and three successive rotations. Angles are in degrees.

20.4. The REA* Data Record - Initial Articulation Reactions

* denotes articulation number (see (1) below)

See Starting Conditions Definition - STRT (Data Category 15) (p. 255) for a discussion of the interaction between the RDEP option and the POS* and REA* data records.

```
     2   5  7   11    16    21         31         41         51
   - --- -- ---- ----- ----- ---------- ---------- ---------- ----------
  |X|   |  |REA1|     |     |          |          |          |...
   - --- -- ---- ----- ----- ---------- ---------- ---------- ----------
      |  |   |     |     |        |          |          |         |
      |  |   |     |     |        |-----------------------------------
      |  |   |     |     |        |
      |  |   |     |     |        |_(4)-(9)6 Reactions in Starting Position (6F10.0)
      |  |   |     |     |
      |  |   |     |     |______(3) Mooring Configuration number (I5)  (default =1)
      |  |   |     |
      |  |   |     |_______(2) Spectrum number (I5) (default=1)
      |  |   |
      |  |   |_(1)Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on Last Data Record in Data Category.(A3)
```

(1) The data record keyword indicates the corresponding articulation number for the positions in columns 21-80; for example, enter REA1 for Articulation 1, REA2 for Articulation 2, ... RE10 for Articulation 10.

(2)-(3) This is to indicate which spectrum and mooring configuration the reaction is defined for, only needed for multiple spectra/mooring configuration cases. If omitted the same initial reactions will be used for all spectra and /mooring configurations.

(4)-(9) These are the initial reactions applied by the articulation to the 1st structure on the relevant DCON data record (The DCON Data Record - Define Constraint Position (p. 171)) in Data Category 12. The reactions are three forces and three moments. The reactions are applied in the global axis system. The LAAR (Administration and Calculation Options for the Aqwa Suite (p. 314)) and LSAR (Administration and Calculation Options for the Aqwa Suite (p. 314)) options, if used, apply only to output reactions.

Chapter 21: Starting Conditions Definition (Aqwa-Drift) - STRT (Data Category 15D)

Note that this chapter has separate sections for analyses at Drift frequency only and those with both Drift and Wave frequencies.

21.1. General Description

Data Category 15 is used in all programs in the Aqwa suite, except Aqwa-Line, to input the 'starting conditions' for the analysis. Although data categories for each type of analysis are similar, they are documented separately as each requires information appropriate to the type of analysis. This description of Data Category 15 is appropriate to Aqwa-Drift only.

Aqwa-Drift solves the second order differential equations of motion by integrating them to form a time-history of motions. The program requires the initial conditions in order to begin the integration. These initial conditions are referred to as starting conditions.

As the differential equation is second order, the solution requires two initial conditions which may be input by the user. These are the position and velocity at the start of the time-history in all 6 degrees of freedom. However, default starting conditions will be assumed by Aqwa-Drift if the user omits any, or all (the latter by entering NONE for the Data Category Keyword) of the data records in this data category.

'Fast', 'Slow' and 'Total' Positions and Velocities

The total motion of a structure in Aqwa-Drift is the sum of its 'slow' drift motion and the 'fast' wave frequency motion. The program, in general, needs the initial conditions of the structure for both the fast and slow motions. Also it is important that the structure experiences as small a transient as possible. This can only be achieved if the program has appropriate values of slow and fast initial conditions. This is not as complicated as it sounds since the program automatically performs the difficult calculations.

The initial conditions for the slow motion are relatively intuitive since these relate to the general motion of the structure about its equilibrium position as predicted by Aqwa-Librium. The fast motions, however, are in response to the wave frequency forces which are randomly phased, so that the user is generally unable to specify them. In this case, the program automatically computes the correct fast motion from the information it has concerning the random waves and the response amplitude operators of the structure.

21.1.1. Analysis Type - Drift only

Starting Conditions - Defaults

The default starting slow position is the position of the structure as originally defined by the user in Data Categories 1 to 4. The default starting slow velocity is zero in all 6 degrees of freedom.

fast position and velocity are not used in a drift frequency analysis. They are assumed to be zero so the total position and velocity are the same as the slow values.

Starting Conditions with the RDEP option

If the RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)) is used with a filename given on the RESTART data record (e.g FILE01), then the position in the file `FILE01.EQP` will override the default slow position. However, if starting positions are defined in Data Category 15 these will in turn override the data in the .EQP file. The default starting slow velocity is zero in all 6 degrees of freedom.

The total position and velocity are the same as the slow values.

POS* or VEL* Specified

The POS* (The POS* Data Record - Starting Positions (p. 262)) and VEL* (The VEL* Data Record - Starting Velocities (p. 262)) data records define the total position and velocity respectively; in a Drift-only analysis they also define the slow position and velocity. The POS* data record will overwrite any values read in from an EQP file.

The POS* and VEL* data records will be over-written by the SLP* and SLV* data records, if they exist.

SLP* or SLV* Specified

The SLP* (The SLP* Data Record - Slow Starting Positions (p. 263)) and SLV* (The SLV* Data Record - Slow Starting Velocities (p. 263)) data records define the slow position and velocity respectively; in a Drift-only analysis they also define the total position and velocity. The SLP* and SLV* data records will overwrite any values read in from an EQP file or from POS* and VEL* data records.

Initial Reactions

It is not possible to specify the initial articulation reactions in Aqwa-Drift. If the positions are correct the articulation reactions will reach equilibrium in the 1st time step.

21.1.2. Analysis Type - Drift + Wave Frequency (WFRQ on JOB data record)

Starting Conditions - Defaults

The default starting slow position is the position of the structure as originally defined by the user in Data Categories 1 to 4. The default starting slow velocity is zero in all 6 degrees of freedom.

The fast position and velocity are calculated by the program and added to the slow position and velocity to form the total position and velocity. If any two structures are connected by an articulation this calculation is omitted for those structures, the fast position and velocity are zero and the total position and velocity are the same as the slow position and velocity.

Starting Conditions with the RDEP option, but NONE in Data Category 15

If the RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)) is used with a filename given on the RESTART data record (e.g FILE01), then the position in the file `FILE01.EQP` will override the default slow position. However, if the slow position is defined in Data Category 15 this will in turn override the data in the .EQP file. The default starting slow velocity is zero in all 6 degrees of freedom.

The fast position and velocity are calculated by the program and added to the slow position and velocity to form the total position and velocity. If any two structures are connected by an articulation this calculation is omitted for those structures, the fast position and velocity are zero and the total position and velocity are the same as the slow position and velocity.

SLP* or SLV* specified, but not POS* or VEL*

The SLP* (The SLP* Data Record - Slow Starting Positions (p. 263)) and SLV* (The SLV* Data Record - Slow Starting Velocities (p. 263)) data records define the slow position and velocity respectively. The SLP* data record will overwrite any values read in from an EQP file.

The fast position and velocity are calculated by the program and added to the slow position and velocity to form the total position and velocity. If any two structures are connected by an articulation this calculation is omitted for those structures, the fast position and velocity are zero and the total position and velocity are the same as the slow position and velocity.

This is the most usual starting condition for this analysis type

POS* or VEL* specified, but not SLP* or SLV*

The POS* (The POS* Data Record - Starting Positions (p. 262)) and VEL* (The VEL* Data Record - Starting Velocities (p. 262)) data records define the total position and velocity respectively.

If the RDEP option is used the slow position will be read from the specified EQP file, otherwise the slow position is the same as the total position. The slow velocity is the same as the total velocity.

Both POS* and SLP* or VEL* and SLV* specified

The slow position is as specified on the SLP* data record. The RDEP option is ignored.

The total position is as specified on the POS* data record.

The slow velocity is as specified on the SLV* data record.

The total velocity is as specified on the VEL* data record.

The initial values of fast position and velocity are calculated from the difference between the slow and total values.

Initial Reactions

It is not possible to specify the initial articulation reactions in Aqwa-Drift. If the positions are correct the articulation reactions will reach equilibrium in the 1st time step.

21.2. Data Category Header

```
           5      11
     ---- -- ---- ----
    |XXXX|  |XXXX|STRT|
     ---- -- ---- ----
          |        |
          |        |_Compulsory Data Category Keyword(A4)
          |
          |_Optional User Identifier(A2)
```

21.3. The POS* Data Record - Starting Positions

* denotes structure number (see (1) below)

See General Description (p. 259) for a discussion of the interaction between the RDEP option and the POS*, VEL*, SLP* and SLV* data records.

```
       2   5  7   11        21        31        41        51
    - --- -- ---- --------- --------- --------- --------- -
   |X|   |  |POS1|XXXXXXXXX|         |         |         |...
    - --- -- ---- --------- --------- --------- --------- -
       |  |   |                 |         |         |     |
       |  |   |                 |----------------------------
       |  |   |                 |
       |  |   |                 |
       |  |   |                 |_(2)-(7)6 Starting Positions (default as
       |  |   |                         defined in Data Categories 1-4)(6F10.0)
       |  |   |
       |  |   |_(1)Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter POS1 for Structure 1, POS2 for Structure 2, ... PO10 for Structure 10.

(2)-(7) This is the total position of the structure indicated by the data record keyword (1) at the start of the time-history simulation. Angles are in degrees.

21.4. The VEL* Data Record - Starting Velocities

* denotes structure number (see (1) below)

See General Description (p. 259) for a discussion of the interaction between the RDEP option and the POS*, VEL*, SLP* and SLV* data records.

```
       2   5  7   11        21        31        41        51        61
    - --- -- ---- --------- --------- --------- --------- --------- ------
   |X|   |  |VEL1|XXXXXXXXX|         |         |         |         |
    - --- -- ---- --------- --------- --------- --------- --------- ------
       |  |   |                |          |         |         |         |
       |  |   |                |---------------------------------------------
       |  |   |                |
       |  |   |                |
       |  |   |                |_(2)-(7)6 Starting Velocities (default zero) (6F10.0)
```

```
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter VEL1 for Structure 1, VEL2 for Structure 2, ... VE10 for Structure 10.

(2)-(7) This is the total velocity of the structure indicated by the data record keyword (1) at the start of the time-history simulation.

21.5. The SLP* Data Record - Slow Starting Positions

* denotes structure number (see (1) below)

See General Description (p. 259) for a discussion of the interaction between the RDEP option and the POS*, VEL*, SLP* and SLV* data records.

```
      2   5  7   11        21        31        41        51
    - --- -- ---- --------- --------- --------- --------- -
   |X|   |  |SLP1|XXXXXXXXX|         |         |         |...
    - --- -- ---- --------- --------- --------- --------- -
        |  |   |                 |         |         |     |
        |  |   |                 |----------------------------
        |  |   |                 |
        |  |   |                 |
        |  |   |                 |_(2)-(7)6 Starting Slow Positions (default as
        |  |   |                          defined in POS* data record in the same data category)(6F10.0)
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter SLP1 for Structure 1, SLP2 for Structure 2, ... SP10 for Structure 10.

(2)-(7) This is the slow position of the structure indicated by the data record keyword (1) at the start of the time-history simulation.

21.6. The SLV* Data Record - Slow Starting Velocities

* denotes structure number (see (1) below)

See General Description (p. 259) for a discussion of the interaction between the RDEP option and the POS*, VEL*, SLP* and SLV* data records.

```
      2   5  7   11        21        31        41        51        61
    - --- -- ---- --------- --------- --------- --------- --------- ------
   |X|   |  |SLV1|XXXXXXXXX|         |         |         |         |      ...
    - --- -- ---- --------- --------- --------- --------- --------- ------
        |  |   |                |          |         |         |         |
        |  |   |                |---------------------------------------------
        |  |   |                |
        |  |   |                |
```

```
        |  |   |                |_(2)-(7)6 Starting Slow Velocities (default zero) (6F10.0)
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter SLV1 for Structure 1, SLV2 for Structure 2, ... SV10 for Structure 10.

(2)-(7) This is the slow velocity of the structure indicated by the data record keyword (1) at the start of the time-history simulation.

Chapter 22: Starting Conditions Definition (Aqwa-Naut) - STRT (Data Category 15N)

22.1. General Description

Data Category 15 is used in all programs in the Aqwa suite, except Aqwa-Line, to input the 'starting conditions' for the analysis. Although data categories for each type of analysis are similar, they are documented separately as each requires information appropriate to the type of analysis. This description of Data Category 15 is appropriate to Aqwa-Naut only.

Aqwa-Naut solves the second order differential equations of motion by integrating them to form a time-history. The program therefore requires the initial conditions in order to begin the integration. These initial conditions are referred to as starting conditions.

Starting Conditions - Defaults

As the differential equation is second order, the solution requires two initial conditions which may be input by the user. These are the position and velocity at the start of the time-history in all 6 degrees of freedom. However, default starting conditions will be assumed by Aqwa-Naut if the user omits any, or all (the latter by entering NONE for the Data Category Keyword) of the data records in this data category.

The default starting position is the position of the structure as originally defined by the user in Data Categories 1 to 4. The default starting velocity is zero in all 6 degrees of freedom.

Starting Conditions with the RDEP option

If the RDEP option (Administration and Calculation Options for the Aqwa Suite (p. 314)) is used with a filename given on the RESTART data record (e.g FILE01), then the positions in the file `FILE01.EQP` will override the default positions. However, if starting positions are defined in Data Category 15 these will in turn override the data in the .EQP file.

The starting velocity will be zero.

Starting Conditions specified in Data Category 15

If the POS* or VEL* data records are used in Data Category 15 the values on these data records will override the defaults or the values in the .EQP file. Note that blank fields on these data records are treated as zero values.

Slow velocity and position are not used in Aqwa-Naut. If the SLP* or SLV* data records are used they will be ignored.

Initial Reactions

It is not possible to specify the initial articulation reactions in Aqwa-Naut. If the positions are correct the articulation reactions will reach equilibrium in the 1st time step.

22.2. Data Category Header

```
          5       11
     ---- -- ---- ----
    |XXXX|  |XXXX|STRT|
     ---- -- ---- ----
          |        |
          |        |_Compulsory Data Category Keyword(A4)
          |
          |_Optional User Identifier(A2)
```

22.3. The POS* Data Record - Starting Positions

* denotes structure number (see (1) below)

See Starting Conditions Definition - STRT (Data Category 15) (p. 255) for a discussion of the interaction between the RDEP option and the POS* and VEL* data records.

```
      2   5  7   11        21        31        41        51
     - --- -- ---- --------- --------- --------- --------- -
    |X|   |  |POS1|XXXXXXXXX|         |         |         |...
     - --- -- ---- --------- --------- --------- --------- -
       |  |   |                |         |         |     |
       |  |   |                |----------------------------
       |  |   |                |
       |  |   |                |
       |  |   |                |_(2)-(7)6 Starting Positions (default as
       |  |   |                        defined in Data Categories 1-4)(6F10.0)
       |  |   |
       |  |   |_(1)Compulsory Data Record Keyword(A4)
       |  |
       |  |_Optional User Identifier(A2)
       |
       |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter POS1 for Structure 1, POS2 for Structure 2, ... PO10 for Structure 10.

(2)-(7) This is the position of the structure indicated by the data record keyword (1) at the start of the time-history simulation. Angles are in degrees.

22.4. The VEL* Data Record- Starting Velocities

* denotes structure number (see (1) below)

See Starting Conditions Definition - STRT (Data Category 15) (p. 255) for a discussion of the interaction between the RDEP option and the POS* and VEL* data records.

```
      2   5  7   11        21        31        41        51        61
     - --- -- ---- --------- --------- --------- --------- --------- ------
```

```
    |X|   |  |VEL1|XXXXXXXXX|         |         |         |         | ...
     - --- -- ---- --------- --------- --------- --------- --------- ------
        |  |   |                |          |         |         |         |
        |  |   |                |--------------------------------------------
        |  |   |                |
        |  |   |                |
        |  |   |                |_(2)-(7)6 Starting Velocities (default zero)
        |  |   |                         (6F10.0) Data Categories 1-4)(F10.0)
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on Last Data Record in Data Category(A3)
```

(1) The data record keyword indicates the corresponding structure number for the positions in columns 21-80; for example, enter VEL1 for Structure 1, VEL2 for Structure 2, ... VE10 for Structure 10.

(2)-(7) This is the velocity of the structure indicated by the data record keyword (1) at the start of the time-history simulation.

Chapter 23: Time Integration Parameters - TINT (Data Category 16)

23.1. General Description

This data category is used for the two time-history solution programs Aqwa-Drift and Aqwa-Naut, to input the parameters relating to the numerical integration scheme used in the analysis.

As the programs use a timestep technique in the analysis, the cost of the analysis is directly proportional to the number of timesteps specified, and NOT the length of the time simulation. The user should therefore be aware of the criteria for the specification of the value of the timestep, which will vary with the problem being analyzed (see the Aqwa-Drift User Manual and The TIME Data Record - Time Integration Parameters (p. 269)).

23.2. Data Category Header

```
          5      11
    ---- -- ---- ----
   |XXXX|  |XXXX|TINT|
    ---- -- ---- ----
         |        |
         |        |_Compulsory Data Category Keyword (A4)
         |
         |_Optional User Identifier (A2)
```

23.3. The TIME Data Record - Time Integration Parameters

```
      2   5  7   11          21        31
    - --- -- ---- ----------- --------- ---------
   |X|   |  |TIME|           |         |         |
    - --- -- ---- ----------- --------- ---------
      |  |   |           |       |         |
      |  |   |           |       |     (3) Start Time (F10.0) (default zero)
      |  |   |           |       |
      |  |   |           |       |_(2) Value of Time-step (F10.0) (default 0.1s)
      |  |   |           |
      |  |   |           |_(1)Number of Time-steps (I10) (default 10)
      |  |   |
      |  |   |_Compulsory Data Record Keyword (A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(1) This number (NT) governs the length of real time simulated, i.e. simulation time is given by (NT-1) × DT (see (2)).

(2) This important parameter (DT) governs the accuracy of the integration of the equations of motion. This value must be small enough to enable an accurate representation of the highest frequency present in the motion of a structure. Failure to do so will at best give an inaccurate simulation, and at worst will cause divergence of the integration scheme and the program will abort.

For pure sinusoidal motion, this value should not be greater than 1/10th of the period of that motion. For non-sinusoidal motion, the user should consider how accurately a set of discrete points (whose interval is the value of the time-step) would represent the motion of the structure (see the Table of Time Integration Parameters (p. 270)).

(3) This is the time (ST) at the start of the time-history simulation period, so that the time at the end of this period is given by ST + (NT - 1) × DT. It is normally left blank or set to zero except when starting the simulation from a previous analysis or when the user wishes to alter the initial phase of frequency-dependent parameters.

To change the time-step during the analysis, multiple TIME data records may be used, up to a maximum of 10.

General Points Regarding the Time Integration Parameters

The values of all of the time integration parameters are dependent on the type of analysis, but with experience the user should have no difficulty in estimating their value for any particular problem.

In addition, it should be pointed out that more program automation of these values (e.g. the automatic variation of time-step based on accuracy of the integration of the equations of motion) has deliberately been avoided. This is intended to make the user more aware of the approximations necessary when representing discontinuities in the motion of a structure which are typically present in non-linear simulation analysis.

The following table shows typical values of time integration parameters for a large barge or tanker. This must not be considered as an accurate guide but an indication of values to be input by the user. If the user's values are considerably different from these, then it is likely that an error has been made in their estimation.

Table 23.1: Time Integration Parameters

Program	Number of Time-Steps	Value of Time-Step (Seconds)	Simulation Time (Seconds)
Aqwa-Drift (Slow Drift Analysis)	2000	5	9,995
Aqwa-Drift (With Wave Frequency)	400	0.5	199.5
Aqwa-Naut			
(8 Second Wave Period)	200	0.40	79.6
(16 Second Wave Period)	200	0.75	149.25

23.4. The HOTS Data Record - For Hot-Start Run

The HOTS data record allows you to start a time domain analysis from a particular time in a previous time history analysis. The program will extract the positions and velocities of the structures at that time from the previous results and use them as the start positions and velocities for the hot-start run. It is advised that you create a separate data file for each hot-start run, and consequently, the `*.POS` and `*.RES` files from the previous run should be copied to the new name.

When the HOTS data record is used there may not always be complete continuity between the two runs.

- The convolution calculation in Aqwa has a 120 second memory, but after a hot restart this memory is lost.
- In analyses with tethers or cable dynamics, the instantaneous position of the cable or tether is lost.

```
      2   5  7   11         21        31
    - --- -- ---- ---------- --------- ---------
   |X|   |  |HOTS|          |         |         |
    - --- -- ---- ---------- --------- ---------
                |       |          |
                |       |          |_ (2)Start Time of the Hot-Start Run (F10.0)
                |       |
                |       |_(1)Time Step Number at which Hot-Start run beings (I10)
                |
                |_Compulsory Data Record Keyword (A4)
```

(1) This is the time step number in a previous run at which the user wants the hot-start run to begin.

(2) This is the time at which you want the hot-start run to begin. If both a start time step number and start time are defined, the time step number takes priority.

When the HOTS data record is defined, the parameters for the TIME data record are now as follows:

```
      2   5  7   11         21        31
    - --- -- ---- ---------- --------- ---------
   |X|   |  |TIME|          |         |XXXXXXXXXX|
    - --- -- ---- ---------- --------- ---------
        |  |   |        |          |         ¦_ Blank
        |  |   |        |          |
        |  |   |        |          |_(2) Value of Time Step (F10.0)
        |  |   |        |
        |  |   |        |_(1)Number of Time Steps for The Hot-Start Run(I10)
        |  |   |
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The number of time steps for this hot-start run only.

(2) This defines the time step size for this hot-start run.

Chapter 24: Aqwa-Librium Iteration Parameters - LMTS (Data Category 16B)

24.1. General Description

This data category is used to input parameters which are required for the iteration solution within the program Aqwa-Librium.

The iteration parameters are used to find the body's position of equilibrium. The progression towards an equilibrium state may also be controlled via input in this data category.

If the user does not specify particular convergence limits, etc., then the program will use default values. The appropriate default for each iteration parameter is given in the following section.

24.2. Data Category Header

```
        5      11
   ---- -- ---- ----
  |XXXX|  |XXXX|LMTS|
   ---- -- ---- ----
        |        |
        |        |_(1)Compulsory Data Category Keyword(A4)
        |
        |_Optional User Identifier(A2)
```

(1) If NONE is entered for the data category keyword, the program assumes default values.

24.3. The MXNI - Maximum Number of Iterations

```
    2   5  7         16
  - --- -- ---- ----- -----
 |X|   |  |MXNI|XXXXX|     |
  - --- -- ---- ----- -----
    |  |   |           |
    |  |   |           |_(1) Maximum Number of Iterations in Search of Equilibrium (Default 100)
    |  |   |
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |
    |  |_Optional User Identifier (A2)
    |
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) If the user does not specify the maximum number of iterations, then the default value of 100 is used.

24.4. The MMVE Data Record - Maximum Movement Per Iteration

```
   2   5  7   11         21        31        41        51
 - --- -- ---- ----- ----- --------- --------- --------- --------- --------- --------- -
|X|   |  |MMVE|     |XXXXX|         |         |         |         |         |         |
 - --- -- ---- ----- ----- --------- --------- --------- --------- --------- --------- -
    |  |   |    |            |
    |  |   |    |            |_(2)Maximum Movements Allowed in Each Iteration (6F10.0)
    |  |   |    |
    |  |   |    |_Structure Number(I5)
    |  |   |
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(2) These are the maximum movements allowed per iteration, for each degree of freedom. Rotations are in degrees. The default values are shown below.

Default values are: 2.00, 2.00, 0.50, 0.573, 0.573, 1.432 (G=9.81)

To take account of different unit systems Aqwa multiplies the default translation values only by G/9.81, where G is the value of gravity input in Data Category 5. These defaults will be over-written by any values input on the MMVE data record, but Aqwa does not apply any additional factors; i.e. the value on the data record is the value that is used.

24.5. The MERR Data Record - Maximum Error Allowable for Equilibrium

```
   2   5  7   11         21        31        41        51
 - --- -- ---- ----- ----- --------- --------- --------- --------- --------- ---------
|X|   |  |MERR|     |XXXXX|         |         |         |         |         |         |
 - --- -- ---- ----- ----- --------- --------- --------- --------- --------- ---------
    |  |   |    |             |
    |  |   |    |             |_(2)Maximum Errors for System to
    |  |   |    |                  be Considered in Equilibrium (6F10.0)
    |  |   |    |
    |  |   |    |_Structure Number (I5)
    |  |   |
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(2) These are the maximum errors allowed in the final equilibrium position, for each degree of freedom. I.e. if the calculated movement is less than this, the structure is assumed to be in equilibrium. Rotations are in degrees. The default values are shown below.

Default values are: 0.02, 0.02, 0.02, 0.057, 0.057, 0.143 (G=9.81)

To take account of different unit systems Aqwa multiplies the default translation values only by G/9.81, where G is the value of gravity input in Data Category 5. These defaults will be over-written by any values input on the MERR data record, but Aqwa does not apply any additional factors; i.e. the value on the data record is the value that is used.

24.6. The STRP Data Record - Output Stability Report

This data record is used when a stability report is requested from an Aqwa-Librium analysis. The report, written in `AB*.LIS` file, gives a list of positions of the structure and the corresponding forces at each position. The positions of the structure are calculated by the program at a number of rotations about one or more hinges defined by the user.

Stability reports are only available for Structure 1 and for hydrostatic forces only. The program will produce errors if any other forces are present. The LSTF option is not compatible with this facility.

```
    2   5  7   11    16    21        31        41        51        61        71
  - --- -- ---- ----- ----- --------- --------- --------- --------- --------- ---------
 |X|   |  |STRP|     |     |         |         |         |         |         |         |
  - --- -- ---- ----- ----- --------- --------- --------- --------- --------- ---------
     |  |   |     |     |       |                             |         |
     |  |   |     |     |       |                             |         |_(5) The Angular Increment
     |  |   |     |     |       |                             |              of the Hinge about
     |  |   |     |     |       |                             |              Global Z (default=1 deg)
     |  |   |     |     |       |                             |
     |  |   |     |     |       |                             |_(4)The Angular Increment about
     |  |   |     |     |       |                                  the Hinge (default=1 deg)
     |  |   |     |     |       |
     |  |   |     |     |       |_(3) The Definition of Hinge Axis Vector (3F10.0)
     |  |   |     |     |
     |  |   |     |     |_(2) Number of Rotations of the Hinge (default=1) (I5)
     |  |   |     |
     |  |   |     |_(1)Number of Rotations about the Hinge (default=30) (I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword (A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

(1) This is the number of angular positions (typically roll angles) for which the forces are calculated.

(2) It is possible to calculate stability about a number of axes. Typically rotation about the X-axis will give roll stability. The stability axis (the hinge) can itself be rotated about the global Z axis, so that pitch stability, or stability for any intermediate position, can be obtained. This parameter is the number of positions of the hinge. If only 1 hinge vector is required, the number of rotations of the hinge and angular increment of the hinge can be omitted.

(3) This is the initial direction of the hinge axis defined as a vector in the FRA. For example, for typical roll stability this would be (1, 0, 0).

(4) This is the increment between the angular positions defined in (1).

(5) This is the increment between the hinge positions defined in (2).

Chapter 25: Change Geometric/Mass Characteristics - GMCH (Data Category 16L)

25.1. General Description

This data category is used to scale and/or change the geometric or mass characteristics of a single body or system of bodies. When scaling or changing body characteristics the results are output to the hydrodynamic data-base, and hence over-write the original data-base file. This data category may also be used to define a new hydrodynamic reference point. This gives the user the fluid forces, etc about a point other than the center of gravity. This data category may be omitted and NONE entered for the data category keyword.

Scaling by Length or Mass

The user may scale various hydrodynamic and response parameters either directly by using a length scale factor, or indirectly by using a mass scale factor. The scaling factors are as follows:

Length Scale Factor = Length_{new} / Length_{old}

The user inputs the Length Scale Factor directly in this data category.

Mass Scale Factor = $(\text{Mass}_{new}/ \text{Mass}_{old})$^(1/3)

The user inputs the new Mass directly in this data category.

The parameters that are scaled are as follows:

- hydrodynamic coefficients and forces
- body responses
- wave frequencies
- water depth

Changes to Mass Distribution and/or Center of Mass

The following changes may be made to a body's mass characteristics:

- The user may define new mass inertia values about the body's center of gravity.
- The user may define a new position of the body's center of mass.

The new coordinates of the center of gravity must relate to the originally defined position of the body.

The above changes in mass characteristics require a new solution for the body's responses. Also note that a change in center of gravity in the lateral direction, will cause an originally equilibrated freely floating body to move away from the original equilibrium position.

New Hydrodynamic Reference Point

If the user requires the hydrodynamic coefficients, fluid forces and body response about a new reference point then this point may be input in this data category. Note that again the new reference point must relate to the originally defined position of the body.

Note:

The results obtained for the new reference point are not written to the database backing files.

25.2. Data Category Header

```
       5      11
  ---- -- ---- ----
 |XXXX|  |XXXX|GMCH|
  ---- -- ---- ----
      |        |
      |        |_(1)Compulsory Data Category Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

25.3. The SCAL Data Record - Length Scale Factor

```
    2   5  7   11         21        31
  - --- -- ---- ----- ----- ---------
 |X|   |  |SCAL|     |XXXXX|         |
  - --- -- ---- ----- ----- ---------
     |  |   |    |            |
     |  |   |    |            |
     |  |   |    |            |_(1) Length Scale Factor (F10.0)
     |  |   |    |
     |  |   |    |_Number(I5)
     |  |   |
     |  |   |_Compulsory Data Record Keyword (A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

(1) The Length Scale Factor is given by:

Length Scale Factor = (new length of structure / old length of structure)

25.4. The MASS Data Record - Mass Scaling Parameter

```
    2   5  7   11         21        31
  - --- -- ---- ----- ----- ---------
 |X|   |  |MASS|     |XXXXX|         |
  - --- -- ---- ----- ----- ---------
     |  |   |    |              |
```

```
        |  |   |    |              |
        |  |   |    |              |_(1) New Mass (F10.0)
        |  |   |    |
        |  |   |    |_Structure Number (I5)
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The new mass value is specified directly.

25.5. The INER Data Record - New Inertia Values

```
     2   5  7   11          21        31        41        51        61        71        81
   - --- -- ---- ----- ----- --------- --------- --------- --------- --------- ---------
  |X|   |  |INER|     |XXXXX|         |         |         |         |         |         |
   - --- -- ---- ----- ----- --------- --------- --------- --------- --------- ---------
        |  |   |    |             |
        |  |   |    |             |
        |  |   |    |             |_(1) The new inertia values w.r.t. the CG (6F10.0)
        |  |   |    |
        |  |   |    |_Structure Number (I5)
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The new inertia values are input in the following order:

I_{xx}, I_{xy}, I_{xz}, I_{yy}, I_{yz}, I_{zz}

25.6. The NCOG Data Record - New Center of Gravity

This Data Record Has Been Withdrawn

```
     2   5  7   11          21        31        41        51
   - --- -- ---- ----- ----- --------- --------- ---------
  |X|   |  |NCOG|     |XXXXX|         |         |         |
   - --- -- ---- ----- ----- --------- --------- ---------
        |  |   |    |            |
        |  |   |    |            |_(1) The New Center of Gravity (3F10.0)
        |  |   |    |
        |  |   |    |_Structure Number (I5)
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The new coordinates of the center of gravity are given with respect to the original definition position of the structure.

25.7. The REFP Data Record - New Hydrodynamic Reference Point

```
     2   5  7   11         21        31        41        51
   - --- -- ---- ----- ----- --------- --------- ---------
  |X|   |  |REFP|     |XXXXX|         |         |         |
   - --- -- ---- ----- ----- --------- --------- ---------
      |  |   |    |              |
      |  |   |    |              |_(1) The New Hydrodynamic Reference Point (3F10.0)
      |  |   |    |
      |  |   |    |_Structure Number (I5)
      |  |   |
      |  |   |
      |  |   |_Compulsory Data Record Keyword (A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(1) The coordinates of the new hydrodynamic reference point are given with respect to the originally defined position of the structure.

Chapter 26: Hydrodynamic Parameters for Non-Diffracting Elements - HYDC (Data Category 17)

26.1. General Description

This data category is used to input two types of parameter which affect non-diffracting elements with hydrodynamic coefficients. The first is a scale parameter which only affects Morison elements, e.g. TUBE elements, whose drag coefficient is dependent on Reynolds Number. The second is a simple multiplying factor for the drag, added mass and slam coefficients affecting all Morison elements.

As the input in this data category only applies to non-diffracting elements, it follows that only those programs which use these elements will accept this data category. This point is clarified below.

Aqwa-Drift: Accepts all elements and parameters.

Aqwa-Fer: Not yet implemented. Note that Morison drag is a non-linear force which must be linearized before a frequency domain solution can be applied.

Aqwa-Librium: Accepts all elements. Note that only the drag parameters are relevant, as a steady state solution has zero ADDED MASS and slam force.

Aqwa-Line: Not yet implemented. At present will only accept diffracting and point mass elements.

Aqwa-Naut: Accepts all elements and parameters.

Note:

The default value for the factor multiplying the slam coefficient is zero, as there are no general formulae documented in the literature (see The SLMM Data Record - Slam Multiplying Factor (p. 284)).

The scale factor is commonly used where the effects of Morison drag on TUBE elements is considered important (e.g. simulating tests at model scale). The multiplying factor is used for parametric studies where the effect of the hydrodynamic coefficients is of particular interest.

26.2. Data Category Header

```
      5      11
 ---- -- ---- ----
|XXXX|  |XXXX|HYDC|
 ---- -- ---- ----
      |        |
      |        |_Compulsory Data Category Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

26.3. The SC1/ Data Record - Scale Factor for Model Test Simulation

If this data record is used the RNDD option (Administration and Calculation Options for the Aqwa Suite (p. 314)) is also needed in the preliminary data category.

```
    2   5  7   11
  - --- -- ---- ----- -----
 |X|   |  |SC1/|     |XXXXX|
  - --- -- ---- ----- -----
     |  |   |      |
     |  |   |      |_(1)Scale Factor (I5) (default implies constant drag coefficients)
     |  |   |
     |  |   |
     |  |   |_Compulsory Data Record Keyword (A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

(1) This scale factor applies to all elements on all structures but in the present version of the program only affects Morison TUBE elements on those structures.

If this data record is omitted the program assumes that the Reynolds Number is sufficiently large for the drag coefficient to be considered constant. If this is not a reasonable assumption then this data record should be input with a value of unity.

The user should read the following sections before using this facility.

Effect of the Scale Factor on Reynolds Number

Experimental evidence shows that the Reynolds Number is not a simple function of the velocity and diameter for cylinders with arbitrary orientation to the direction of the fluid flow. However, considerable improvement in agreement with model tests has been obtained by using the Scale Factor to obtain a local Reynolds Number and interpolating from classic experimental results,

where

Local Reynolds Number = $(U.D/\nu)/(\text{Scale Factor}^{3/2})$

U = Local velocity transverse to the axis of the TUBE

D = The diameter of the TUBE

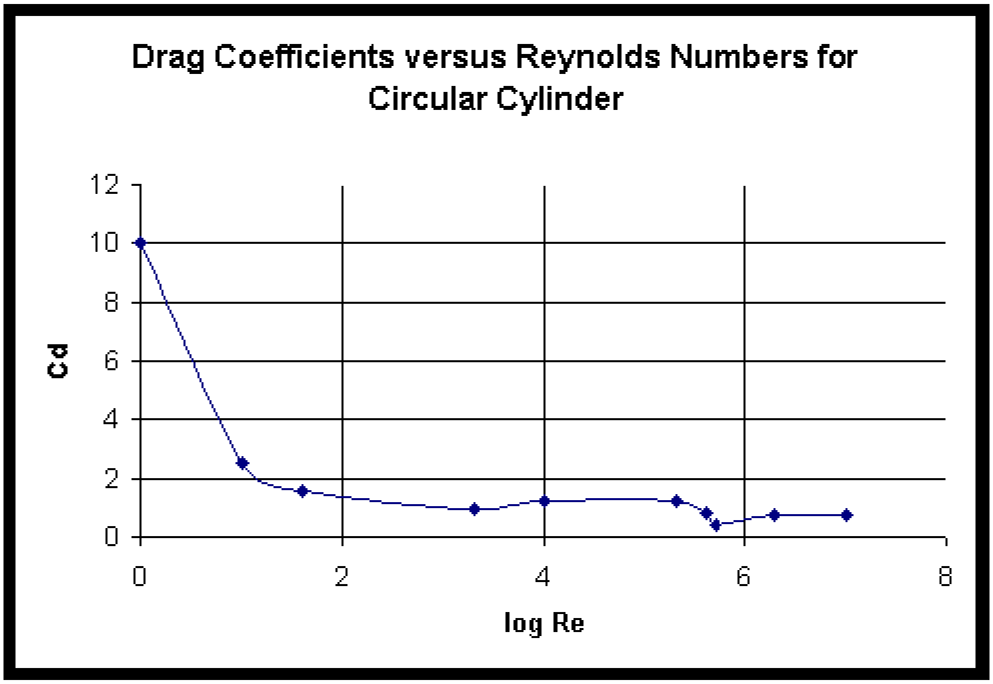
ν = Kinematic viscosity of water

Effect of the Scale Factor on Hydrodynamic Coefficients

If this data record is omitted then the drag coefficients used are those input in Data Category 4 by the user, or default coefficients assumed by the program if the user inputs zero. However, when this data record is input, these coefficients for all Morison tube elements on all structures are ignored. The program will instead interpolate coefficients from the Wieselburger graph of drag coefficient versus Reynolds Number (as shown below) for a smooth cylinder, where the Reynolds number is calculated in the manner shown above.

Drag Coefficient Variation with Reynolds Number

Note that the following curve is only used when the SC1/ data record is defined in data category 17 and is only for TUBE elements. The relative flow velocity normal to the tube is used in the calculation of the Reynolds Number Re.



26.4. The DRGM/ADMM Data Record - Drag/Added Mass Multiplying Factor

```
     2   5  7   11         21
   - --- -- ---- ----- ----- ---------
  |X|   |  |DRGM|     |XXXXX|         |
   - --- -- ---- ----- ----- ---------
  |X|   |  |ADMM|     |XXXXX|         |
   - --- -- ---- ----- ----- ---------
      |  |   |     |             |
      |  |   |     |             |_(2)Value of Multiplying Factor (Default 1.0) (F10.0)
      |  |   |     |
      |  |   |     |
      |  |   |     |_(1)Structure Number (I5)
      |  |   |
      |  |   |_Compulsory Data Record Keyword (A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2. If '1' is input, this will correspond to the structure defined in Data Category ELM1. If '2' is input, this will correspond to the structure defined in Data Category ELM2, etc (see note 1).

(2) This value is the multiplying factor for all drag/added mass coefficients for non-diffracting elements on the structure specified (1).

Note:

The multiplying factors relate to drag/added mass coefficients for the structure specified on this data record only. The program does NOT multiply the values in the Geometric Properties Table (Table 2.4.1) by this factor. It uses the original values in the table and THEN multiplies them by this factor.

This factor applies to the drag/added mass coefficients input in Data Category 4 by the user, or the Data Category 4 default coefficients assumed by the program if the user inputs zero.

26.5. The SLMM Data Record - Slam Multiplying Factor

```
    2   5  7   11         21
  - --- -- ---- ----- ----- ---------
 |X|   |  |SLMM|     |XXXXX|         |
  - --- -- ---- ----- ----- ---------
    |  |   |     |            |
    |  |   |     |            |_(2) slam Multiplying Factor (Default zero) (F10.0)
    |  |   |     |
    |  |   |     |
    |  |   |     |_(1) Structure Number (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2; in other words, if '1' is input then this will correspond to the structure defined in Data Category ELM1. If '2' is input then this will correspond to the structure defined in Data Category ELM2, etc. Note that this multiplying factor relates to slam coefficient for the structure specified on this data record only.

(2) This value is the multiplying factor for all slam coefficients for MORISON elements on the structure specified (1).

Effect of the Multiplying Factor on Slam Coefficients

If this data record is not input, the default multiplying factor of zero, is assumed by the program. This means that all the slam forces, which only exist for Morison elements, are automatically zero.

The effect of a non-zero multiplying factor is primarily to bring the slam forces into effect, i.e. the values of the slam coefficients for each element are simply multiplied by this factor.

Slam Coefficients and the Time-Step

The value of the slam coefficient, for each element, is based on the premise that the slam force is equal to the rate of change of the added mass tensor (with time) multiplied by the velocity.

This means that the time-step (specified in Data Category 16) must be sufficiently small to accurately represent the added mass at each stage of immersion/emergence. In general this will depend on the geometry of each element and its orientation to the water surface.

In practice, this severe restriction of the size of the time-step means that this facility is only used when specifically investigating the effects of slam forces on individual elements during critical stages of the simulation period, as the momentum change due to slam forces are normally small and have little effect on the overall motion of the structure.

Chapter 27: Additional File Output - PROP (Data Category 18)

27.1. General Description

This Data Category is used to input requests for additional listing file output where specific information is required to define its extent and format. It is supplementary to the output obtained from the general printing requests of the Options List in the Preliminary Data Category, as the requests in this Data Category are necessarily more detailed. The requests for additional output fall into the following main categories.

Output of Nodal Positions/Motions

This output is related to positions and/or motions of nodes on a structure which are of particular interest to the user (e.g. a helicopter deck, mooring line attachment points, or crane tip). Additional information at these positions (a maximum of 35) is obtained by simply specifying the node number (see Geometric Properties - GEOM (Data Category 4) (p. 95)) of those nodes in this data category. The difference between the positions/motions on two different structures or a structure and any fixed node may also be obtained.

Output of Positions/Motions and Forces at the CG

This gives more information about the positions/motions and the individual forces in the equations governing the position of the center of gravity of a structure at any stage in the analysis.

Please note that the program will output default information essential to the analysis automatically. This facility is available in order that the user may request additional information to:

- Simply clarify results obtained
- Obtain a deeper understanding of the results
- Find out reasons for unexpected results
- Detect errors in the modeling

The user should be aware of the information applicable to a particular analysis, as (Introduction (p. 17)) explains this in detail. However, the user can request all information to be output, and no errors will occur if a request is encountered for information which is not available for the particular analysis. In the event that the information requested is not available, the program will inform the user but will not produce an error message.

Note:

This data category is optional. Enter NONE if no additional information is required.

27.2. Data Category Header

```
       5      11
 ---- -- ---- ----
|XXXX|  |XXXX|PROP|
 ---- -- ---- ----
      |        |
      |        |_Compulsory Data Category Keyword(A4)
      |
      |_Optional User Identifier(A2)
```

27.3. The NODE Data Record - Nodal Position for Listing File Output

Maximum of the total number of NODE data records that may be input is 200.

```
   2   5  7   11    16    21    26
 - --- -- ---- ----- ----- ----- -----
|X|   |  |NODE|     |     |     |     |
 - --- -- ---- ----- ----- ----- -----
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |_(4) Node Number (I5)
    |  |   |     |     |     |
    |  |   |     |     |     |_(3) Structure Number (I5)
    |  |   |     |     |
    |  |   |     |     |_(2) Node Number (I5)
    |  |   |     |
    |  |   |     |_(1) Structure Number (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2. If '1' is input then this will correspond to the structure defined in Data Category ELM1. If '2' is input then this will correspond to the structure defined in Data Category ELM2, etc. As the NODE data record is a request for output of the position/motion of the node number specified (2), structure number '0' (i.e. a fixed node) is illegal in this field and will produce an error, since zero structure indicates a fixed node.

(2) This is the node number whose position/motions are requested during the analysis. The position of this node on the structure (1) must be defined in Data Category 1.

Note that these motions are with respect to the position defined by (3) and (4).

(3)-(4) This structure number and its corresponding node number (4) define the reference point for the positions/motions defined by parameters (1) and (2).

Both these fields may be left blank, in which case the program will assume that the output at the position defined by (1) and (2) is with respect to the origin of the Fixed Reference Axes, i.e. the ABSOLUTE values.

If '0' is input as the structure number (3), together with a node number (4), the program will recognize that this node number (4) references the fixed position as defined in Data Category 1 in the Fixed Reference Axis System (FRA). Note that a non-zero structure number (3) must be followed by a valid node number (4) on that structure.

Information Output at Nodal Positions

The input of the NODE data record is designed to enable the user to request the positions/motions of any point on a structure with respect to any other point, whether on a structure or fixed in space (i.e. the difference between the positions/motions of two points). For each NODE data record, the program outputs the results described below. In the following table, Node 1 refers to the structure/node defined in fields (1) and (2) above, and Node 2 refers to the structure/node defined in fields (3) and (4).

Solver	Output
Aqwa-Line	The RAOs of Node 1. Note that: a. Aqwa-Line must be run for stages 1 to 5. b. The NRNM (p. 319) option must be used. c. It is not possible to obtain motions relative to Node 2.
Aqwa-Librium	The positions of Node 1 relative to Node 2 at each static equilibrium position found.
Aqwa-Drift, Aqwa-Naut	The positions of Node 1 relative to Node 2 at each step in the time history. If the ALLM (p. 289) data record is also used, the velocities and accelerations of Node 1 relative to Node 2 at each time step are also reported.
Aqwa-Fer	The RAOs and significant motions of Node 1 relative to Node 2.

27.4. The ALLM Data Record - All Motions

```
     2   5  7    11 13
   - --- -- ---- -- ----
  |X|   |  |ALLM|  |ACEF|
   - --- -- ---- -- ----
      |  |   |       |
      |  |   |       |_(1)Nodal Effective Acceleration(A4)
      |  |   |
      |  |   |_Compulsory Data Record Keyword(A4)
      |  |
      |  |_Optional User Identifier(A2)
      |
      |_Compulsory END on last data record in Data Category(A3)
```

The ALLM data record enables the user to expand or limit the information output associated with the positions on the NODE data record. The default information, at these positions specified (where the output format is freedom dependent), is displacement only in the X, Y, and Z translational freedoms. Input of this data record, which is optional, has the following effect:

ALLM expands the output associated with the positions specified on all NODE data records to include velocity and acceleration as well as displacement. When this information is not available this data record has no function and is ignored.

(1) This field is an option. It calculates the significant value of the nodal effective acceleration in Aqwa-Fer. The significant values of the nodal effective accelerations at the positions, which are specified on all NODE data records not relative to another node nor wave surface, will be output.

27.5. The PCGP Data Record - Print Center of Gravity Parameters

Please note that this optional facility has not yet been implemented.

```
     2   5  7   11
   - --- -- ---- ----- ----- ----- ----- ----- ----- --
  |X|   |  |PCGP|     |XXXXX|     |     |     |     |  ...
   - --- -- ---- ----- ----- ----- ----- ----- ----- --
      |  |   |     |           |     |     |     |     |
      |  |   |     |           |--------------------------
      |  |   |     |           |
      |  |   |     |           |_(2) Up to 12 Parameter Numbers (12I5)
      |  |   |     |
      |  |   |     |_(1) Structure Number (I5)
      |  |   |
      |  |   |_Compulsory Data Record Keyword (A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2. If '1' is input, this will correspond to the structure defined in Data Category ELM1. If '2' is input this will correspond to the structure defined in Data Category ELM2 etc.

(2) Not yet implemented.

Information Output at Center of Gravity

A general classification of additional information available for output by each program is as follows:

Aqwa-Drift: The position/velocity/acceleration and each individual force in the equation of motion at each step in the time-history.

Aqwa-Fer: Wave spectrum values, force spectrum values and their significant values.

Aqwa-Librium: The individual forces acting on the structure at each equilibrium position found (static equilibrium). Tabulated values of dynamic stability boundaries (dynamic stability).

Aqwa-Naut: The position/velocity/acceleration and each individual force in the equation of motion at each step in the time-history.

27.6. The PREV Data Record - Print Every nth Timestep

```
     2   5  7   11
   - --- -- ---- -----
  |X|   |  |PREV|     |
   - --- -- ---- -----
```

```
        |  |   |     |
        |  |   |     |_(1)Timestep increment(I5)
        |  |   |
        |  |   |_Compulsory Data Record Keyword(A4)
        |  |
        |  |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The timestep increment determines how often the full printout of positions and forces is printed to the output listing file. For example, if the timestep increment was five then the printout would contain information on each structure at timesteps 1,6,11,16 etc. This facility can be used to limit the size of the printout to a manageable size for long simulations.

Note that recording of positions and forces in the graphics file is independent of the parameter on this data record. See the GREV (p. 297) data record for more information.

27.7. The PRNT/NOPR Data Record - Print/No Print Parameters Values

These data records are used to change the list of variables to be output on the listing file and on backing file for graphics post processing. Note that they are not applicable to Aqwa-Line and Aqwa-Fer. The default selection of parameters to be printed for all possible types of Aqwa-Drift/Librium/Naut analysis is shown in the table below.

```
     2   5  7    11
     - --- -- ---- ----- ----- -----
    |X|   |  |PRNT|     |     |     |
     - --- -- ---- ----- ----- -----
    |X|   |  |NOPR|     |     |     |
     - --- -- ---- ----- ----- -----
        |  |   |     |     |     |
        |  |   |     |     |     |_(4) Articulation Number (I5)
        |  |   |     |     |
        |  |   |     |     |_(3) Parameter Number (I5)
        |  |   |     |
        |  |   |     |_(2) Structure Number (I5)
        |  |   |
        |  |   |_(1)Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) PRNT causes the specified parameter to be added to the list of output. NOPR causes it to be removed from the list.

(2) The structure number must correspond to one of the structures defined in Data Category 2. If '1' is input, this will correspond to the structure defined in Data Category ELM1. If '2' is input, this will correspond to the structure defined in Data Category ELM2, etc. If the structure number is omitted, the specified parameters are output (PRNT) or omitted (NOPR) for all structures.

(3) The parameter number refers to a type of output as shown in the list below. If the parameter number is omitted all the parameters for the specified structure will be output (PRNT) or omitted (NOPR).

(4) For articulation reactions, the 3rd number on the data record is the number of the articulation (1-50) for which reactions are required.

The FROUDE-KRYLOV and DIFFRACTION forces are sub-divided differently for Aqwa-Drift and Naut, as shown in the table below.

PARAMETER (#)	Aqwa-DRIFT	Aqwa-NAUT
DIFFRACTION (16)	Radiation force if no convolution, diffraction and Froude-Krylov force on diffracting panels	Diffraction force on diffracting panels
FROUDE-KRYLOV (20)	Froude-Krylov force on Morison elements only	Froude-Krylov force on all elements
WAVE INERTIA (23)	Diffraction force on Morison elements	Diffraction force on Morison elements

```
 -----------------------------------------------------------------------------
| FULL LIST OF AVAILABLE   | Aqwa-DRIFT DEFAULT FOR  | Aqwa-DRIFT DEFAULT FOR  |
|    PARAMETERS            |  DRIFT MOTION ONLY      | PLUS W/FREQUENCY MOTION |
|--------------------------|-------------------------|-------------------------|
| 1. POSITION              | 1. POSITION             | 1. POSITION             |
| 2. VELOCITY              | 2. VELOCITY             | 2. VELOCITY             |
| 3. ACCELERATION          | 3. ACCELERATION         | 3. ACCELERATION         |
| 4. RAO BASED POSITION    |                         | 4. RAO BASED POSITION   |
| 5. RAO BASED VELOCITY    |                         | 5. RAO BASED VELOCITY   |
| 6. RAO BASED ACCEL       |                         |                         |
| 7. WAVE FREQ POSITION    |                         | 7. WAVE FREQ POSITION   |
| 8. WAVE FREQ VELOCITY    |                         | 8. WAVE FREQ VELOCITY   |
| 9. WAVE FREQ ACCEL       |                         | 9. WAVE FREQ ACCEL      |
|10. SLOW POSITION         |                         |10. SLOW POSITION        |
|11. SLOW VELOCITY         |                         |11. SLOW VELOCITY        |
|12. SLOW ACCEL            |                         |12. SLOW ACCEL           |
|13. SLOW YAW              |                         |                         |
|14. MOORING               |14. MOORING              |14. MOORING              |
|15. GYROSCOPIC            |                         |                         |
|16. DIFFRACTION           |                         |16. DIFFRACTION          |
|17. LINEAR DAMPING        |17. LINEAR DAMPING       |17. LINEAR DAMPING       |
|18. MORISON DRAG          |                         |                         |
|19. DRIFT                 |19. DRIFT                |19. DRIFT                |
|20. FROUDE KRYLOV         |                         |     SEE NOTE ABOVE      |
|21. GRAVITY               |21. GRAVITY              |21. GRAVITY              |
|22. CURRENT DRAG          |22. CURRENT DRAG         |22. CURRENT DRAG         |
|23. WAVE INERTIA          |                         |                         |
|24. HYDROSTATIC           |24. HYDROSTATIC          |24. HYDROSTATIC          |
|25. WIND                  |25. WIND                 |25. WIND                 |
|26. SLAM                  |                         |                         |
|27. THRUSTER              |27. THRUSTER             |27. THRUSTER             |
|28. YAW DRAG              |28. YAW DRAG             |28. YAW DRAG             |
|29. SLENDER BODY FORCES   |                         |                         |
|30. ERROR PER TIMESTEP    |30. ERROR PER TIMESTEP   |30. ERROR PER TIMESTEP   |
|31. TOTAL REACTION FORCE  |31. TOTAL REACTION FORCE |31. TOTAL REACTION FORCE |
|33. L/WAVE DRIFT DAMPING  |33. L/WAVE DRIFT DAMPING |33. L/WAVE DRIFT DAMPING |
|34. EXTERNAL FORCE        |                         |                         |
|35. RADIATION FORCE       |      DEFAULT WITH CONV OPTION, ZERO WITHOUT       |
|36. FLUID MOMENTUM        |                         |                         |
|38. FLUID GYROSCOPIC FORCE|                         |                         |
|39. ADD STRUCT STIFF FORCE|                         |                         |
|40. ROLL DRAG FORCE       |                         |                         |
|47. ARTICULATION REACTION |                    SEE (3) ABOVE                  |
|50. TOTAL FORCE           |50. TOTAL FORCE          |50. TOTAL FORCE          |
 -----------------------------------------------------------------------------


 -----------------------------------------------------------------------------
| FULL LIST OF AVAILABLE   |  Aqwa-LIBRIUM DEFAULTS  | Aqwa-NAUT DEFAULTS      |
|    PARAMETERS            |                         |                         |
|--------------------------|-------------------------|-------------------------|
| 1. POSITION              | 1. POSITION             | 1. POSITION             |
| 2. VELOCITY              |                         | 2. VELOCITY             |
```

```
 | 3. ACCELERATION         |                          | 3. ACCELERATION        |
 | 4. RAO BASED POSITION   |                          | 4. RAO BASED POSITION  |
 | 5. RAO BASED VELOCITY   |                          | 5. RAO BASED VELOCITY  |
 | 6. RAO BASED ACCEL      |                          |                        |
 | 7. WAVE FREQ POSITION   |                          |                        |
 | 8. WAVE FREQ VELOCITY   |                          |                        |
 | 9. WAVE FREQ ACCEL      |                          |                        |
 |10. SLOW POSITION        |                          |                        |
 |11. SLOW VELOCITY        |                          |                        |
 |12. SLOW ACCEL           |                          |                        |
 |13. SLOW YAW             |                          |                        |
 |14. MOORING              |14. MOORING               |14. MOORING             |
 |15. GYROSCOPIC           |                          |                        |
 |16. DIFFRACTION          |                          |16. DIFFRACTION         |
 |17. LINEAR DAMPING       |                          |17. LINEAR DAMPING      |
 |18. MORISON DRAG         |                          |18. MORISON DRAG        |
 |19. DRIFT                |19. DRIFT                 |                        |
 |20. FROUDE KRYLOV        |                          |20. FROUDE-KRYLOV       |
 |21. GRAVITY              |21. GRAVITY               |21. GRAVITY             |
 |22. CURRENT DRAG         |22. CURRENT DRAG          |22. CURRENT DRAG        |
 |23. WAVE INERTIA         |                          |                        |
 |24. HYDROSTATIC          |24. HYDROSTATIC           |24. HYDROSTATIC         |
 |25. WIND                 |25. WIND                  |25. WIND                |
 |26. SLAM                 |                          |                        |
 |27. THRUSTER             |27. THRUSTER              |                        |
 |28. YAW DRAG             |                          |                        |
 |29. SLENDER BODY FORCES  |                          |                        |
 |30. ERROR PER TIMESTEP   |                          |30. ERROR PER TIMESTEP  |
 |31. TOTAL REACTION FORCE |                          |31. TOTAL REACTION FORCE|
 |34. EXTERNAL FORCE       |                          |                        |
 |35. RADIATION FORCE      |                          |                        |
 |36. FLUID MOMENTUM       |                          |                        |
 |38. FLUID GYROSCOPIC FORCE|                         |                        |
 |39. ADD STRUCT STIFF FORCE|                         |                        |
 |40. ROLL DRAG FORCE      |                          |                        |
 |41. MANEUVERING FORCE    |                          |                        |
 |47. ARTICULATION REACTION |                    SEE (3) ABOVE                 |
 |50. TOTAL FORCE          |50. TOTAL FORCE           |50. TOTAL FORCE         |
  ------------------------------------------------------------------------------
```

This is the full list of output parameters for Aqwa-Librium, Drift and Naut. Further output can be requested using additional data records in Data Category 18.

27.8. The PTEN Data Record - Print Cable Tensions/Tether Forces

```
      2   5  7   11
    - --- -- ---- -----
   |X|   |  |PTEN|     |
    - --- -- ---- -----
       |  |   |     |
       |  |   |     |_(1) Structure Number (I5)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number indicates that the tensions in all cables, catenaries, hawsers, and tethers attached to this defined structure are to be printed in the listing file (how often is governed by the PREV data record) and written to backing file for plotting in the AGS. If the structure number is omitted, mooring tensions are output for all structures.

27.9. The WPON/WPOF Data Records - Print Wave Parameters ON/OFF

The WPON and WPOF data records are used instead of ZRWS/ZRON/ZROF to output incident or disturbed wave height at a node. These data records are only applicable to time domain analyses which include wave frequency motions. The disturbed wave height output is only available for Aqwa-Naut. If the ALLM (p. 289) data record is present, the vertical velocity and acceleration of incident waves are also output.

These data records are input before/after the particular NODE data records which then have a slightly different configuration, as described below:

```
    2   5  7   11         21
  - --- -- ---- ----- ----- ----------
 |X|   |  |WPON|     |     |
  - --- -- ---- ----- ----- ----------
    |  |   |     |     |    |
    |  |   |     |     |    |_(3)(Optional) Filename from which
    |  |   |     |     |          the .PAG database is imported
    |  |   |     |     |
    |  |   |     |     |_(2)(optional) Structure Sequence Number in .PAG file (I5)
    |  |   |     |
    |  |   |     |_(1)(Optional) Structure Sequence Number in current analysis (I5)
    |  |   |
    |  |   |_WPON keyword
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record (A3)
```

```
    2   5  7   11
  - --- -- ---- -----
 |X|   |  |WPOF|
  - --- -- ---- -----
    |  |   |
    |  |   |
    |  |   |_ WPOF keyword
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record (A3)
```

(1), (2), and (3) parameter inputs of the WPON data record are used to define the disturbed wave height output. (1) and (2) work together to decide the structure that outputs the disturbed wave height at the nodes associated with it. If (3) is given but (1) and (2) are not given, the disturbed wave height results are output for all the nodes defined in the following NODE data records:

(1) This structure number corresponds to one of the structures defined in Element Topology - ELM* (Data Category 2) (p. 67). If it is not input or input as '0', the structure number defined in (2) is ignored as well.

(2) It is the structure sequence number in the .PAG file which corresponds to the current structure sequence number defined in (1). It is only required when (1) is input and not input as '0'.

(3) The file name with the .PAG extension imports the database of pressure at the mean free surface grids, which is used to calculate and output the disturbed wave height. If it is not input, the incident wave height is output for the nodes defined in the following NODE data records.

Note:

When the structure sequence number in the current analysis (1) is not defined for the disturbed wave height output, the total number of structures in the .PAG file must be the same as that of the current analysis model.

Note:

WPON and WPOF act as switches during the input of the NODE data records and have the function of switching the wave parameters option ON and OFF.

The NODE Data Record when WPON is Active

```
   2   5  7   11    16    21    26
 - --- -- ---- ----- ----- ----- -----
|X|   |  |NODE|     |     |     |     |
 - --- -- ---- ----- ----- ----- -----
    |  |   |     |     |     |     |
    |  |   |     |     |     |     |_(4) Node Number (I5)
    |  |   |     |     |     |
    |  |   |     |     |     |_(3) Structure Number (I5)
    |  |   |     |     |
    |  |   |     |     |_(2) Node Number (I5)
    |  |   |     |
    |  |   |     |_(1) Structure Number (I5)
    |  |   |
    |  |   |_Compulsory Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record (A3)
```

(1) This structure number must correspond to one of the structures defined in Element Topology - ELM* (Data Category 2) (p. 67). Structure number 0 (a fixed node) is illegal in this field.

(2) This is the node number at which output of the wave parameters is requested. The position of this node on the structure (1) must be defined in Node Number and Coordinates (Data Category 1) (p. 59).

(3)-(4) These fields are optional. They are used to specify that the node defined in (1) and (2) is fixed. If used, the structure number must be 0 and the node number (4) must be the same as node (2).

27.10. The ZRON/ZROF Data Records - Print Z Coordinate Relative to Wave Surface ON/OFF

The ZRON and ZROF data records enable the user to output the position of one or more nodes relative to the undiffracted wave surface, with all other nodes output as normal values. The data record has no parameters and consists only of the data record keyword, for example:

```
    2  5  7   11
  - --- -- ----
 |X|   |  |ZRON|
  - --- -- ----
     |  |   |
     |  |   |
     |  |   |
     |  |   |_ZRON or ZROF Data Record Keyword
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

Note:

- The ZRON and ZROF data records act as switches during the input of the NODE data records and have the function of switching the Z relative to the wave surface option on and off.
- The ZRWS data record is global, and may be input anywhere in Data Category 18, these data records therefore replace the existing ZRWS data record when only some nodes with Z relative to the wave surface are required. The use of the ZRWS data record with either the ZRON or ZROF will cause an error.
- The simplest usage would be input all nodes which are NOT required to be output with Z relative to the wave surface and then to use the ZRON data record before inputting the remainder of the nodes which are required to have Z relative to the wave surface.

27.11. The ZRWS Data Record - Print Z Coordinate Relative to Wave Surface

This data record is used to output the relative vertical distance from the undiffracted wave surface to a node defined in a NODE data record. All nodes defined in NODE data records in Data Category 18 will be affected except those for relative distances between two nodes.

```
    2  5   7   11
  - --- -- ----
 |X|   |  |ZRWS|
  - --- -- ----
     |  |   |
     |  |   |
     |  |   |
     |  |   |_Data Record Keyword (A4)
     |  |
     |  |_Optional User Identifier (A2)
     |
     |_Compulsory END on last data record in Data Category (A3)
```

27.12. The PPRV Data Record - Print POS/DCP Every nth Timestep

```
    2   5  7   11
  - --- -- ---- -----
 |X|   |  |PPRV|     |
  - --- -- ---- -----
     |  |   |     |
     |  |   |     |_(1)Timestep increment(I5)
     |  |   |
```

```
        |   |   |_Compulsory Data Record Keyword(A4)
        |   |
        |   |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The timestep increment determines how often the program will print positions, velocities, dynamic cable properties, etc., to the output `*.POS` and `*.DCP` files. For example, if the timestep increment was five then the printout would contain information on each structure/cable at timesteps 1,6,11,16, etc.

This facility can be used to limit the number of position/velocity output within the given period of time, which is particularly useful in creating an animation (sequence file) without having to have one picture for each time step.

27.13. The GREV Data Record - Graphics Output Every nth Timestep

```
     2   5  7   11
   - --- -- ---- -----
  |X|   |  |GREV|     |
   - --- -- ---- -----
        |   |   |     |
        |   |   |     |_(1)Timestep increment(I5)
        |   |   |
        |   |   |_Compulsory Data Record Keyword(A4)
        |   |
        |   |_Optional User Identifier(A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The timestep increment determines how often the full graphics and plotting results are output. For example, if the timestep increment was five then the backing files would contain information on each structure at timesteps 1,6,11,16 etc.

This facility can be used to limit the size of the printout to a manageable size for long simulations.

27.14. The PRMD Data Record - Print Mooring Drag

This data record causes the drag force on all tethers and dynamic mooring lines to be printed to the listing file, for cable dynamics analyses in Aqwa-Librium, Drift and Naut.

In Drift and Naut the frequency of printing is governed by the PREV data record.

In Librium the PBIS option is also required.

```
     2   5  7   11
   - --- -- ---- -----
  |X|   |  |PRMD|     |
   - --- -- ---- -----
        |   |   |
        |   |   |
        |   |   |
        |   |   |_Compulsory Data Record Keyword (A4)
        |   |
        |   |_Optional User Identifier (A2)
```

```
        |
        |_Compulsory END on last data record in Data Category (A3)
```

27.15. The PMST Data Record - Print Mooring Section Tensions

This data record causes the tensions between sections of dynamic mooring lines and tether forces/moments to be output. The frequency of printing is defined by the PREV (The PREV Data Record - Print Every nth Timestep (p. 290)) and GREV (The GREV Data Record - Graphics Output Every nth Timestep (p. 297)) data records respectively. This is only applicable to cable dynamics analyses. The behavior for each program is as follows:

Aqwa-Librium: Written to `.LIS` file only. The PBIS option (Printing Options for Output of Calculated Parameters (p. 311)) must also be used.

Aqwa-Fer: Significant tensions written to `.LIS` file only. If the PRTS option (Printing Options for Output of Calculated Parameters (p. 311)) is also used, response spectra will also be printed. Tethers are not allowed in Aqwa-Fer.

Aqwa-Drift and Naut: Written to `.LIS` and `.PLT` files.

```
       2   5  7   11
     - --- -- ---- -----
    |X|   |  |PMST|     |
     - --- -- ---- -----
        |  |   |
        |  |   |
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

27.16. The SSPC Data Record - Print Sub-Spectrum Response

This printing option is applicable in Aqwa-Fer only.

This data record causes the RAOs and transfer function matrix for a specified sub-spectrum to be output in the .LIS and .PLT files as appropriate. The default is that the main sub-spectrum is used. The main sub-spectrum is the one that has the highest significant wave height.

```
       2   5  7   11
     - --- -- ---- -----
    |X|   |  |SSPC|     |
     - --- -- ---- -----
        |  |   |      |
        |  |   |      |_(1) Sub-Spectrum number (I5)
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) If this number is '0', blank or a number greater than the number of spectra in the group, the main sub-spectrum number of each wave spectral group is used.

27.17. Tether Additional Data Requirements

This section describes the additional data requirements for the printing, graphics, and statistics post-processing of tether elements for Aqwa-Librium, Aqwa-Drift and Aqwa-Naut (not valid in Aqwa-Fer).

For a full description of Data Category 18, see Additional File Output - PROP (Data Category 18) (p. 287).

27.17.1. The TPRV Data Record - Tether Printing Interval

```
   2   5  7   11
 - --- -- ---- -----
|X|   |  |TPRV|     |
 - --- -- ---- -----
    |  |   |     |
    |  |   |     |_(1) Number of steps (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1) Enter a non-zero integer 'N' where listing file time history output for tethers is required every 'N' timestep.

27.17.2. The TGRV Data Record - Tether Graphics/Statistics Interval

```
   2   5  7   11
 - --- -- ---- -----
|X|   |  |TGRV|     |
 - --- -- ---- -----
    |  |   |     |
    |  |   |     |_(1) Number of steps (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1) Enter a non-zero integer 'N' where graphics output and statistics post-processing for tethers is required every 'N' timesteps.

27.17.3. The TSTS/TSTF Data Record - Tether Start/Finish Timesteps for Statistics

Input for Aqwa-Drift only.

If these data records are not input tether statistics post-processing will be on all records specified by the TGRV Data Record.

```
   2   5  7   11
 - --- -- ---- -----
|X|   |  |TSTS|     |
 - --- -- ---- -----
```

```
|X|   |  |TSTF|     |
 - --- -- ---- -----
    |  |   |     |
    |  |   |     |_(1) Start/Finish Timestep (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1) Enter the timestep at which the tether statistics post processing should start (Default =1) on the TSTS data record and the timestep at which the tether statistics post processing should finish (Default = last step) on the TSTF data record.

27.17.4. The PTRT Data Record - Print Tether Nodal/Element Responses

```
   2   5  7        16
 - --- -- ---- ---- ----
|X|   |  |PTRT|XXXX|    |
 - --- -- ---- ---- ----
    |  |   |         |
    |  |   |         |_(1) Tether Number (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1) The tether number designates the nodal motions, nodal/element force response along the defined tether to be printed in the listing file and written to the backing file for plotting in AGS. If the tether number is omitted, the results are output for all tethers.

Note:

It is recommended to avoid using this data record for limiting the size of the graphic files with the extension names, .PLT and .PLD. The relevant tether data are stored in the .TET file and can be accessed by AqwaReader.exe. See AqwaReader Manual for more information.

27.17.5. The PTST Data Record - Print Statistics for Tether Nodal/Element Responses

```
   2   5  7       16
 - --- -- ---- ---- ----
|X|   |  |PTST|XXXX|    |
 - --- -- ---- ---- ----
    |  |   |         |
    |  |   |         |_(1) Tether Number (I5)
    |  |   |
    |  |   |_Compulsory Data Record Keyword (A4)
    |  |
    |  |_Optional User Identifier (A2)
    |
    |_Compulsory END on last data record in data category (A3)
```

(1) The tether number designates statistic results of nodal motions, nodal/element force response along the defined tether to be printed in the listing file for Aqwa-Drift only. If the tether number is omitted, the results are output for all tethers.

Note:

This data record will be ignored if The PTRT Data Record - Print Tether Nodal/Element Responses (p. 300) is not defined.

27.18. The PRES Data Record – Element Load Output

The PRES data record specifies the structure for which the hydrodynamic pressure/load on elements are calculated and output. This data record is only valid in Aqwa-Naut analysis.

When this card is defined, the program makes the following assumptions:

- The convolution approach is used to estimate the radiation pressure components on the diffraction panels.
- The LHFR option is previously defined in the Aqwa-Line analysis from which the hydrodynamic database is imported.
- The hydrostatic and incident wave components are calculated under the instantaneous incident wave surface.

```
     2   5  7   11          21
   - --- -- ---- ----- ----- ----------
  |X|   |  |PRES|     |     |
   - --- -- ---- ----- ----- ----------
      |  |   |     |          |
      |  |   |     |          |_Filename (no extension) from which the .PAC etc
      |  |   |     |            database is imported
      |  |   |     |
      |  |   |     |_(1) Structure Number (I5)
      |  |   |
      |  |   |_Compulsory Data Record Keyword (A4)
      |  |
      |  |_Optional User Identifier (A2)
      |
      |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2. If '2' is input, this will correspond to the structure and its associated internal tanks defined in Data Category ELM2. If '0' is input, this will correspond to all the structures (including all internal tanks) defined in this analysis model. Element load output is valid for the structure(s) consisting of panels and Morison elements. It is skipped automatically for a structure that has the point mass element(s) only.

27.19. The PRTD Data Record - Pressure Output Duration

The PRTD data record defines the time duration and time step interval for outputting the hydrodynamic pressures/loads on elements. This data record is only valid in Aqwa-Naut analysis.

```
     2   5  7   11          21         31         41
   - --- -- ---- ---------- ---------- ----------
  |X|   |  |PRTD|          |          |          |
```

```
     - --- -- ---- ---------- ---------- ----------
        |  |   |       |                       |
        |  |   |       |                       |_(3) Output Load on Element Every Nth Timestep (I10)
        |  |   |       |          |
        |  |   |       |          |_(2) Finishing Time Step Number (I10)
        |  |   |       |
        |  |   |       |_(1) Starting Time Step Number (I10)
        |  |   |
        |  |   |_Compulsory Data Record Keyword (A4)
        |  |
```

(1) Default value is 1 if it is not defined or not positive.

(2) Default value is the number of the total time steps defined in Data Category 16: Time Integration Parameters – TINT.

(3) Default value is 1 if it is not defined or not positive.

Chapter 28: Element and Nodal Loads - ENLD (Data Category 21)

28.1. General Description

This data category is used to input the request for output of loads on Morison elements. At present, this is only available for TUBE elements in Aqwa-Drift and Aqwa.

The loads are output in the form of loads at the nodes joining each element. The user should input "RESTART 6 6" on the RESTART data record in Data Category 0. The *.RES file and *.POS file from a preceeding Drift or Naut run (stages 4 to 5) should be copied before this run can be performed.

There are two basic forms of nodal load output. The first is for space frames where all elements are assumed encastre-encastre and more than two elements can be joined at a single node. The second is for riser-type structures, where riser geometry is assumed and, by definition, only two tube elements can join at a node. In addition, there are rules concerning the element description, which the user must be aware of in order to obtain the correct riser-type format (see The RISR Data Record - Nodal Load Output for a Riser Structure (p. 304)).

You should note that the post-processing Stage 6 graphics output overwrites any previous graphics output. This means that if you wish to keep the output from Stage 5, then Stage 6 post-processing must be carried out as a separate run.

28.2. Data Category Header

```
          5      11
     ---- -- ---- ----
    |XXXX|  |XXXX|ENLD|
     ---- -- ---- ----
          |        |
          |        |_Compulsory Data Category Keyword (A4)
          |
          |_Optional User Identifier (A2)
```

28.3. The ISEL and LSEL Data Records - Element/Nodal Load Record Selection

These two data records perform the same function, however the LSEL data record allows input of timestep numbers with more than 5 digits.

```
      2   5  7   11    16
    - --- -- ---- ----- -----
   |X|   |  |ISEL|     |     |
    - --- -- ---- ----- -----
       |  |   |     |     |
```

```
       |  |   |     |     |
       |  |   |     |     |
       |  |   |     |     |_(2) Terminal Record for output (I5)
       |  |   |     |
       |  |   |     |_(1) Initial Record for output (I5)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on last data record in Data Category (A3)


      2   5  7   11          21
    - --- -- ---- ---------- ----------
   |X|   |  |LSEL|          |          |
    - --- -- ---- ---------- ----------
       |  |   |        |          |
       |  |   |        |          |
       |  |   |        |          |
       |  |   |        |          |_(2) Terminal Record for output (I10)
       |  |   |        |
       |  |   |        |_(1) Initial Record for output (I10)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
       |  |_Optional User Identifier (A2)
       |
       |_Compulsory END on last data record in Data Category (A3)
```

(1) The initial record is the first record (starting time step number) that the user wishes to include in the output and statistical post-processing of the nodal loads.

(2) The terminal record is the last record (finishing time step number) that the user wishes to include in the output and statistical post-processing of the nodal loads. Thus the total number of records for post-pressing is Terminal-Initial+1.

28.4. The RISR Data Record - Nodal Load Output for a Riser Structure

The riser data record specifies that inter-element forces are to be calculated assuming that a riser-type structure has been defined.

When this card is input, the program makes the following assumptions:

- Only tube elements are used to describe the riser in Data Category 2.
- The first node of the first tube describing the riser is the node at the seabed end. The first node of all the other elements must be the second node of the previous element.
- If there is a connection to a fixed point this must be at the seabed end of the riser.

```
      2   5  7   11
    - --- -- ---- -----
   |X|   |  |RISR|     |
    - --- -- ---- -----
       |  |   |     |
       |  |   |     |
       |  |   |     |
       |  |   |     |_(1) Structure Number (I5)
       |  |   |
       |  |   |_Compulsory Data Record Keyword (A4)
       |  |
```

```
        |  |_Optional User Identifier (A2)
        |
        |_Compulsory END on last data record in Data Category (A3)
```

(1) The structure number must correspond to one of the structures defined in Data Category 2. If '1' is input, this will correspond to the structure defined in Data Category ELM1. If '2' is input, this will correspond to the structure defined in Data Category ELM2, etc.

28.5. The TUBE Local Axes

The local axes used for output of element loads from Stage 6 are defined as follows:

Local X-axis - along the TUBE axis from Node #1 to Node #2

Local Y-axis - perpendicular to the local X-axis, in the global XY plane

Local Z-axis - orthogonal to the local X- and Y-axes with vertical component in the positive global Z-direction

For the special case of a vertical tube:

Local X-axis - along the TUBE axis from Node #1 to Node #2

Local Y-axis - forms a right-handed set with local X- and Z-axes

Local Z-axis - in the negative global X-direction

The local axis vectors are output in the `.LIS` file.

Chapter 29: Options for Use in Running Aqwa Programs

There are 3 types of options that can be used to control an Aqwa analysis.

- Command line options. These can be used when running from a command prompt.
- Job options. These are input on the JOB data record and control the type of analysis carried out.
- Program options. These are input on the OPTIONS data record in the preliminary data category.

29.1. Command Line Options

Command line options can be specified on the command line when running Aqwa from a command prompt on Windows or Linux.

Windows

Options are preceded by a forward slash; for example:

```
C:\Program Files\ANSYS Inc\v251\aqwa\bin\<platform>\aqwa.exe /nowind altest
```

would run the data file `ALTEST.DAT` using the option NOWIND.

At present there are only two command line options available.

/NOWIND - No Windows

This option automatically closes all windows that may be opened during a run. This means that no response is required from the user at the end of a run.

/STD - Use Command File

This option instructs Aqwa to accept commands from an Aqwa command file. For compatibility with previous versions of Aqwa this option (only) may be entered without the leading forward slash.

Linux

When running on Linux, no command line options are needed. To run Aqwa from the command line on Linux, run the script `aqwa.sh`; for example:

```
/<installation_directory>/ansys_inc/v251/aqwa/bin/<platform>/aqwa.sh ALTEST
```

Note:

Installing in /usr or /opt if you have root rights is recommended.

The launcher script is Bourne shell compliant.

The script sets up several environment variables including:

- LD_LIBRARY_PATH, which allows you to specify the directory where your compiled user force library is stored, in addition to any other dynamic libraries required by Aqwa. Details on the path set for these libraries can be found in the launching script `aqwa.sh`.
- AQWA_STACKLIMIT (p. 28), which allows you to set the maximum size of your stack.

29.2. Job Type Options

Each program has more than one type of possible analysis. These options are used on the JOB data record to indicate which type is required. If no option is input then the default analysis type will be used. These defaults and the optional analysis types are listed below. See also the JOB data record (The JOB Data Record (p. 53)).

Aqwa-Drift Default - Drift frequency motions only

Option 1 - WFRQ - Drift frequency and wave frequency motions

Aqwa-Fer Default - Drift frequency and wave frequency motions

Option 1 - DRFT - Drift frequency motions only

Option 2 - WFRQ - Wave frequency motions only

Aqwa-Line Default - Radiation/Diffraction analysis

Option 1 - FIXD - All structures fixed

Aqwa-Librium Default - Static and dynamic stability

Option 1 - STAT - Static stability only

Option 2 - DYNA - Dynamic stability only

Aqwa-Naut Default - Time history regular wave response

Option 1 - IRRE - Time history analysis in irregular waves. This applies to both diffracting structures (when convolution (p. 314) is used) and Morison structures. Note that in Aqwa-Naut, wave drift force is not included in either regular or irregular waves.

29.3. Program Options for Use in Aqwa Program Suite

The options in this section may be used when running the indicated programs within the Aqwa suite. They should appear on the OPTIONS data record (The OPTIONS Data Record (p. 55)) in the Administration Data Category 0.

The options are valid for more than one program in the Aqwa suite and the applicability is indicated by a string of characters shown in parentheses at the beginning of the description of each option, using the following code:

A = All programs

B = Aqwa-Librium

D = Aqwa-Drift

F = Aqwa-Fer

L = Aqwa-Line

N = Aqwa-Naut

For example, the string (BDL) at the beginning of an option description means that the option is valid for Aqwa-Librium/Drift/Line

Since many options are related to printing of output on the listing file, these are listed in separate sections.

29.3.1. Printing of the Expanded Input Data List for each Data Category

By default, the printing of the expanded input data list for each data category is output to the listing file at the end of the three data record image input Stages (1, 2, 4). Default output is therefore

For a run of Stages 1 to 5 - Output of expanded data list for Data Categories 1 to 18

For a run of Stages 2 to 5 - Output of expanded data list for Data Categories 6 to 18

For a run of Stages 3 to 5 - No output

For a run of Stages 4 to 5 - Output of expanded data list for Data Categories 9 to 18

For a run of Stage 5 - No output

PRDL - Print Data List from Backing File

When a restart is performed, by default, the expanded data list is NOT output for the previous stages, which have already been performed. This option requests that the expanded data list for all data categories for previous stages be printed. This option is normally used to confirm that the correct backing files have been assigned for a particular analysis.

NODL - No Data List

Switching off Output of All Data Categories

The user may switch off all output of expanded data by using the NODL option, see below on how this behavior may be modified with additional options. Note that output involving calculations, for example calculation of the mass and inertia of the structure, will still be output.

Switching of Output Flag for a Single Data Category

The user may switch the output flag of a single data category by including the name of the data category keyword in the options list. The function will depend on whether the NODL option is present or not:

- If the NODL option is not present in the options list, the expanded data list for that data category will be switched off.
- If the NODL option is present in the options list, the expanded data list for that data category will be switched ON again.

For example, the user may switch off the output for one or more data categories by including the data category keyword(s) and not using the NODL option or the user may switch off all but the output for one or more data categories by including the data category keyword(s) and the NODL option.

As the data category keyword may be dependent on the structure number, the data category keywords used in the options list are as follows:

Data Category 1 - COOR

Data Category 2 - ELEM

Data Category 3 - MATE

Data Category 4 - GEOM

Data Category 5 - GLOB

Data Category 6 - FDRN

Data Category 7 - WFSN

Data Category 8 - DRCN

Data Category 9 - DRMN

Data Category 10 - HLDN

Data Category 11 - ENVR

Data Category 12 - CONS

Data Category 13 - SPEC

Data Category 13N- WAVE

Data Category 14 - MOOR

Data Category 15 - STRT

Data Category 15D - STRT

Data Category 15N - STRT

Data Category 16 - TINT

Data Category 16B - LMTS

Data Category 16L - GMCH

Data Category 17 - HYDC

Data Category 18 - PROP

29.3.2. Printing Options for Output of Calculated Parameters

PBIS - Print Force Components at Each Iteration Step

(B) This option causes the program to output the component forces acting on each structure (e.g. gravity, hydrostatic, current, and mooring forces) for each iteration in the search for equilibrium.

(DN) Prints out positions and forces on each structure at each integration stage; i.e. twice per timestep. The scope of the printout can be controlled by selections in Data Category 18.

PFLH - Print Fer Low & High Frequency

(F) With this option Aqwa-Fer will output separate drift (low) and wave frequency (high) significant values of all parameters. Drift (low) frequencies are defined as those below the lowest frequency in the wave spectrum.

PPEL - Print Properties of Each Element

(BDFLN) This option allows the user to output complete details of each element used in the body modeling. All important details of the body elements are output together with the resultant properties of the bodies. It is only applicable when running Stage 1 of the analysis.

PRAF - Print All Freedoms

(BDFN) This option allows the user to output results for all freedoms, even if some have been de-activated using the DACF data record in Data Category 12.

PRAS - Print Articulation (Reaction) Spectrum

(F) Prints spectrum of articulation reactions, in the global axes.

PRCE - Print Data Record Echo for Data Categories 1 TO 5

(BDFLN) This option informs the program to output the input received by the program in reading Data Categories 1 to 5. This is the body modeling.

PRCS - Print Coupled Spectra

This Option has been Withdrawn

(F) Prints fully-coupled matrix for force spectrum (PRFS), response spectrum (PRRS) and the transfer matrix (PRTI).

PRFS - Print Force Spectral Density Matrix at Spectrum Integration POINTS

(F) This option is used to output the wave force spectra for both drift and wave frequency at the integration points of the response spectrum for the direction of the corresponding wave spectrum. By default, this option only outputs the leading diagonal of this matrix, which therefore omits the information relating to the phase between the freedoms of the structures.

The forces are in the fixed reference axis system.

PRPR - Print Pressures

(L) This option is used to output the total hydrostatic varying and hydrodynamic pressures at the diffraction element centers, and the total hydrodynamic pressures (unit in heads of water) at the field points in an Aqwa-LINE model.

> **Note:**
>
> The hydrodynamic pressures on the field points are not output when vessel travels with a constant speed in multiple wave directions.

PRPT - Print Potentials

(L) This option is used to output the modified and unmodified values of the potential at the diffraction element centers. This information may be used to define the fluid flow field about the body. Detailed information on the composite potential can be found in the Aqwa Theory Manual.

The format of the composite potential output in the `.LIS` file is as follows:

Double symmetric body

Type #1 composite potentials are printed at the diffraction elements and at the field points in the first quadrant of the fluid region around the body

Type #2 composite potentials are printed at the diffraction elements and at the field points in the second quadrant of the fluid region around the body

Type #3 composite potentials are printed at the diffraction elements and at the field points in the third quadrant of the fluid region around the body

Type #4 composite potentials are printed at the diffraction elements and at the field points in the fourth quadrant of the fluid region around the body

Single symmetric body

Type #1 composite potentials are printed at the diffraction elements and at the field points in the first half of the fluid region around the body

Type #2 composite potentials are printed at the diffraction elements and at the field points in the second half of the fluid region around the body

PRRI - Print RAOS at Spectra Integration Points

(F) This option is used to output the fully coupled RAOs which are used to calculate the response spectrum. The peak values will, in general, not be contained in the output, as it is not necessary for accurate integration of the response spectra, which is achieved in Aqwa-Fer within one percent.

However, the peak value will never exceed the values output by more than 80 percent, as long as the damping exceeds one half percent critical.

Note that these RAOs are calculated for the direction of the corresponding spectra in the fixed reference axis system.

PRRP - Print Recalculated Parameters

(F) Informs Aqwa-Fer to print certain parameters where they are recalculated for each spectrum. At present, this applies to the CRAO option and also causes the undamped and damped natural frequencies to be output, for each spectrum, for each mooring configuration.

PRRS - Print Response Spectrum at Spectra Integration Points

(F) This option is used to output the response spectrum at the integration points of the response spectra for the fully coupled system of the equations of motion. By default, this option only outputs the leading diagonal of this matrix, which therefore omits the information relating to the phase between the freedoms of the structures.

The response is in the fixed reference axis system.

PRSS - Print Source Strengths

(L) Informs Aqwa-Line to output the source strengths and the composite source strengths if structural geometric properties are employed. The composite strengths are linear combinations of source strengths at the diffraction element centers on the all the quadrants or halves of the hull surface. Detailed information on the composite source strength can be found in the Aqwa Theory Manual.

The format of the composite source strength output in the `.LIS` file is as follows:

Double symmetric body

Type #1 composite source strengths are printed at the diffraction elements in the first quadrant of the hull surface

Type #2 composite source strengths are printed at the diffraction elements in the second quadrant of the hull surface

Type #3 composite source strengths are printed at the diffraction elements in the third quadrant of the hull surface

Type #4 composite source strengths are printed at the diffraction elements in the fourth quadrant of the hull surface

Single symmetric body

Type #1 composite source strengths are printed at the diffraction elements in the first half of the hull surface

Type #2 composite source strengths are printed at the diffraction elements in the second half of the hull surface

PRST - Print Global Stiffness Matrix

(B) This option causes the global stiffness matrix, which is computed in equilibrium analysis (Stage 5), to be output.

PRTI - Print Transfer Matrix at Spectra Integration Points

(F) This option is used to output the transfer matrix at the integration points of the response spectra for the fully coupled system of the equations of motion. By default, this option only outputs the leading diagonal of this matrix, which therefore omits the information relating to the phase between the freedoms the structures. Do not use this option if the information is not required, as the computing costs are substantially increased during integration of the wave frequency motions.

PRTS - Print Tension and Reaction Spectra

(F) This option is used to output significant value, Tz and spectral density for tension in composite moorings and articulation reactions. These results are written to the `.LIS` file only; they are not yet available for plotting in the AGS.

Articulation reactions are output in the local articulation axes (LAA) if the LAAR (p. 316) option is on, or in the local structural axes (LSA) if the LSAR (p. 317) option is on. By default, they are output in the fixed reference frame (FRA).

29.3.3. Administration and Calculation Options for the Aqwa Suite

AHD1 - Print ASCII Hydrodynamic Database

(L) Instructs Aqwa-Line to print the hydrodynamic database (the .HYD file) in a compact ASCII format to a new file with a `.AH1` extension. If the option AHD? is ALSO used, a file will be printed that explains the format.

AHD? - Print Annotated ASCII Hydrodynamic Database

(L) When used with the AHD1 option, instructs Aqwa-Line to print a sample of the `.AH1` file, with annotation to explain the format.

AQTF - ASCII Output of Full QTF Matrix

(L) The AQTF run-time option for Aqwa-Line will output an ASCII file `AL*.QTF` which can be used for external postprocessing. A description of the file format may be found in The CQTF Data Record - Import of QTF Database (p. 142). Details of how Aqwa computes the QTF matrices can be found in General QTF Coefficient Matrix in Multiple Directional Waves in the *Aqwa Theory Manual*.

CONV - Convolution

(DN) Instructs Aqwa-Drift or Naut to use the convolution method in the radiation force calculation. This is a more rigorous approach to the radiation force calculation in the time domain and will enhance the capability of handling a non-linear response of structures. This method is used by default but can be turned off using NCNV (p. 318).

CQTF - Calculation of Full QTF Matrix

(L) The CQTF run-time option for Aqwa-Line requests calculation of the full QTF matrix. Note that this option does not give printed output; the AQTF (p. 314) option is needed to obtain this.

CRAO - Calculate RAO Option

(F) Instructs Aqwa-Fer to calculate and output the RAOs for each structure, INCLUDING the mooring lines, but assuming each body is independently moving. These may be used to assess the effect of the coupling of the complete system by comparing these RAOs with those for the fully coupled system (see PRRI (p. 312)). This is done for the first spectrum of each mooring line combination only, unless the PRRP (p. 313) option is used.

CRNM - Calculate RAOs with No Moorings

(BDFLN) This option may be used with Aqwa-Line but is more useful with the program Aqwa-Fer. This option instigates the calculation of RAOs using the values of added mass, wave damping, stiffness and wave forcing specified by the user. The RAOs are then written into the database.

DATA - Data Check Only

(BDFLN) This option is used to check the data input to the program and provides a means by which the user may check all input data whilst incurring minimum cost of the program run. This option is equivalent to performing the analysis up to the end of the second stage in Aqwa-Line, and up to the end of Stage 4 in Aqwa-Drift/Fer/Librium/Naut. If the data proved to be correct, then the program would be restarted at next stage of the analysis by using the RESTART option.

END

This is used to indicate the end of the option list.

FDLL - Call Routine "user_force"

(DN) This option instructs the program to call a routine called "user_force" at each stage of the calculation. This routine can be used to add externally calculated forces to the simulation.

FIAM – Output the added mass matrix at the infinite frequency

(N) This option switches on the printing of the `*.ADM` file which contains the fluid added mass matrix at the infinite frequency.

FQTF - Use Full QTF Matrix

(FD) This option specifies that the full matrix of difference frequency QTFs is to be used when calculating slowly varying drift forces. See also SQTF (p. 320).

GLAM - Output Significant Motions in Global Axis

(F) This option switches the axis system in Aqwa-Fer output into the global system.

GOON - Ignoring Modeling Rule Violations

(L) This option allows the analysis to go on in spite of the modeling rule violations. Most of the modeling errors will be turned into warnings by this option. Users are advised not to use this option unless the violations are minor and difficult to correct. For more information on modeling rules, see Mesh Quality Check in the *Aqwa Theory Manual*.

LAAR - Local Articulation Axis System for Articulation Reaction Force Output (LAA)

(BFDN) This option is used to output articulation reaction forces in the local articulation axis system. This means that the moments in unconstrained freedoms, e.g. the hinge axis, will always be zero within roundoff. Note that for fixed articulations or ball-joints the local axes are parallel to the FRA.

LDRG - Linearized Drag

(L) This option is used in Aqwa-Line to output RAOs, including linearized Morison drag, on all TUBE and DISC elements. It is only available for a single spectrum which must be defined in Data Category 13. Although multiple structures can be analyzed they must not be connected by an additional structural stiffness matrix, articulations, or moorings. The run must include stage 5. Morison element linearization is not available when forward speed is defined.

(F) This option is used in Aqwa-Fer to include linearized drag in the calculations. Linearized drag includes:

- Morison drag on all TUBE and DISC elements
- Current hull drag
- Wind hull drag
- Nonlinear roll damping

Note:

Wind hull drag is always included, irrespective of the use of the LDRG option.

Unlike Aqwa-Line, it is available for multiple spectra. Multiple structures can be analyzed with any combination of connections provided by Aqwa.

LHFR - Calculate Low and High Frequency Hydrodynamic Properties

(L) This option is used in Aqwa-Line to calculate the first order hydrodynamic properties at low and high wave frequencies. The low wave frequency corresponds to the encounter frequency of $0.001 \cdot \max\left\{1, \sqrt{\frac{g}{d}}\right\}$ rad/s, where g = acceleration due to gravity and d = water depth. The high wave frequency corresponds to the absolute value of the encounter frequency, i.e. 100 rad/s.

This option is automatically turned on if the full QTF option CQTF (p. 315) is used.

LNST - The Linear Starting Conditions

(N) This is used to start a simulation with the motions and velocities derived from the Aqwa-Line results. This can be used to limit the transient at the start of a simulation.

LSAR - Local Structural Axis System (LSA) for Articulation Reaction Force Output

(BFDN) This option is used to output articulation reaction force in the local structural axis system. This means that the direction of the output reaction force will follow the structure.

LSTF - Use Linear Stiffness Matrix to Calculate Hydrostatic Forces

(BN) This option should be used when the user wishes to use the linear stiffness matrix (calculated by Aqwa-Line or input in Data Category 7) as opposed to the program recalculating the hydrostatic stiffness from the hydrostatic element model. This normally will reduce the time to run the program substantially.

MCNV - Calculate C.I.F. Using Added Mass and Damping

(DN) From version 5.3K onward the default method for calculation of the Convolution Integral Function uses the radiation damping only. This option forces the program to use the previous method based on both added mass and damping.

MCOL – Print ASCII Hydrodynamic Database in the LSDYNA/MCOL Format

(L) This option instructs Aqwa-Line to print the hydrodynamic database in a compact ASCII format into a new file with a `.mco` extension. The data is with respect to the LSDYNA/MCOL coordinate system of which the z-axis is downwards.

MNVR – Calculate Maneuvering Loads

(N) The MNVR run-time option for Aqwa-Naut requests calculation of low frequency maneuvering loads.

MQTF - Calculate QTF Matrix with Directional Interaction

(L) The MQTF run-time option for Aqwa-Line requests calculation of QTF coefficients including interaction between different wave directions. This will result in output of a new binary file with a `.MQT` extension. This can be utilized in a subsequent Aqwa-Librium. Aqwa-Fer, or Aqwa-Drift analysis using the FILE (p. 150) and CSTR (p. 150) data records in the Drift Motion Parameters (p. 145) data category.

MRAO - Calculate Motions Using RAOs Only

(DN) This option instructs Aqwa-Drift or Naut to calculate motions using RAOs only. These may be defined by the user in Deck7. Note that this option suppresses all motion except that defined by the RAOs. In particular current, wind, drift forces, moorings etc. have no effect on the motions of the structure.

NASF - No Additional Structural Stiffness

(LBFDN) This option will cause any additional structural stiffness, whether in the database or input in Data Category 7, to be ignored. Its purpose is to allow an Aqwa-Line run including additional stiffness to be followed by stages 3 - 6 in another module which may include moorings with an equivalent stiffness.

NCNV – Switch off Convolution

(DN) This option switches off the convolution method (CONV (p. 314)) in AQWA-Drift/NAUT. In AQWA DRIFT and NAUT, the convolution method is set as default for the radiation force calculation. This option forces AQWA-Drift to use the RAO based radiation method instead of the convolution method, or forces AQWA-Naut in the regular wave case to include the added mass and damping matrices at the defined regular wave period in the equation of motion.

NGGQ - No Gauss Quadrature

(L) This option will cause Aqwa-Line to use the old method (pre 5.5D) for integration of the Green's Function. It has been added for compatibility with previous versions.

NOCP - No Current Phase Shift

(ND) This option switches off the wave phase shift due to a current speed.

NODL - No Data List

(BDFN) This option switches off all extended data output in the `.LIS` file.

NODR - No Drift Calculations

(L) This option flags the program not to perform the Mean Wave Drift Force calculations.

NOFP - No Free Wave Elevation Output at Field Points

(L) This is to switch off the output of field point wave elevation in the `.LIS` file.

NOLL - No Progress Window

(LFDN) This option stops the progress window being displayed.

NOMG - Do Not Merge Databases

(L) This option stops the merging of hydrodynamic databases and re-calculation of QTFs. It is required if a `.HYD` file is imported (into Aqwa-Line only) but the `.PAC` and `.VAC` files are not available.

NOST - No Statistics

(D) This option stops the automatic calculation of statistics at the end of each simulation run. Statistical processing can be lengthy for long simulations. This option can be used to reduce processing time if statistics are not required.

NOWD - No Automatic Wave Drift Damping Calculation

(D) This option stops the automatic calculation of wave drift damping for a floating structure in Aqwa-Drift. When this option is used, the wave drift damping should be defined in data category 9. Note that the wave drift damping calculated by the program is only for the floating structure defined in Aqwa-Line, damping from risers, etc is not included. The NYWD option stops calculation of wave drift damping for yaw motion only.

NPPP - No Pressure Post-Processing

(L) This option tells the program that there will be no pressure post-processing and therefore the connectivity warnings can be omitted.

NQTF - Near Field Solution for Mean Drift Force Calculation

(L) This option invokes Aqwa-Line to use the near field solution in the calculation of mean drift force. By default the far field solution is used which only calculates the mean drift force in three horizontal degrees of freedom (i.e. surge, sway and yaw). The far field solution is also unable to consider the hydrodynamic interaction between structures or a structure with forward speed.

NRNM - Calculates Nodal RAOs With No Moorings

(L) This option is used to output in Aqwa-Line run RAOs at particular nodes defined in Data Category 18. The run stages should be from 1 to 5.

NWHT – Use JONSWAP wave spectrum of import Wave Height Time History

(N) This option suppresses the LFP reproduction of irregular waves from the import wave height time history record. The JONSWAP fit of the wave spectrum will be used. This reproduces the approach used in Aqwa-Naut before the introduction of the LFP methodology.

NYWD - No Yaw Wave Drift Damping

(D) This option suppresses the calculation of wave drift damping for yaw motion. To prevent the calculation of ALL wave drift damping use the NOWD option.

PLFS - Plot Free Surface. (This option is no longer necessary in version 5.2C and later versions)

(L) This option is used in conjunction with field point data records FPNT in Data Category 2 to output free surface elevation at specified field points.

PRBL - Print .LIS Banner Page

(BDFLN) This option switches on printing of the old lineprinter-style banner page in the `.LIS` file.

RBDF – Run the co-simulation analysis with Ansys Rigid Dynamics

(N) This option switches on the co-simulation mechanism for the Aqwa-Naut analysis.

RDDB - Read Database

(BDFN) Read the hydrodynamics database from the restart (`.RES`) file created by a previous Aqwa-Line run.

This option is used if the user wishes to modify the hydrodynamic data calculated in a previous Aqwa-Line run, without having to re-run the Aqwa-Line radiation/diffraction analysis.

Note:

The RDDB option is only needed if the hydrodynamics file from the previous Aqwa-Line run has been accidentally deleted.

As the model definition has to be read from the restart file before the hydrodynamics can be read, there is no possibility to change the model definition, when using this option.

RDEP - Read Equilibrium Position

(BFDN) This option can be used in Librium, Fer, Drift and Naut to read in the structures equilibrium position from a previous Librium run as the start position. An AB*.EQP file should be copied to AF*.EQP before a Fer run, to AD*.EQP before a Drift run or to AN*.EQP before a Naut run. The .EQP file will be copied automatically if the file root is entered on the RESTART (p. 56) data record.

REST - Restart

(ALL) This option is used when the program is being restarted at any stage greater than the first (see Analysis Stages (p. 31)). A restart data record must follow the options list when the restart option is used This data record indicates the stage at which the program is to continue and the stage at which the program is to stop.

RNDD - Reynolds No Drag/C for Morison Elements

(Switched by SC1/Data Record)

(BDN) Together with the SC1/ data record in Data Category 17 this option causes drag coefficients to be calculated using the Wieselburger curve for Reynold's number dependent drag coefficients. Drag coefficients in Data Category 4 (including defaults) are set to zero.

SDRG - Use Slow Velocity for Hull Drag Calculation

(D) This option is used if users wish to use the slow velocity (drift frequency velocity) for the hull drag calculation, instead of the total velocity (drift frequency velocity + wave frequency velocity) which is the default.

SFBM - Calculate Shear Forces and Bending Moments

(L) This option instructs Aqwa-Line to calculate shear forces and bending moments in Stage 5. A .SHB file is produced which can be read by the AGS.

SQTF - Use Sum Frequency QTFs

(D) This option specifies that the full matrix of sum frequency QTFs is to be used when calculating slowly varying drift forces. Note that this option also sets the FQTF (p. 315) option. It is not possible to perform an analysis using only the sum QTFs.

SUFC - Look for External User-Defined Force Server

(DN) This option instructs the program to look for an external server for calculating user-defined forces. For more information, see External Server for User-Defined Force Calculation (p. 327).

TRAN - Transient Analysis

(DN) This option switches off the slow axis system and stops printout of harmonic analysis at the end of a simulation run. This option should not in general be used. It is only provided as a workround for Drift analysis for both drift and wave frequency motions if it diverges in the time integration.

TRAO - Transient RAO Motion

(D) When this option is used Aqwa-Drift will re-calculate the forces based on the RAOs, which can be input by the user in Data Category 7. This allows RAOs obtained from tank tests (for example) to be used with the CONV (p. 21) option in transient analyses. If the RAOs are not modified this option has little effect.

URAO - Update .PAC, .VAC, and QTF with User-Defined RAOs

(L) This option instructs Aqwa-Line to update the hydrodynamic databases (.PAC and .VAC files), and to recalculate QTFs based on the RAOs input by the user in Data Category 7. It is required that a .HYD file is imported (into Aqwa-Line only) and the .PAC and .VAC files are available.

The option is ignored when the NOMG (p. 318) option is set.

WHLS - Use Wheeler Stretching

(N) This option specifies that Wheeler stretching should be used in Aqwa-Naut when calculating the Froude-Krylov force based on the instantaneous wave surface.

Regular Waves

- For the default second order Stokes wave theory, Wheeler stretching is used. When the WHLS option is on, the mean water level set-down in regular Stokes waves will also be included in the wave elevation calculation (see Equation 2.15) and the hydrodynamic pressure will be calculated with some extra terms (see Equation 13.48 and Equation 13.53).

- If the AIRY data record is used, Airy wave theory and Wheeler stretching is used.

Irregular Waves

Wheeler stretching is always used in irregular waves.

- With the WHLS option, linear wave theory is used.

- Without the WHLS option, Wheeler stretching is used together with linear wave theory and a second order correction on wave elevation, pressure, and fluid particle velocity and acceleration.

Chapter 30: External Force Calculation

Aqwa-Drift and Aqwa-Naut can accept forces calculated at each timestep by a user-defined routine. This routine may be accessed through a compiled dynamic link library (DLL) or from a process running on an external server. Details of both methods are given in the following sections, but the effect of each is similar.

Either of both forms of external force calculation can be used. Aqwa sums the forces from each and adds them to any other external forces (for example, those specified in a .XFT file). The combined values utilized by Aqwa can be output to the listing and .PLT files by requesting the output of external forces using the PRNT (p. 291) data record. These may also then be plotted in Workbench or the Aqwa Graphical Supervisor.

The information that Aqwa sends to the external routine at each calculation stage [1] of each timestep is:

- An external file name, for the external server only.
- A mode flag:
  - 0: Initialization. The routine is called once with mode 0 before the simulation.
  - 1: Called during the simulation. Force and added mass output expected.
  - 99: Termination. Signifies that the simulation is complete.
- A set of optional integer control parameters (all zero if not defined).
- A set of optional real control parameters (all zero if not defined).
- The number of structures in the model.
- The instantaneous analysis time (not clock time).
- The time step size.
- The calculation stage (1 or 2).
- The position of each structure in 6 DOF [2].
- The velocity of each structure in 6 DOF [3].
- The position of the center of gravity when the structure is in the definition position.

The information that Aqwa expects from the external routin at each calculation stage of each timestep is:

- A force to be applied at the center of gracity of each structure in 6 DOF [3].

- An added mass in 6 DOF to be added to the existing added mass.
- An error flag. The run will stop if this flag is non-zero.

1. Aqwa integration stages: Aqwa time integration is based on a 2-stage predictor corrector method. This routine is called twice at each time step, once with calculation stage = 1 and once with calculation stage = 2. On stage 2, the position and velocity are predictions of the position and velocity at the next time step. For instance, if the initial time is 0.0 and the step 1.0 second then the calling sequence is as follows for the first 3 integration steps:

   Time = 0.0, time step = 1.0, stage = 1

   Time = 0.0, time step = 1.0, stage = 2

   Time = 1.0, time step = 1.0, stage = 1

   Time = 1.0, time step = 1.0, stage = 2

   Time = 2.0, time step = 1.0, stage = 1

   Time = 2.0, time step = 1.0, stage = 2

2. The position uses the fixed reference axes (FRA). Aqwa defines the orientation of a structure using Euler angles. These are the angles which are printed in the listing file output and passed to the external routine. They are the angle by which the structure has to be rotated about the FRA to reach its given position, applied in the order RX, RY, RZ (roll, pitch, yaw). `Euler_to_LSA.mcd` is a PTC Mathcad worksheet which illustrates the transformation from LSA to FRA and vice versa. Conversion of Euler Angles to LSA (p. 329) is a text version of the Mathcad worksheet `Euler_to_LSA.mcd`.
3. The axes used are parallel to the FRA and centered at each structure's center of gravity.

30.1. Using a Compiled Dynamic Library

This is done by calling the routine **`user_force`**, which is stored in a compiled file. You can write and compile your own routine as long as it follows the requirements in this section.

On Windows, the name of the `.DLL` file must be `user_force64.dll`, and the file must be located in the same directory as the Aqwa executables (typically `C:\Program Files\ANSYS Inc\v251\aqwa\bin\winx64`).

On Linux, the name of the file must be `libuser_force.so`. You can define the location of the file using the LD_LIBRARY_PATH environment variable (defaults to `/<installation_directory>/ansys_inc/v251/aqwa/bin/linx64)` .

The standard Windows Aqwa installation includes the following example files in the directory `C:\Program Files\ANSYS Inc\v251\aqwa\doc`, and it is recommended that you copy and modify these as appropriate:

- `user_force.f90` - example Fortran subroutine
- `user_force.c` - example C routine

Example of Fortran Subroutine user_force (p. 325) is a copy of the Fortran subroutine `user_force.f90`.

This capability is activated by using the FDLL (p. 315) option.

Up to 100 integer and 100 real control parameters can optionally be input in Data Category 10. These are passed to **user_force** at each call and can be used to define variables such as control constants or calculation options. The input format is shown in The IUFC/RUFC Data Records - External Forces (p. 159).

30.2. Example of Fortran Subroutine user_force

```
SUBROUTINE USER_FORCE(MODE,I_CONTROL,R_CONTROL,NSTRUC,TIME,TIMESTEP,STAGE, &
                       POSITION,VELOCITY,COG, &
                       FORCE,ADDMASS,ERRORFLAG)

!DECLARATION TO MAKE USER_FORCE PUBLIC WITH UN-MANGLED NAME

!DEC$ attributes dllexport , STDCALL , ALIAS : "USER_FORCE" :: user_force

!DEC$ ATTRIBUTES REFERENCE :: I_CONTROL, R_CONTROL
!DEC$ ATTRIBUTES REFERENCE :: POSITION, VELOCITY, COG, FORCE, ADDMASS
!DEC$ ATTRIBUTES REFERENCE :: MODE, NSTRUC, TIME, TIMESTEP, STAGE
!DEC$ ATTRIBUTES REFERENCE :: ERRORFLAG

IMPLICIT NONE

INTEGER MODE, NSTRUC, STAGE, ERRORFLAG
REAL TIME, TIMESTEP
INTEGER, DIMENSION (100) :: I_CONTROL
REAL, DIMENSION (100) :: R_CONTROL
REAL, DIMENSION (3,NSTRUC) :: COG
REAL, DIMENSION (6,NSTRUC) :: POSITION, VELOCITY, FORCE
REAL, DIMENSION (6,6,NSTRUC) :: ADDMASS

! Input Parameter Description:
!
! MODE(Int)     - 0 = Initialisation. This routine is called once with mode 0
!                      before the simulation. All parameters are as described
!                      below except for STAGE, which is undefined. FORCES and
!                      ADDMASS are assumed undefined on exit.
!                      IERR if set to > 0 on exit will cause
!                      the simulation to stop.
!
!                 1 = Called during the simulation. FORCE/ADDMASS output expected.
!
!                99 = Termination. This routine is called once with mode 99
!                      at the end of the simulation.
!
! I_CONTROL(100)- User-defined integer control parameters input in .DAT file.
! R_CONTROL(100)- User-defined real control parameters input in .DAT file.
!
! NSTRUC(Int)   - Number of structures in the simulation
!
! TIME          - The current time (see STAGE below)
!
! TIMESTEP      - The timestep size (DT, see STAGE below)
!
! STAGE(Int)    - The stage of the integration scheme. AQWA time integration is
!                 based on a 2-stage predictor corrector method. This routine is
!                 therefore called twice at each timestep, once with STAGE=1 and
!                 once with STAGE=2. On stage 2 the position and velocity are
!                 predictions of the position and velocity at TIME+DT.
!                 e.g. if the initial time is 0.0 and the step 1.0 seconds then
!                 calls are as follows for the first 3 integration steps:
!
!                 CALL USER_FORCE(.....,TIME=0.0,TIMESTEP=1.0,STAGE=1 ...)
!                 CALL USER_FORCE(.....,TIME=0.0,TIMESTEP=1.0,STAGE=2 ...)
!                 CALL USER_FORCE(.....,TIME=1.0,TIMESTEP=1.0,STAGE=1 ...)
!                 CALL USER_FORCE(.....,TIME=1.0,TIMESTEP=1.0,STAGE=2 ...)
!                 CALL USER_FORCE(.....,TIME=2.0,TIMESTEP=1.0,STAGE=1 ...)
!                 CALL USER_FORCE(.....,TIME=2.0,TIMESTEP=1.0,STAGE=2 ...)
!
```

```
! COG(3,NSTRUC) - Position of the Center of Gravity in the Definition axes.
!
! POSITION(6,NSTRUC) - Position of the structure in the FRA; angles in radians
!
! VELOCITY(6,NSTRUC) - Velocity of the structure in the FRA
!                      angular velocities in radians/s
!
!
! Output Parameter Description:
!
! FORCE(6,NSTRUC) - Force on the Center of gravity of the structure. NB: these
!                   forces are applied in the Fixed Reference axis e.g.
!                   the surge(X) force is ALWAYS IN THE SAME DIRECTION i.e. in
!                   the direction of the X fixed reference axis.
!
! ADDMASS(6,6,NSTRUC)
!                 - Added mass matrix for each structure. As the value of the
!                   acceleration is dependent on FORCES, this matrix may be used
!                   to apply inertia type forces to the structure. This mass
!                   will be added to the total added mass of the structure at
!                   each timestep at each stage.
!
! ERRORFLAG       - Error flag. The program will abort at any time if this
!                   error flag is non-zero. The values of the error flag will
!                   be output in the abort message.

!------------------------------------------------------------------------
! MODE=0 - Initialize any summing variables/open/create files.
!          This mode is executed once before the simulation begins.
!------------------------------------------------------------------------

      IF (MODE.EQ.0) THEN

   CONTINUE


!------------------------------------------------------------------------
! MODE=1 - On-going - calculation of forces/mass
!------------------------------------------------------------------------

      ELSEIF (MODE.EQ.1) THEN
         FORCE = (-1.0E6 * POSITION) - (2.0E5 * VELOCITY)
         ADDMASS = 0
         ERRORFLAG = 0


!------------------------------------------------------------------------
! MODE=99 - Termination - Output/print any summaries required/Close Files
!           This mode is executed once at the end of the simulation
!------------------------------------------------------------------------

!      ELSEIF (MODE.EQ.99) THEN



!------------------------------------------------------------------------
! MODE# ERROR - OUTPUT ERROR MESSAGE
!------------------------------------------------------------------------

       ELSE

       ENDIF
       RETURN

END SUBROUTINE USER_FORCE
```

30.3. External Server for User-Defined Force Calculation

The external server feature is activated by linking the Aqwa executable and an external process through a TCP socket. The feature requires the SUFC (p. 320) option to be activated. When both the SUFC (p. 320) and FDLL (p. 315) options are activated, the external forces calculated by both methods are summed.

The Aqwa executable sends data listed in External Force Calculation (p. 323) to the external process through the socket at each time step. Simultaneously, the Aqwa executable listens to the socket for the information generated by the external process

30.3.1. Using the Provided Python Module

The provided Python module is installed as *`ANSYS_INSTALL_DIR`*`\v251\aqwa\utils\ExternalForceCalculation\AqwaSocketMgr.py`.

An example Python script which makes use of this module is also installed as *`ANSYS_INSTALL_DIR`*`\v251\aqwa\utils\ExternalForceCalculation\AqwaSocketUserForceExample.py`.

You may use your own installation of Python, or the version of the Python interpreter installed with Aqwa, located at *`ANSYS_INSTALL_DIR`*`\v251\commonfiles\CPython`. A .BAT script is also installed that allows you to run Python scripts by dragging and dropping files onto it (*`ANSYS_INSTALL_DIR`*`\v251\aqwa\utils\ExternalForceCalculation\StartAqwaPythonUserForceServer.bat`).

The `AqwaSocketUserForceExample.py` script has the following structure:

- The **`from AqwaSocketMgr import *`** command.
- Several user-defined external force functions:
  - **`def UF1(Analysis,Mode,Stage,Time,TimeStep,Pos,Vel):`**

    `...`
  - **`def UF2(Analysis,Mode,Stage,Time,TimeStep,Pos,Vel):`**

    `...`
  - **`def UF3(Analysis,Mode,Stage,Time,TimeStep,Pos,Vel):`**

    `...`
- A line which initializes the server: **`Server = AqwaUserForceServer()`**

  The server creates a socket, binds it to a free port number, and begins listening on that port.
- One or more commands of the form: **`Server.Run(UF1)`**

  These commands cause the server to wait for a connection from the Aqwa process. When the connection is established, the server receives data from the process, calculates the user-defined external forces, and returns the external forces and added mass using the function **`UF1`**. The server iterates this function until instructed to stop by the Aqwa process.

After being instructed to stop, the server returns to a waiting state. This approach allows you to define several different functions and to select which one to use at runtime, potentially based on runtime information provided by Aqwa itself.

The Python class **AqwaUserForceServer** is defined in AqwaSocketMgr.py as a subclass of **AqwaSocketMgr**.

After the connection is established (when executing code in a user-defined external force function), the **Server** object has several attributes automatically defined:

- **Server.hostname** and **Server.port**: Information about the connection
- **Server.Analysis**: An object containing information and tools specific to the currently running analysis:
  - **Analysis.InputFileName**: the full path of the file currently being run in Aqwa without the .DAT extension
  - **Analysis.NOfStruct**: number of structures defined in the input file
  - **Analysis.I_Control** and **Analysis.R_Control** arrays: user parameters defined in the input file using the IUFC (p. 159) and RUFC (p. 159) data records
  - **Analysis.COGs**: the position of each structure's center of gravity in the definition axis system
  - **Analysis.Pos**: The position of each structure's center of gravity in the global axis system at the current simulation time
  - **Analysis.Vel**: The velocity of each structure's center of gravity in the global axis system at the current simulation time
  - **Analysis.Time**: The current simulation time
  - **Analysis.GetNodeCurrentPosition(Struct,DefAxesX,DefAxesY,DefAxesZ)**: A function returning the position of a node of the given structure at the current time from its original position in the definition axis
  - **Analysis.ApplyForceOnStructureAtPoint(Struct,FX,FY,FZ,AppPtX,AppPtY,AppPtZ)**: A function returning the Force object (including the moment) applied at the structure's center of gravity, resulting from the application of a force at a particular point of the structure

These attributes can be used in the Python script for any purpose. For example, it is possible to define a list of user-defined functions and to select one for a particular run by parsing the values of the **Analysis.I_Control** array. Such a selection could also be made using the **Analysis.InputFileName** value. Note that the analysis object is accessible within a user-defined function as the first argument in the function: **Analysis**.

The functions **Analysis.GetNodeCurrentPosition** and **Analysis.ApplyForceOnStructureAtPoint** are provided to simplify the process of expressing forces and moments on the COGs of structures. AqwaSocketUserForceExample.py shows an example of their use.

Additionally, the modules provide two classes **BlankAddedMass** and **BlankForce** which are used for initializing the Force and Added Mass containers that are returned by the user-defined functions.

These classes support basic algebraic operations (sum, difference, scalar multiplication), as shown in the `AqwaSocketUserForceExample.py` script.

30.3.2. Workflow

A typical workflow for using the external server follows:

1. Start the Python server (use either method):

   a. From the command line (in the running directory): **`\Path_to_Python\python.exe AqwaSocketUserForceExample.py`**

   b. By drag-and-drop: Drag and drop the `AqwaSocketUserForceExample.py` onto the `StartAqwaPythonUserForceServer.bat` file, both of which should be present in the running directory.

   The server waits for connections and generates a file in the running directory: `AQWA_SocketUserForceServerDetails.cfg`.

2. Start Aqwa to run the designated `.DAT` file in the running directory, either from the command line or by drag and dropping the file onto the Aqwa executable. The `.DAT` must have the SUFC (p. 320) option turned on.

3. On startup, Aqwa takes the following steps:

   a. Aqwa looks for the `AQWA_SocketUserForceServerDetails.cfg` file in the current working directory (where the data file is stored).

      If the server script and input file are located in the same directory, the program can discover the hostname and port in this way.

   b. If the previous step fails, Aqwa examines the contents of the environment variable **ANSYS_AQWA_SOCKET_USERFORCE_SERVERINFOFILE**. This can manually be set as the path to the configuration file, including the file name itself.

   c. If the previous two steps fail, Aqwa examines the contents of the environment variable **ANSYS_AQWA_SOCKET_USERFORCE_SERVER**. You can manually set the value of this environment variable as **`hostname:portnumber`** using the contents of `AQWA_SocketUserForceServerDetails.cfg`.

   d. If all of the previous steps fail, Aqwa stops and generates the log file `AQWA_SocketUserForceLog.txt`.

4. Aqwa then tries to connect to the server using the information discovered in step 3. Once the connection is established, data exchange begins.

30.4. Conversion of Euler Angles to LSA

Aqwa defines the orientation of a structure using Euler angles. These are the angles which are printed in the `.LIS` file and passed in the argument list to the subroutine **`user_force`**. They are the angles by which the structure has to be rotated about the FRA axes to reach its given position, applied in the order rx, ry, rz (or roll, pitch, yaw). This worksheet shows how to obtain the direction cosines of the LSA axes from these angles.

Assume the Euler angles are θ_1,θ_2, and θ_3 for rotations about the x- (roll), y- (pitch), and z-axes (yaw).

$\mathrm{ORIGIN} \equiv 1$

Euler angles

$$\theta := \begin{pmatrix} 30° \\ 10° \\ 50° \end{pmatrix}$$

Unit vectors in LSA

$$x := \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \qquad y := \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$$

Roll about FRA x-axis

$$r(\theta) := \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos(\theta) & -\sin(\theta) \\ 0 & \sin(\theta) & \cos(\theta) \end{pmatrix} \qquad r(\theta_1) \cdot y = \begin{pmatrix} 0 \\ 0.866 \\ 0.5 \end{pmatrix}$$

Pitch about FRA y-axis

$$p(\theta) := \begin{pmatrix} \cos(\theta) & 0 & \sin(\theta) \\ 0 & 1 & 0 \\ -\sin(\theta) & 0 & \cos(\theta) \end{pmatrix} \qquad p(\theta_2) \cdot x = \begin{pmatrix} 0.985 \\ 0 \\ -0.174 \end{pmatrix}$$

Yaw about FRA z-axis

$$q(\theta) := \begin{pmatrix} \cos(\theta) & -\sin(\theta) & 0 \\ \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \end{pmatrix} \qquad q(\theta_3) \cdot x = \begin{pmatrix} 0.643 \\ 0.776 \\ 0 \end{pmatrix}$$

Overall motion

$$qpr := q(\theta_3) \cdot p(\theta_2) \cdot r(\theta_1)$$

$$qpr = \begin{pmatrix} 0.633 & -0.608 & 0.48 \\ 0.754 & 0.623 & -0.206 \\ -0.174 & 0.492 & 0.853 \end{pmatrix}$$

The columns of qpr give the direction cosines of the LSA x-, y-, z-axes in the FRA:

$$r(-\theta_1) \cdot p(-\theta_2) \cdot q(-\theta_3) \cdot (qpr^{\langle 1 \rangle}) = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$$

$$r(-\theta_1) \cdot p(-\theta_2) \cdot q(-\theta_3) \cdot (qpr^{\langle 2 \rangle}) = \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix}$$

$$r(-\theta_1) \cdot p(-\theta_2) \cdot q(-\theta_3) \cdot (qpr^{\langle 3 \rangle}) = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

Note that the inverse of qpr is the same as its transpose, so use qpr^T to convert from FRA to LSA.

$$qpr^T \cdot qpr = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

If the position of the COG in the FRA is CG, then the position of x in the FRA is given by:

$$CG := \begin{pmatrix} 12 \\ 5 \\ -3 \end{pmatrix} \quad X_{FRA} := CG + qpr \cdot x \quad X_{FRA} = \begin{pmatrix} 12.633 \\ 5.754 \\ -3.174 \end{pmatrix}$$

Expanding multiplication, using $cx = \cos\left(\theta_x\right)$ and $sx = \sin\left(\theta_x\right)$:

Rotations applied in the order roll, pitch, yaw	$\begin{pmatrix} cz & -sz & 0 \\ sz & cz & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} cy & 0 & sy \\ 0 & 1 & 0 \\ -sy & 0 & cy \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & cx & -sx \\ 0 & sx & cx \end{pmatrix}$
Equivalent single transformation matrix	$\begin{pmatrix} cz \cdot cy & -sz \cdot cx + cz \cdot sy \cdot sx & sz \cdot sx + cz \cdot sy \cdot cx \\ sz \cdot cy & cz \cdot cx + sz \cdot sy \cdot sx & -cz \cdot sx + sz \cdot sy \cdot cx \\ -sy & cy \cdot sx & cy \cdot cx \end{pmatrix}$