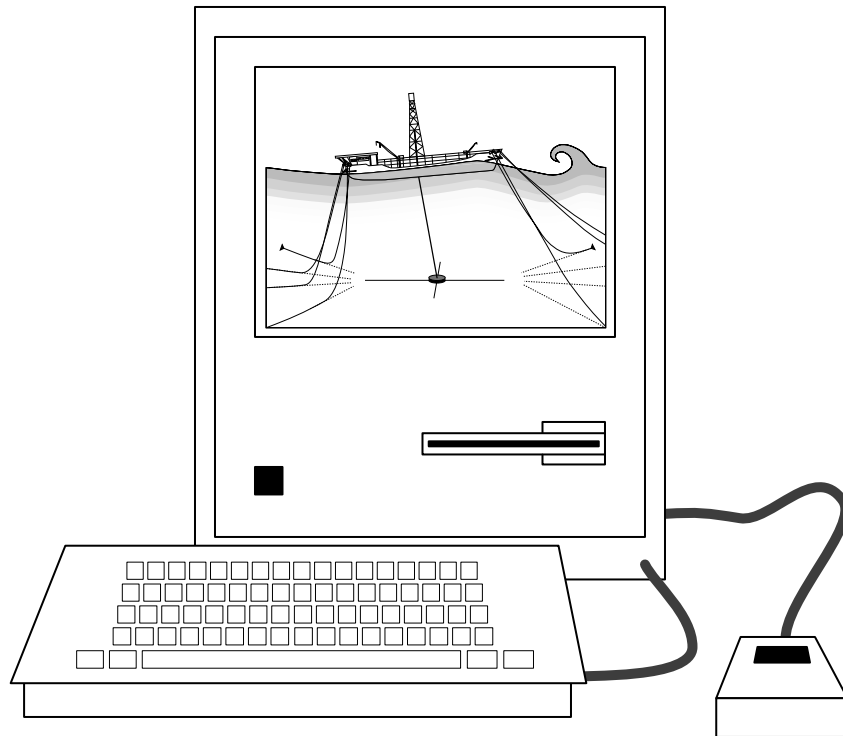


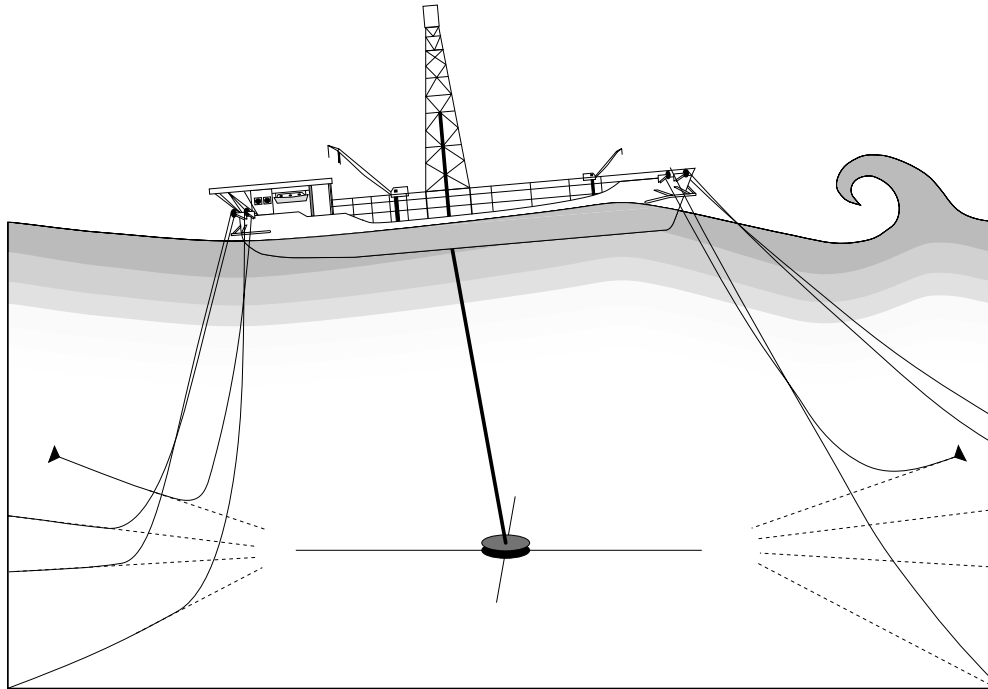
# ***Introducing Moorsim™ and SPMsim™***



## ***Comprehensive Mooring Software from SeaSoft® Systems***

- **Executive Summary**
- **Overview**
- **Sample Input Stream**
- **Sample Output Stream**

## *Description and Capabilities of Moorsim and SPMsim*



### **Executive Summary**

**Moorsim** and **SPMsim** are comprehensive software programs used for design, evaluation, maintenance and line failure analysis of catenary-type spread mooring systems. They provide detailed mooring line and vessel performance data under specifiable water depth and environmental conditions, including characteristic (r.m.s.) and peak mooring line loads in the forecast maximum storm. A wide range of environmental conditions is accommodated, including extensive built-in wave spectral types, azimuthal spreading of wave directions, an optional independent background swell, and steady or fluctuating wind and/or current. Catenary-based mooring systems are characterized by extreme nonlinearities at every phase of performance analysis; **Moorsim** and **SPMsim** accommodate

these nonlinearities at all levels, including system statics, quasi-statics (low-frequency oscillations with typical periods of one to ten minutes) and dynamics (wave-frequency oscillations with typical periods of 4 to 30 seconds). **Moorsim** and **SPMsim** are suitable for on-board use in an advisory capacity during mooring setup or storm preparation. The programs are especially useful for deep-water applications which are difficult to study thoroughly using conventional model-scale tests. Comparison of the nonlinear dynamic load calculation with the (approximate) quasi-static catenary calculation is provided as an output option. Execution is carried out in the frequency domain, resulting in short run times and unambiguous predictions of statistical response values.

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## INTRODUCTION

In the development of **Moorsim** and **SPMsim**, the principal objective has been to produce state-of-the-art software packages accessible to any technically trained offshore professional. The packages are thus oriented specifically towards the practicing marine/offshore engineer and naval architect; the software has been designed so that even a first-time or infrequent user can produce meaningful results. Ease of use represents, second only to output quality, the most important design consideration; this has resulted in a tool which, in the hands of a single individual, can usually produce comprehensive, wave-basin quality executions "from scratch" in one hour or less, including data input and output.

### ***Scope of the Package***

**SeaSoft** models the highly nonlinear dynamics of catenary-moored vessels with multi-element mooring lines. The programs have been designed to provide wave-basin-type environments that function in the following capacities:

- **Mooring System Design**

The programs provide detailed mooring line performance data for a particular vessel/mooring line combination under specifiable water depth and environmental conditions. This permits, for example, reliable estimation of peak mooring line loads in the forecast "maximum storm" at a particular site. The analysis can then be used to optimize mooring line characteristics for a specific site/environment.

- **Mooring System Evaluation & Failure Analysis**

The flexibility of these programs with regard to variations in vessel, mooring line and environmental characteristics makes them excellent tools for evaluation of existing mooring line configurations and detailed analysis of line failures.

- **Real-Time on-Board Advisory**

Microcomputer execution capability permits on-board installation of the programs which can then be used to adjust mooring line tensions and vessel heading to achieve minimum peak line loads in given environmental conditions. This capability should be especially useful in extreme conditions when the probability of line failure is significant.

Physical mooring line characteristics, including mass, elastic and hydrodynamic properties of each element of a multi-element mooring line, are fully specifiable. The mooring line load calculation, unlike the quasi-static catenary calculations which are often erroneously applied in this situation, is fully dynamic and utilizes a proprietary algorithm for the fast and efficient calculation of nonlinear dynamic loads. Long-period oscillations of the system are also characterized and contributions to long-period motions from low-frequency components of variable wind, current and wave-drift forces are computed.

### ***Comparison with Existing Procedures***

Comprehensive programs such as these are not a part of the existing universe of offshore engineering software; rather, they represent a wholly new approach to the problem of mooring system analysis. Historically, analyses have been performed, piecemeal, along the following lines:

- **Statics**

A static mooring analysis is prepared based upon a classical catenary description of the mooring lines and mooring layout. This analysis will normally include estimates of the mean environmental forces and moments arising from wind, waves and current and provide an estimate of the mean load in each mooring line arising from the action of mean environmental forces.

- **Low-Frequency Dynamics**

Rules of thumb or more sophisticated analyses using analytical models or extrapolation from model test results on similar systems are then used to estimate low-frequency vessel motion oscillation amplitudes and associated mooring load variations.

- **Wave-Frequency Vessel Motion Estimates**

An estimate of wave-frequency vessel motions is made by any of several methods which may include time- or frequency-domain modeling, model test extrapolation or rules of thumb.

### • Mooring Line Load Estimation

In the most sophisticated analyses, a time-domain evaluation of wave-frequency load oscillations in the most exposed mooring lines, as determined by the fairlead motions determined in the preceding steps, is carried out. This part of the calculation is so computationally extensive that seldom, if ever, is the analysis extended to all mooring lines.

At a lower level of sophistication, rather than performing a fully dynamic line load analysis, many analysts simply apply the estimated fairlead motions, comprising both low- and wave-frequency components, to static catenary offset curves for the mooring lines to infer wave-frequency mooring load fluctuations. This procedure so seriously underestimates the level of dynamical line load fluctuations in many cases of importance that its use should not be tolerated under any circumstances.

The fragmented approach to comprehensive mooring system performance analysis described above can seldom be carried to completion in less than one or two man-weeks, requiring as it does the interfacing of five or more independent software modules or equivalent hand calculations (mooring statics, environmental load calculation, low-frequency motion estimation, vessel wave-frequency motion analysis, dynamical line load analysis). By contrast, a full execution can be executed in seconds using **SeaSoft** on a desktop microcomputer after perhaps one hour of data preparation and input. Run in batch mode, **SeaSoft** programs are capable of processing in excess of ten thousand unique environments in an overnight batch run on today's microcomputers.

### **Comparison with Time-Step Simulations**

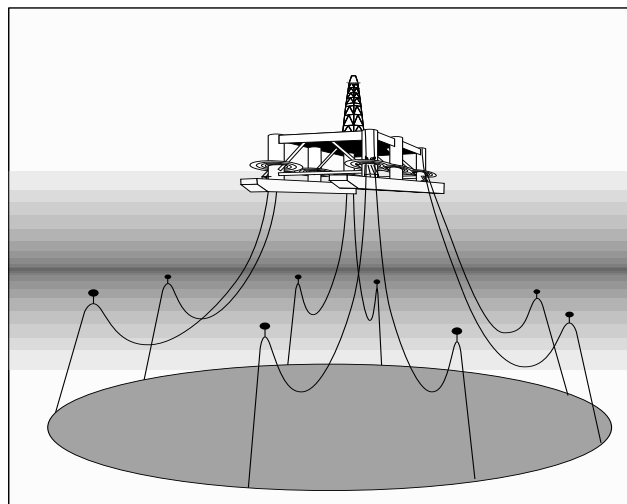
In offshore engineering, time-domain computer calculations have historically played a central role in the analysis of all types of mooring systems because of the importance and ubiquity of nonlinear effects in these systems; time-domain analysis provides a

straightforward and formally unobjectionable tool for dealing with such nonlinearities. However, this approach can be faulted on account of both its manpower inefficiency and its ineffectiveness in producing a useable analytical model of the systems of interest.

Some of the most important features of moored vessel dynamics *cannot* be adequately addressed in a time-domain simulation. Two aspects of time-domain inadequacy are particularly troublesome with regard to catenary-based mooring systems: the *long natural periods of motion* associated with low-frequency oscillations and the overwhelming *multi-line computational overhead* required to obtain line load time histories for all mooring lines.

### • Long Natural Periods of Motion

In the analysis of moored vessels in deep water, it is not uncommon to find natural periods of surge, sway and yaw of 10 to 30 minutes. Even in shallow water, single point mooring systems often have natural periods of sway/yaw motions exceeding 20 minutes. In order to obtain meaningful statistical information on the low-frequency component of mooring system motions and loads under these conditions, 50 to 100 cycles of low-frequency motion should be modeled since



the nonlinearity of the processes formally precludes inferring the probability distribution for mooring loads and other dynamical variables from a short time history. (By contrast, linear systems excited by Gaussian input variables can be characterized by a relatively short time history since only the rms amplitudes of output variables need be determined to completely specify the Gaussian output probability distributions). Therefore, using a time-domain simulation, a typical computer run comprising 10 to 30 prototype hours would be necessary to predict peak motion and load probability distributions. Note that the simulation should be run for this length of time even to simulate a much shorter (say, 4 hour) storm in order to reliably estimate the peak load probability distribution, which estimate must in-

clude, in essence, an ensemble of several non-identical but statistically equivalent 4-hour storm time series because of the very long natural periods involved.

- **Multi-Line Computational Overhead**

For catenary-based mooring systems, simulations and model tests have shown that in many realistic situations, nonlinear wave-frequency dynamical effects can conspire to produce extremely large line load variations in the "slack", or "down-weather" lines, contrary to intuition; this fact normally requires modeling of each mooring line, not simply the most exposed lines. In a formally complete time-domain development this results in an immense calculational load since generally a minimum of 8 lines are involved, all with different average tension levels and different fairlead motion time histories. In the event loads and damping from riser hoses and other flexible structures require simulation, the number of lines involved can approach 100.

Time-domain simulation of 10 to 30 prototype-scale hours of a system as complex as a catenary-moored vessel and its complement of mooring lines and risers in deep water is out of the question for day-to-day engineering practice, even on the next generation of supercomputers. These problems are much more sensibly treated according to nonlinear approximation methods applicable to narrow-banded spectral processes that bypass entirely the time-domain approach in favor of the solution of nonlinear quasi-periodic systems. There currently exist excellent, benchmarked, analytical tools, used in all **SeaSoft** programs, based on a marriage of the analysis of nonlinear periodic systems with nonlinear statistical methods, which circumvent this computational load, bypassing completely conventional time-domain analysis.

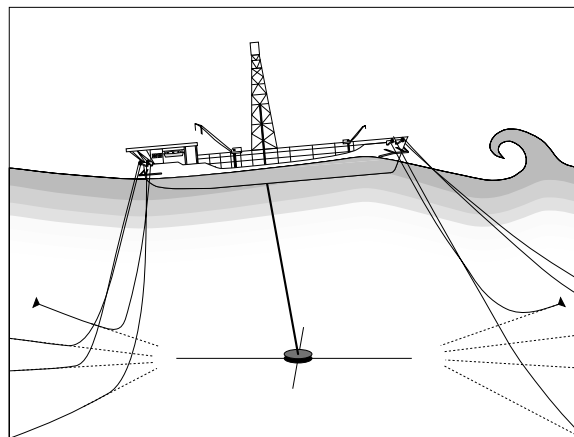
In summary, accumulated evidence from experienced offshore engineering analysts suggests that a brute force attack in the time domain is rarely the most productive procedure for analysis of catenary-

based mooring systems and is unlikely to provide a software solution which is useable on a day-to-day basis by engineering staff. Too cumbersome to use and too demanding of computational resources, time-domain simulations are characterized by voluminous output streams and difficult-to-interpret results; they are unlikely to find a permanent place in the "engineers toolbox".

## GENERAL FEATURES

**Moorsim** and **SPMsim** share with all **SeaSoft** programs the following general features:

- Input/output of data in either English or metric units.
- Attractive formatted tabular output on 8-1/2 x 11 inch sheets for easy inclusion in reports or other documentation.
- Transportability to virtually any computer, achieved by careful adherence to ANSI FORTRAN-77 standards in source code preparation. All code has been carefully optimized to execute efficiently on microcomputers.
- Output control, allowing user selection of output variables for each run and specification of output device (console, printer or magnetic media).
- Complete control over water depth, with full accommodation of shallow-water wave effects which generally become significant in water less than 300 feet deep whenever wave periods exceed about 14 seconds or when wind-driven seas exceed a significant wave height of about 30 feet.
- A comprehensive user manual which outlines program use and explains in detail its capabilities. The manual contains a detailed sample input/output session comprising a realistic application. The manual includes a table of contents, a glossary and an index.
- A data entry and editing interface (the "editor")



which provides simplified access to the main computational program. The editor permits input files, once created, to be easily modified to account for major or minor changes or errors. The editor program utilizes an easy-to-use single-item replacement format for data entry and update. Input files can be archived and reused any number of times. Backup files are made each time an input file is modified, facilitating the archival process and protecting against inadvertent loss of important data. Built-in "help" menus virtually eliminate the need for user manual reference. Insofar as possible, these programs use the same input/output format, procedures and nomenclature conventions as other **SeaSoft** programs so that the user of any **SeaSoft** product will easily be able to use and interpret program procedures and results.

These programs share with all **SeaSoft** program packages the following *regular wave* capabilities:

- Complete user control over regular wave periods, directions, and wave heights or slopes used in calculation of regular wave response characteristics (RAOs).
- Output of both amplitude and phase of regular wave response characteristics for all requested regular wave conditions and all requested output variables.
- Wave-height dependent RAOs, reflecting important system nonlinearities.

These programs share with all **SeaSoft** program packages the following *irregular wave* capabilities:

- Wave spectral type specification, including:
  - Pierson-Moskowitz
  - Mean, Sharp, Very Sharp JONSWAP
  - Bretschneider/ISSC
  - User-Specified
- Calculation of r.m.s. values, r.m.s. rates and characteristic spectral periods of all requested variables.

- Specification of the degree of azimuthal spreading of irregular wave energy; i.e., the degree of wave crest shortening due to cross seas, leading to modeling of operations in short-crested irregular waves.
- Specification of simultaneous swell (period, height, direction).

### **PROGRAM PACKAGE CONTENTS**

Complete packages comprise the user manual, the machine-executable program units, and support services provided by **SeaSoft**. The latter include bug reports, corrections and support for user problems encountered during execution.

#### ***Editor***

The Editor module is used to create an input data file which is required for execution of the Executor. This input file contains physical information necessary for the program such as water depths, vessel physical characteristics, and so on. The file results from an interactive session between the user and the Editor. The Editor can also be used to modify any previously created input data file, which will be necessary if the vessel characteristics or site or environmental characteristics need to be changed prior to another execution of the program.

#### ***Executor***

The Executor is the heart of the packages. It carries out all computations requested during input file creation and prepares formatted tabular output containing results of the program run. The formatted output will be transmitted to the console, the print device, or to a formatted output file according to instructions given by the user during preparation of the input file.

#### ***User Manual***

The user manual constitutes the major tutorial tool provided with the program package. The manual includes an extensive glossary and an index which, along with the table of contents, permits quick location of specific topics.



## Support Services

SeaSoft provides software maintenance and support services at no cost for a six month period following license purchase and on a contractual basis thereafter; support is generally included in the lease fee for software lease agreements.

## PROGRAM OVERVIEW

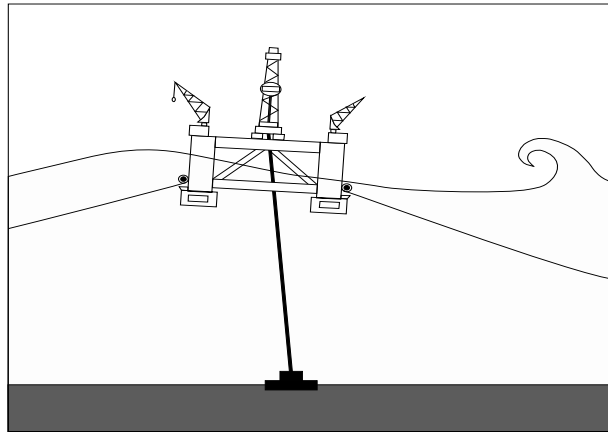
As outlined earlier in this document, a comprehensive program must include three distinct phases of calculation: "Static", "low-frequency" (typical periods of oscillation of one to twenty minutes) and "wave-frequency" (typical periods of oscillation of 4 to 20 seconds). The logical program flow thus comprises:

### Statics

- Calculation of static offset characteristics for each of up to sixteen mooring line types, where each line type comprises up to ten uniform, nonlinear elastic sublimes; each of these can be assigned arbitrary mass, elastic and hydrodynamic properties. The calculation incorporates a proprietary (analytically exact) treatment of the nonlinear catenary-elastic behavior of mooring line materials.

- For determination of mean mooring line profile, any one of the following specification conditions may be used: line tension at fairlead, horizontal line tension component, fairlead-anchor separation, line departure angle from horizontal at fairlead.

- The user-interface program (the Editor) has extensive help capabilities to provide weight, elasticity and breaking strength estimates for a wide range of mooring materials including wire rope, chain, Kevlar, polypropylene and nylon.



- Low-frequency vessel motions in the moor can be excited by slowly-varying wind and current speeds and by the action of second-order wave-drift forces. All these conditions are modeled in order to obtain a realistic estimate of forces acting to drive low-frequency oscillations of the system and the periods and amplitudes of resulting oscillations. Wave-drift forces are automatically computed; alternatively, they can be supplied by the user for special applications.

- Damping of low-frequency motions is automatically determined using a comprehensive nonlinear model for current, wind, wave and mooring line damping contributions. Alternatively, low-frequency damping levels may be user specified.

- Low-frequency motions give rise to low-frequency mooring line tension oscillations whose magnitude is inferred from the oscillation amplitude and the static restoring force curve computed for each mooring line.

- The natural periods, rms and storm-extreme low-frequency vessel motion amplitudes and low-frequency contribution to line tension oscillations are estimated.

### Wave-Frequency Dynamics

Wave-excited dynamics are characterized by extensive regular and irregular wave calculations. These features

provide complete flexibility for modeling of realistic full-scale conditions as well as model-basin test conditions.

### Regular Wave Analysis

Wave-frequency contributions to vessel motions are computed at the vessel position as determined by the specified mean mooring line profile and the



modeled low-frequency oscillations. This calculation is normally done by one of the **SeaSoft** vessel motion programs; for example **Shipsim**, **Discsim** or **Semisim**. Alternatively, vessel motion RAOs can be user supplied. Vessel motion calculation is carried out in the frequency domain and wave-frequency vessel motions are assumed to be uninfluenced by mooring line tension oscillations. (Low-frequency vessel motions, by contrast, depend heavily on mooring line tension oscillations.) Calculation of maximum and minimum mooring line tension values at fairlead and anchor due to regular wave excitation is fully nonlinear. Regular wave characteristics including amplitude, period and direction relative to still-water vessel heading are specifiable.

- **Irregular Wave Analysis**

The results of regular wave motion calculations for the vessel are superposed to provide irregular wave mooring line fairlead motion statistics. These fairlead motions are then used in turn as input for a nonlinear irregular wave analytical model of mooring line tension oscillations. The outputs from these calculations are statistics of fairlead motions and mooring line tension oscillations at fairlead and anchor, including maximum/minimum expected line tension values for a given storm duration. The irregular wave calculation can be done for a wide choice of irregular wave spectra and for either long-crested irregular waves such as those produced in a wave basin, or naturally occurring short-crested irregular waves. In addition an independent swell component of arbitrary height, period and direction can be specified simultaneously with the irregular sea.

- **Mooring Line Design Analysis**

For mooring line design purposes the analysis of system response to wave excitation, described above, is supplemented by a wave-frequency analysis of mooring line performance which is unencumbered by the complex phasing of the six degrees of vessel motion in a wave field. This analysis comprises, at each specified period of oscillation, a modeled user-specified constant amplitude tangential motion of the fairlead end of the mooring lines, which artificial motion thereby serves to excite mooring line tension oscillations. This capability is useful for standardized quantitative characterization of mooring line performance at wave frequencies.

### **Characteristic & Peak Tension Estimates**

These programs provide a variety of options for characterization of line loads in irregular wave conditions, including estimates of the mean tension level, the one or two standard deviation tension level, the most probable peak tension level in a storm of specified duration, and upper/lower bounds on the storm peak tension levels. The bounding calculations are useful because they are independent of assumptions relating to the statistical independence or correlation between low- and wave-frequency load contributions; they therefore give an indication of peak load estimate sensitivity (and hence, uncertainty) to the underlying design and environmental setting.

### **INPUT FILE PREPARATION**

For execution, the programs require data of four distinct generic types: (1) site data consisting of water depth and water density, (2) physical data on the mass and geometrical properties of the vessel, (3) a physical description of each mooring leg and (4) environmental data comprising principally regular and irregular wave conditions desired for the program.

#### **Site Data and Units of Measure**

The characteristics of the site chosen for the program must be available to the program; these are site water depth and water density. Fluid density is completely specifiable so that unusual conditions, such as very high salinity (and hence high density), can be easily modeled. The water depth is required so that correct shallow-water wave characteristics will be used in the program. The programs account automatically for all shallow water effects, including wavelength foreshortening and wave speed reduction. The choice of units to be used may be either English (e.g., foot/pound/second) or metric (meter/kilogram-weight/second).

#### **Vessel Data**

These programs have been designed for seamless integration with other **SeaSoft** wave-frequency vessel motion modules such as **Semisim**, **Shipsim** and **Discsim**. The vessel data required by these programs is, generally speaking, an absolute mini-

mum required for realistic motion modeling; in particular, it is not necessary to be in possession of lines drawings to perform meaningful motion programs for any of these programs. Alternatively, vessel response data can be imported from non-SeaSoft vessel motion programs, if required.

### **Waves**

Environmental conditions that can be specified for modeling comprise three classes of wave data: regular waves, irregular waves and swell. Because one often finds "cross seas" in which irregular waves from a local weather disturbance are superimposed upon an unrelated swell from a distant storm, The programs permit specification of either irregular waves or background swell or both.

#### **• Regular Wave Characteristics**

Regular waves are simply long-crested surface waves of well-defined period. Waves of this type are commonly used in wave basin measurements to determine the RAOs ("Response Amplitude Operators") of a vessel. The programs begin by calculating, at a user-specified collection of regular wave periods, system force, torque and motion response characteristics (i.e., RAOs). The choice of regular wave periods to be used in RAO calculations will depend on whether or not irregular wave performance is to be estimated.

#### **• Irregular Wave Characteristics**

Irregular waves in nature can be considered a superposition of regular waves of differing periods and directions. In test facilities, however, it is generally not feasible to obtain a spread in wave directions due to the need to generate waves with a single monolithic wavemaker, although some testing facilities do have limited capabilities for generating multi-directional waves. The programs permit analysis of both types of irregular waves (i.e. short and long crested) so that both model basin tests and open ocean conditions may easily be modeled. The degree of wave-crest shortening due to azimuthal spreading of wave energy is under precise user control.

Many standard irregular wave spectra are built into these programs, including Bretschneider, Pierson-Moskowitz, and Mean, Sharp and Very Sharp Jonswap. In addition, there is provision for a user-specified spectrum.

#### **• Swell Characteristics**

Swell is a special class of irregular wave which is important in nature and therefore has been incorporated into the programs. Swell can be considered a superposition of regular waves of differing, but nearly equal, wave periods all with the same direction (i.e. the frequency spectrum is very narrow banded and the swell is long crested). This type of irregular wave is characterized by the phenomenon of "beats" or "sets" in which one observes clusters of larger waves separated by quieter periods with much smaller waves. Swell is generally associated with relatively long waves from the site of distant weather systems. Irregular seas, by contrast, are normally considered to have developed locally and recently by action of local winds. They therefore have a relatively high content of short-period waves which have not had sufficient time to decay due to dissipative and non-linear mechanisms or to propagate away from the local area.

The swell spectrum utilized is a characteristic narrow-banded spectrum with user-specifiable direction, height, spectral width and peak period.

### **Wind**

Wind is modeled by specifying mean speed, direction and speed fluctuation spectrum at the 10 meter level above the sea surface. Built-in spectral types include Davenport and API spectra, user-specified spectra and steady wind (no speed fluctuation).

### **Current**

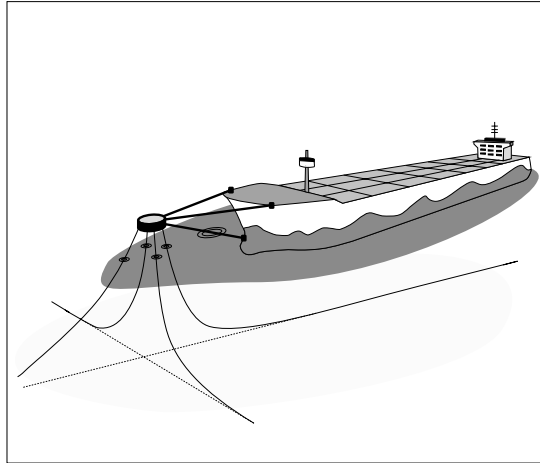
Current is modeled by specifying the mean speed, direction and speed fluctuation spectrum at the sea surface. Built-in spectral types include user-specified spectra and steady current (no speed fluctuation). Current speed variation with depth is accommodated by a constant profile (no variation with depth), a standard 1/7th power law decay with depth, and a user-specified profile.

### **External Forces**

The capability of specifying, in addition to environmental forces, external forces and moments on the vessel has been incorporated to permit modeling of the action of thrusters, tugboats, or various wave-basin testing practices such as the emulation of constant wind or current by constant forces applied to the vessel.

## MOORSIM - SPMSIM DIFFERENCES

From the user's point of view **SPMsim** is, for practical purposes, operationally identical to **Moorsim**; the principal difference in these two programs is the way low-frequency vessel motions are treated. **SPMsim** applies to catenary-based single-point mooring systems, primarily turret-moored vessels. For this class of system, the three low-frequency degrees of freedom of the vessel (surge, sway and yaw) can be approximately characterized by three normal modes comprising a "surge" mode lying in a plane defined by the equilibrium offset vector of the mooring point (e.g., the turret) and two coupled "sway-yaw" modes. This classification, which depends specifically on the single-point nature of the mooring structure, requires a different low-frequency dynamical model than spread-mooring configurations of the type modeled by **Moorsim**.



- The designer of mooring systems for deepwater semisubmersibles is trying to justify use of line support buoys in his design. The extreme water depth precludes a comprehensive model test of the system. Does a full dynamical model, including subtleties such as the role of the buoys in damping low-frequency vessel oscillations in the moor, indicate that the buoy solution is dynamically preferable to a straight wire-rope moor?

## TYPICAL APPLICATIONS

- A drilling company wishes to bid on a drilling contract for a lease area in water deeper than that for which their wire-rope mooring system was designed. Will the simple addition of anchor-end chain provide the required station keeping capability and will the redesigned mooring system produce tolerable line tension oscillations in the forecast 10 year storm?

- A drilling company is experiencing periodic link failures in the oil-rig-quality mooring chain on a drillship even though logs of shipboard tensiometer readouts do not indicate that line tensions have exceeded tolerable limits. Can the repeated failures be attributed to predictable environmentally-produced line tension oscillations, perhaps implicating maladjusted tensiometer equipment, or is the quality of the chain suspect?

- A moored weather buoy is lost due to a mooring line failure in an exceptionally heavy winter storm. Can the line failure be attributed to the storm alone, or is material fatigue implicated?

- The operator of a spread-moored drillship in the path of an intense tropical storm demands a most-loaded line safety factor of two, based upon forecast environmental conditions at the drillsite, before permitting the vessel and crew to ride out the storm in the full moor. Does the existing moor meet this requirement, and if not, will a relatively minor heading adjustment, accomplished by line payout adjustments, help in meeting the requirement?

- The operator of a bow-mounted turret-moored production tanker wishes to use a tugboat to pull the stern of the vessel into the prevailing wind and waves to provide a quiet leeward zone for offloading operations. Can this operation be carried out without compromising the integrity of the turret structure, which was not designed for the transverse loads which will be associated with this maneuver?

- What is the worst-case environment (wave, wind and current) out of a discreet historical database of 20,000 environment conditions with respect to turret loads on an FPSO moored in the Gulf of Mexico? Does this worst case environment depend on vessel loading?

The following appendices document a trial run of **Moorsim**. Appendix A contains samples of operator console displays presented during a session with the user-interface program used to create and modify the data file required for program execution. Appendix B contains overall system-related tabular output from **Moorsim**. Appendix C contains sample vessel-specific output.

APPENDIX A: Sample Input Stream

NOTES:

The following pages are hardcopy images of console screens which might occur during a typical execution of **Moorsim**. These screens will be referred to by their "Console Page Numbers", as given in the starred headers, rather than by appendix page number appearing at the bottom of the page. (For example, "Console Page 1" corresponds to "\*\*\*\* Page 1: Site conditions \*\*\*\*" below.)

Data input is accomplished by selecting the number of a data value which is to be changed whereupon the user is prompted for the new value. (For example, selection of item 4 on Console Page 1 below will produce a prompt to input a new "Site water depth".) Some items are "toggles"; selection of such items results in the "toggling" of the item to its alternative value. For example, selection of item 3 ("Units of measure") on Console Page 1 below would induce a toggle from "English" to "Metric" units.

Operations requiring the input of a large number of equally spaced values (for example, the wave period array on Console Page 13) may be carried out, at user discretion, by a fast automated procedure which permits input of an entire array by specifying its initial value and the increment between values.

```

+-----+
|                                             |
|                                             |
|          **  Welcome to MoorSim  **          |
|                                             |
|          MoorSim  Version 2.93             |
|          Copyright (C) 1988 by             |
|          Richard J. Hartman, Ph.D.         |
|                                             |
+-----+

```

\*\*\*\* Page 1: Site conditions \*\*\*\*

Two-line Identification for this execution:

```

1) [Generic Drillship ]
2) [16' P-M SWH; 1 kt current; 34 kt wind, all on the beam ]
3) Units of measure: English
4) Site water depth:      3000.00 feet

```

```

5) Water density:      64.00 lbs/cubic foot

**** Page 2: General Mooring Information ****

1) Fairlead layout characterization: Spread Moor
2) Number of mooring legs (Max 16) ..... 8
3) Number of distinct mooring leg types (Max 16) 1
4) Maximum horizontal load ..... 1000.00 kips
5) Number of points in interpolation table(s) ... 30
6) Mean line profile determined by ..... line tension
7) Modify individual values of line tension

8) Low-frequency surge damping is ..... Computed
10) Low-frequency sway damping is ..... Computed
12) Low-frequency yaw damping is ..... Computed

14) Reset default added mass coefficient ..... 1.00
15) Reset default square-law drag coefficient ..... 1.00

```

line tension

```

1) 100.00
2) 100.00
3) 100.00
4) 100.00
5) 100.00
6) 100.00
7) 100.00
8) 100.00

9) Auto repeat

**** Page 3: More General Mooring Information ****

1) Number of mooring legs associated with each type -
   8 in Type A
2) Number of sublimes associated with each type -
   2 in Type A

3) Edit fairlead positions
4) Edit plan-view line departure angles

5) Number of lines for dynamic evaluation (Max 16): 4
6) Line numbers selected for dynamic evaluation:
   7, 8, 1, 2,

7) Vessel heading in quiescent conditions:      .00 Degrees
8) Vessel type for dynamics ..... Ship/barge-type

- Mooring line type multiplicity -

1) 8.00

```

2) Auto repeat  
 - Number of sublins for each distinct type -  
 1) 2.00  
 2) Auto repeat

>>> Enter coordinates for Fairleads

	x	y	z
1)	224.00	10.40	50.00
2)	206.00	19.20	50.00
3)	-216.00	23.20	50.00
4)	-222.00	11.20	50.00
5)	-222.00	-11.20	50.00
6)	-216.00	-23.20	50.00
7)	206.00	-19.20	50.00
8)	224.00	-10.40	50.00

Plan-view GLOBAL Angles (Zero forward; Positive C-clockwise)

1) 22.50  
 2) 67.50  
 3) 112.50  
 4) 157.50  
 5) 202.50  
 6) 247.50  
 7) 292.50  
 8) 337.50

9) Auto repeat

\*\*\*\* Page 3A: Subline Specifics \*\*\*\*

-> Subline attached to fairlead

1) Moor leg type A (of 1 type(s))  
 2) Subline number: 1 of 2

3) Subline composition .....	Wire
4) Subline length .....	6000.00 feet
5) Subline outside diameter .....	3.00 inches
6) Wt/unit length in water .....	13.86 lbs/foot
7) Breaking strength .....	827.10 kips
8) Added mass coefficient .....	1.00
9) Transverse drag coefficient .....	1.00
10) Compliance coefficient #1 (alpha1) .....	0.157E-04 (k.lbs)**-1
11) Compliance coefficient #2 (alpha2) .....	0.000E+00 (k.lbs)**-2
12) Compliance coefficient #3 (alpha3) .....	0.000E+00 (k.lbs)**-3
15) Line numbers associated with type A:	1, 2, 3, 4, 5, 6, 7, 8,

("?" for default physical data: "C", "D", "I" to Copy, Delete, Insert)

\*\*\*\* Page 3A: Subline Specifics \*\*\*\*

-> Subline attached to anchor

1) Moor leg type A (of 1 type(s))  
 2) Subline number: 2 of 2

3) Subline composition .....	Chain
4) Subline length .....	1000.00 feet
5) Subline outside diameter .....	2.75 inches
6) Wt/unit length in water .....	65.71 lbs/foot
7) Breaking strength .....	815.24 kips
8) Added mass coefficient .....	1.00
9) Transverse drag coefficient .....	3.00
10) Compliance coefficient #1 (alpha1) .....	0.116E-04 (k.lbs)**-1
11) Compliance coefficient #2 (alpha2) .....	0.000E+00 (k.lbs)**-2
12) Compliance coefficient #3 (alpha3) .....	0.000E+00 (k.lbs)**-3

Appendix B: Sample Mooring Output

SeaSoft Systems Program Library

Volume 12

Catenary Spread-Moor Vessel Model

MOORSIM Version 2.93

Copyright (C) 1988  
By Richard J. Hartman, Ph.D.

Generic Drillship  
16' P-M SWH; 1 kt current; 34 kt wind, all on the beam

\*\*  
\*\*\*\*\* I. Line Characteristics Summary \*\*\*\*\*  
\*\*

>>> Line Type A of 1 Type(s)

- Segment - Type	Length (ft)	Nominal Diameter (in)	Submerged Weight (lbs/ft)	— Elastic Coefficients —		
				Alpha 1 (k.lbs** <sup>-1</sup> )	Alpha 2 (k.lbs** <sup>-2</sup> )	Alpha 3 (k.lbs** <sup>-3</sup> )
1 Wire	6000.00	3.00	13.86	0.157E-04	0.000E+00	0.000E+00
2 Chain	1000.00	2.75	65.71	0.116E-04	0.000E+00	0.000E+00

Table Index	Top	Anchor	Horizontal	- Line angle -		Endpoint	Bottom
	Tension (k.lbs)	Tension (k.lbs)	Tension (k.lbs)	Top (deg)	Anchor (deg)	Separation (ft)	Length (ft)
1	41.96	.00	.00	90.0	.0	3973.50	3973.50
2	51.94	10.00	10.00	78.9	.0	5006.31	3324.28
3	53.73	11.79	11.79	77.3	.0	5089.06	3219.82
4	55.83	13.89	13.89	75.6	.0	5173.80	3100.29
5	58.32	16.38	16.38	73.7	.0	5259.96	2963.93
6	61.24	19.31	19.31	71.6	.0	5346.93	2808.90
7	64.69	22.76	22.76	69.4	.0	5434.07	2633.22
8	68.76	26.83	26.83	67.0	.0	5520.78	2434.82
9	73.55	31.62	31.62	64.5	.0	5606.46	2211.50
10	79.20	37.28	37.28	61.9	.0	5690.58	1960.96
11	85.86	43.94	43.94	59.2	.0	5772.66	1680.77
12	93.71	51.79	51.79	56.4	.0	5852.30	1368.36
13	102.96	61.05	61.05	53.6	.0	5929.17	1021.03
14	114.02	71.97	71.97	50.9	.0	5998.15	920.90
15	127.37	84.83	84.83	48.2	.0	6055.10	820.90
16	143.38	100.00	100.00	45.8	.0	6103.01	703.19
17	162.44	117.88	117.88	43.5	.0	6144.46	565.87
18	185.04	138.95	138.95	41.3	.0	6181.55	406.88
19	211.75	163.79	163.79	39.3	.0	6215.92	224.03
20	243.22	193.07	193.07	37.5	.0	6248.82	14.93
21	280.42	228.07	227.58	35.7	3.8	6278.04	.00
22	324.58	270.39	268.27	34.3	7.2	6301.24	.00
23	376.89	321.17	316.23	33.0	10.1	6320.39	.00
24	438.77	381.79	372.76	31.8	12.5	6337.00	.00
25	511.88	453.87	439.40	30.9	14.5	6352.30	.00
26	598.20	539.34	517.95	30.0	16.2	6367.25	.00
27	700.03	640.49	610.54	29.3	17.6	6382.65	.00
28	820.10	760.02	719.69	28.7	18.8	6399.21	.00
29	961.62	901.14	848.34	28.1	19.7	6417.58	.00
30	1128.38	1067.59	1000.00	27.6	20.5	6438.40	.00

\*\*  
 \*\*\*\*\* II. Equilibrium Condition Summary \*\*\*\*\*  
 \*\*

>>> Program-estimated still-water line conditions

Line #/Type	Total Tension (k.lbs)		Horizontal Tension (k.lbs)	Endpoint Separation (ft)	Bottom Length (ft)	Fairlead Line Angle (deg)	
	Top	Anchor				Plan	Profile
1/a	100.00	58.09	58.09	5904.57	1132.19	22.50	54.53
2/a	100.00	58.09	58.09	5904.57	1132.19	67.50	54.53
3/a	100.00	58.09	58.09	5904.57	1132.19	112.50	54.53
4/a	100.00	58.09	58.09	5904.57	1132.19	157.50	54.53
5/a	100.00	58.09	58.09	5904.57	1132.19	202.50	54.53
6/a	100.00	58.09	58.09	5904.57	1132.19	247.50	54.53
7/a	100.00	58.09	58.09	5904.57	1132.19	292.50	54.53
8/a	100.00	58.09	58.09	5904.57	1132.19	337.50	54.53

\*\*  
 \*\*\*\*\* II. Equilibrium Condition Summary \*\*\*\*\*  
 \*\*

>>> Specified environmental conditions produced the following net moment and force components:

	Global system	Vessel system
X Force	.13 k.lbs	.31 k.lbs
Y Force	-271.16 k.lbs	-271.16 k.lbs
Vertical Moment	846.86 foot-kips	846.86 foot-kips

>>> Specified environmental conditions produced the following net global quasi-static displacements:

	Global system	Vessel system
X Displacement	.24 ft	.47 ft
Y Displacement	-323.98 ft	-323.98 ft
Yaw Displacement	-.04 deg	-.04 deg
Vessel Orientation	359.96 deg	

>>> Estimated mean line conditions in specified environment

Line #/Type	Total Tension (k.lbs)		Horizontal Tension (k.lbs)	Endpoint Separation (ft)	Bottom Length (ft)	Fairlead Line Angle (deg)	
	Top	Anchor				Plan	Profile
1/a	122.85	80.48	80.48	6035.82	854.76	25.34	49.13
2/a	203.40	156.02	156.02	6205.17	281.23	68.65	39.96
3/a	203.33	155.96	155.96	6205.09	281.65	111.36	39.96
4/a	122.93	80.55	80.55	6036.14	854.19	154.66	49.11
5/a	87.43	45.51	45.51	5788.61	1618.19	199.54	58.66
6/a	73.58	31.65	31.65	5606.85	2210.32	246.23	64.52
7/a	73.55	31.62	31.62	5606.40	2211.64	293.77	64.54
8/a	87.38	45.46	45.46	5788.06	1620.34	340.46	58.68



Appendix C: Sample Vessel Output

SeaSoft Systems Program Library

Volume 1

Displacement-Hull Offshore Vessels

SHIPSIM Version 3.2

Copyright (C) 1988  
By Richard J. Hartman, Ph.D.

Generic Drillship  
16' P-M SWH; 1 kt current; 34 kt wind, all on the beam

\*\*  
\*\*\*\*\* I. PHYSICAL CHARACTERISTICS SUMMARY \*\*\*\*\*  
\*\*

— SITE CHARACTERISTICS —

WATER DEPTH ..... 3000.00 FEET  
WATER DENSITY ..... 64.00 LBS/CUBIC FOOT

— VESSEL CHARACTERISTICS —

DISPLACEMENT ..... 33042.00 K.LBS  
VERTICAL (Z) KB ..... 13.00 FEET  
VERTICAL (Z) KG ..... 27.50 FEET  
LONGITUDINAL GM ..... 576.50 FEET  
TRANSVERSE GM ..... 4.89 FEET  
PITCH GYRADIUS ..... 103.40 FEET  
ROLL GYRADIUS ..... 28.80 FEET  
YAW GYRADIUS ..... 107.40 FEET

— DYNAMICALLY SIMILAR BOX CHARACTERISTICS —

BOX LENGTH ..... 370.35 FEET  
BOX WIDTH ..... 72.49 FEET  
BOX DRAFT ..... 19.23 FEET

\*\*  
\*\*\*\*\* II. UNMOORED VESSEL MOTION CHARACTERISTICS \*\*\*\*\*  
\*\*

— NATURAL PERIODS AT ZERO SPEED —

NATURAL ROLL PERIOD . . . . . 18.1 SECONDS  
NATURAL PITCH PERIOD . . . . . 7.1 SECONDS  
NATURAL HEAVE PERIOD . . . . . 7.8 SECONDS

— QUASI-LINEAR ZERO SPEED DAMPING COEFFICIENTS —

NATURAL ROLL DAMPING . . . . . 3.9 PERCENT  
NATURAL PITCH DAMPING . . . . . 13.1 PERCENT  
NATURAL HEAVE DAMPING . . . . . 16.9 PERCENT

REGULAR WAVE HEIGHT . . . . . 11.3 FEET  
WATER DEPTH . . . . . 3000.0 FEET

\*\*  
\*\*\*\*\* II. UNMOORED VESSEL MOTION CHARACTERISTICS \*\*\*\*\*  
\*\*

— REGULAR WAVE DATA: WAVE HEADING = 270.0 DEG  
WAVE HEIGHT = 11.3 FT  
FORWARD SPEED = .0 FT/SEC

+++ QUASI-LINEAR RESPONSE RAOs (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE SLOPE (DEG)	SURGE	SWAY	HEAVE
			(FT./FT.)	(FT./FT.)	(FT./FT.)
			AM/PHASE	AM/PHASE	AM/PHASE
5.00	128.1	15.88	0.00/ -90.4	.36/ 89.7	.06/ -116.4
6.00	184.5	11.02	0.00/ -93.2	.56/ 87.8	.25/ -109.7
7.00	251.1	8.10	0.00/ -99.2	.69/ 83.6	.67/ -92.6
8.00	328.0	6.20	0.00/ -105.7	.79/ 79.0	1.22/ -60.2
9.00	415.1	4.90	0.00/ -110.2	.85/ 75.6	1.35/ -31.9
10.00	512.5	3.97	0.00/ -112.4	.90/ 74.0	1.28/ -17.4
11.00	620.1	3.28	0.00/ -112.6	.92/ 73.8	1.21/ -10.2
12.00	738.0	2.76	0.00/ -111.7	.94/ 74.6	1.15/ -6.4
13.00	866.1	2.35	0.00/ -110.0	.95/ 75.8	1.12/ -4.2
14.00	1004.5	2.02	0.00/ -108.1	.96/ 77.2	1.09/ -2.8
15.00	1153.1	1.76	0.00/ -106.0	.96/ 78.7	1.07/ -2.0
16.00	1311.9	1.55	0.00/ -104.1	.96/ 80.1	1.06/ -1.4
17.00	1481.1	1.37	0.00/ -102.3	.97/ 81.4	1.05/ -1.0
18.00	1660.4	1.22	0.00/ -100.7	.97/ 82.5	1.04/ -.7
19.00	1850.0	1.10	0.00/ -99.3	.97/ 83.5	1.03/ -.6

\*\*  
\*\*\*\*\* II. UNMOORED VESSEL MOTION CHARACTERISTICS \*\*\*\*\*  
\*\*

— REGULAR WAVE DATA: WAVE HEADING = 270.0 DEG  
WAVE HEIGHT = 11.3 FT  
FORWARD SPEED = .0 FT/SEC

+++ QUASI-LINEAR RESPONSE RAOs (S.A./S.A.) +++

WAVE PERIOD (SEC)	WAVE LENGTH (FT)	WAVE SLOPE (DEG)	ROLL	PITCH	YAW
			(DEG/DEG)	(DEG/DEG)	(DEG/DEG)
			AM/PHASE	AM/PHASE	AM/PHASE
5.00	128.1	15.88	.18/ 87.0	0.00/ -73.7	0.00/ -.3
6.00	184.5	11.02	.41/ 81.5	0.00/ -41.4	0.00/ -2.2
7.00	251.1	8.10	.64/ 77.3	0.00/ 11.6	0.00/ -6.4
8.00	328.0	6.20	.85/ 75.6	0.00/ 54.6	0.00/ -11.0
9.00	415.1	4.90	1.02/ 75.7	0.00/ 73.3	0.00/ -14.4
10.00	512.5	3.97	1.17/ 77.1	0.00/ 81.7	0.00/ -16.0
11.00	620.1	3.28	1.30/ 79.0	0.00/ 85.7	0.00/ -16.2
12.00	738.0	2.76	1.43/ 81.3	0.00/ 87.8	0.00/ -15.4
13.00	866.1	2.35	1.59/ 83.8	0.00/ 88.8	0.00/ -14.2
14.00	1004.5	2.02	1.79/ 86.8	0.00/ 89.4	0.00/ -12.8
15.00	1153.1	1.76	2.08/ 90.7	0.00/ 89.7	0.00/ -11.3
16.00	1311.9	1.55	2.60/ 97.2	0.00/ 89.8	0.00/ -9.9
17.00	1481.1	1.37	3.75/ 112.3	0.00/ -91.0	0.00/ 171.4
18.00	1660.4	1.22	5.34/ 164.8	0.00/ 89.9	0.00/ -7.5
19.00	1850.0	1.10	2.32/ -139.3	0.00/ -90.5	0.00/ 173.5