Appendix H

Description of STARIS

STARIS Riser Dynamics Simulation

Starmark Offshore's STARIS riser dynamics computer software package is a versatile tool that investigates the dynamic behavior (including motions, lateral, angular, and axial displacements, and stresses) of marine drilling, running, completion, workover, and production risers.

Although STARIS is a sophisticated and flexible analytical tool, its target is the practical design, analysis, and operational evaluation of offshore riser systems. STARIS's flexibility and usefulness are enhanced because:

1. Data input format is geared toward a wide variety of simulation capabilities.
2. Output reports and plots may be selected for any level of detail required, including fatigue, riser dynamics animation, and operational envelopes.

The Time–Domain Method for simulation of riser behavior is generally recognized as the most accurate, realistic, and reliable riser analysis technique. API RP 17A, *Design and Operation of Subsea Production Systems* [9], states:

> *"The time domain solution technique is the most general and the most accurate. Time domain solution technique should be employed during the final design phase for confirmation of response predictions from static and frequency analyses."*

In addition, API RP 17G, *Design and Operation of Completion/Workover Riser Systems* [8], states:

> *"The time domain method is superior in accuracy and reliability to the frequency domain method. The time domain solution method is required to predict dynamic or transient riser response as well as to confirm the suitability and reliability of the frequency domain method to model riser dynamic behavior."*

Fortunately, for flexibility in design and analysis, STARIS can simulate riser behavior with:

1. Time–Domain Method (TDM),
2. Frequency–Domain Method (FDM), or
3. Static–Domain Method (SDM).

Only one STARIS input data statement must be changed to select the analysis method. Although FDM calculations yield results in an economical and quick manner, every riser analysis should be checked with TDM calculations, a task easily done with STARIS. Note, as personal computer processing power and speed continue to increase, the TDM is rapidly diminishing the attractiveness of the approximate FDM.

STARIS is currently available for *IBM–compatible Personal Computers* running Linux (Unix) or Microsoft Windows NT 4.0 operating system as well as for *Apple Computers* running the Mac OS X operating system.

STARIS takes advantage of 32–bit or 64–bit technology for improvements in execution speed, computation safety, and reliability. Versions of STARIS for mainframes, workstations, and other PC operating are available on a custom basis.

One version of STARIS is designed to run on *Linux Beowulf PC Clusters* (configured for Distributed Networked Environments) for increased execution speed and analysis capabilities. Parallel computing capabilities are *not* implemented at this time in STARIS since a single run case (one combination of tension, offset, fluid, and storm condition) only requires a few seconds on a 1–GHz speed computer for execution. However, when running thousands of cases, as is typical with STARIS, the Linux Beowulf Cluster is a very useful tool to speed analysis efforts.

H.1 History of STARIS

STARIS is the latest version in a series of riser dynamics computer simulation programs developed by Dr. Robert M. Sexton since the early 1970s. It is one of the most advanced and comprehensive riser analysis tools readily available today for conducting multiple case analyses (time, frequency, and static domain) for drilling, running, completion, workover, and production riser systems in various operational modes (connected riser, selfstanding buoyant riser, hanging riser, riser running and retrieval).

Several riser dynamics simulation computer programs preceded the development of the latest version of STARIS:

1. The author's first riser program, Exxon's DYNRAN, completed in 1975 at Exxon Production Research Company, included several advanced features such as time domain simulation with random waves and vessel motion. Finite differences were used to model the governing equations of motion of the tensioned beam. The author's 1976 OTC paper number 2650, *Random*

Wave and Vessel Motion Effects on Drilling Riser Dynamics [22] describes the program in detail.

2. Another riser program was developed in 1978, RISLAN. Although written completely from scratch, that program was similar to the previous program but with a streamlined, user friendly input data format.

3. In 1982, the third major riser program, STARIS Version 3, was developed completely from scratch, and included several advancements: finite–element method; time domain and frequency domain calculation methods; and multiple case capabilities. The finite element method was selected to provide flexibility to model complicated riser and equipment problems and to overcome the severe limitations of finite difference solution methods in meshing and in the accuracy of bending stress and bending moment calculations.

4. From 1988 to 1991, STARIS Version 4 was completely rewritten in C computer language (previous versions used Fortran) to take advantage of advances in Personal Computer technology, including complete dynamic memory allocation, data structures, data input language, error checking, custom reports and plots, and menu systems. The STARSYS menu system provides easy, user friendly access to the STARIS package. A spreadsheet interface allows Lotus 1–2–3 format (.WKS, version 1.0) spreadsheets to be used for data analysis and plotting. Also, the WIGGLE module animates the riser dynamics to allow a fuller visual understanding and appreciation of riser behavior. The FATIGUE module allows assessment of riser fatigue life. Vortex–Induced Vibration (VIV) module allows identification of riser operations with potential vortex shedding sensitivity problems. The CRITTER module allows specification of operating and design criterion contours and the rapid development of operating envelopes (design envelopes, Tension–Offset Envelopes, Riser Running and Retrieval envelopes) using STARIS's multiple case capability. The TAPOPT module assists in the design optimization of Tapered Stress Joints (TSJ). The MUDVIB module permits the simulation of axial mud column vibrations during hanging riser dynamics of a closed riser.

5. In 1992, STARIS Version 4.5 was released and included two nonlinear wave theories for shallow water riser analysis: the Stokes Fifth Order wave and the Stream Function wave. The latest version of STARIS executes in 32–bit domain under Windows NT to gain greater execution speed and computation safety and reliability. With 32–bit technology, there are no software memory limitations so that a large number of elements (2000 elements have been

tried) and riser regions, waves, currents, tensions, etc., may be used in a riser simulation.

6. Current enhancements to STARIS underway include: (1) source code migration to C++ Object–Oriented Technology for greater ease of development, maintenance, reliability, and expandability; (2) development of improved model for riser–tension system; (3) improvement to fatigue life calculation method; (4) calculation of multiple risers; (5) linking with vessel motion and mooring system software; and (6) addition of flexible risers.

The STARIS computer program consists of over 1,500,000 lines of C and C++ source code in 300 files. The program has good internal source code documentation and written documentation for ease of future language modification and maintenance. Hence, STARIS provides an efficient tool for future riser analysis and allows rapid modifications and enhancements to meet the riser analyst's changing requirements.

H.2 Program Usage

STARIS has been used for analysis and design of marine risers for waterdepths from 20 ft to 15,000 ft. Typical applications include the following:

1. Various riser systems for drilling, completion, workover, production, and export.
2. Tapered Stress Joints design and optimization.
3. Lowering string risers for seafloor templates.
4. Running Strings.
5. Jack–up rig risers.
6. Shallow water riser systems.
7. Deepwater riser systems.
8. Titanium or composite risers.
9. Subsea equipment and lateral foundations.
10. Tendons for Tension–Leg Platforms.

11. Riser operational analysis: (1) connected riser Tension–Offset Envelopes; (2) hanging riser survival envelopes; (3) envelopes for Riser Running and Retrieval (RRR); and envelopes for Riser Landing Operations (RLO).

12. Riser casing pipe and soil interaction using nonlinear soil p–y curves.

STARIS has been used directly for or on behalf of most major petroleum and offshore companies, including Westinghouse Electric Corporation, Petrobras, Petro–Canada Exploration, FMC Subsea, ABB Vetco Gray, ABB Offshore, TransOcean SedcoForex, Reading and Bates Drilling Company, Falcon Drilling Company, Japan Drilling Company, British Petroleum Exploration, Mobil Research and Development Corporation, Arco, Exxon, Amoco, Shell Offshore, Unocal, Chevron, Saipem, Sonsub, Shaffer, Phillips Petroleum, Norsk Hydro, Golar–Nor Production, NSF/TAMU Ocean Drilling Program, Sovereign Oil and Gas, Agip, Occidental Petroleum, Elf, Amerada Hess, Marathon, Oryx, Ghana National Petroleum Corporation, and MODEC (U.S.A.), ENSCO International.

H.3 Technical Features

1. High–order, two–dimensional, linear finite–element formulation handles tapered tensioned beam elements. The riser modeling technique permits riser joints, tapers, connectors, flexible joints, subsea equipment, and casing pipe lateral foundations to be included in the dynamics simulation, if desired. The accuracy of bending moment and bending stress calculations is enhanced due to the sophisticated finite element formulation that solves for displacement, slope, and curvature (and hence bending moment) at each solution node along the riser.

2. Consistent and accurate methods calculate the sensitive riser bending stresses, the air–water interface, and wave zone hydrodynamic loads on the riser.

3. Time Domain, Frequency Domain, and Static Domain Methods of solution use the same basic input data. Excellent agreement for displacement and stress for the API BUL 2J [23] comparison cases using TDM and FDM calculation methods have been obtained.

4. Various riser configurations may be readily simulated: connected, hanging, and self-standing riser, riser running and retrieval.

5. STARIS's wave model and vessel motion model include capabilities for both Airy regular waves and irregular (random) waves. Also, two nonlinear wave

theories, Stream Function Wave and Stokes Fifth Order Wave, are provided to handle shallow water riser problems.

6. Hydrodynamic drag coefficient may depend upon Reynolds Number for improved and more accurate treatment of hydrodynamic damping and excitation along the riser.
7. Multiple parametric variations may be performed in one computer run for different applied riser tensions, floating platform offsets, regular or random waves, currents, storms, and mud weights and internal pressures.
8. Free format data input and keyword input allows user friendly data input and complete control and specification of all riser parameters. Mixed English and Metric input units are allowed.
9. Comprehensive program output format presents all key intermediate results for each case, if desired.
10. Various report options can be selected to customize desired STARIS output.
11. Output data link to spreadsheets (such as Microsoft Excel, Lotus 1–2–3, and Corel Quattro Pro) assists in processing output and drawing graphs on a personal computer. Spreadsheet files (in Lotus 1–2–3 version 1.0 format, .WKS) are created directly by STARIS.
12. Fatigue analysis module (FATIGUE) calculates fatigue life based on UK DOE and DNV fatigue calculation procedures.
13. Riser axial dynamics (uncoupled with the lateral riser dynamics) are calculated in the frequency domain. Axial dynamics can be combined with the riser lateral riser dynamics to investigate envelopes of behavior for stress and motion for the hanging riser. Also, mud column vibrations in a closed hanging riser are calculated by the MUDVIB module.
14. Vortex Induced Vibration (VIV) calculation identifies potential vortex shedding excitation problems along the riser.

H.4 Validation and Comparisons

STARIS calculations have been favorably compared (i.e., benchmarks and correlations) to API BUL 2J, *API Bulletin on Comparison of Marine Drilling Riser Analyses* [23], January 1977, for time, frequency, and static calculation methods.

Also, excellent comparisons with STARIS have been obtained with available theoretical solutions for beams, tensioned beams, and beams on elastic foundations. Note, STARIS readily allows the solution of textbook type problems for ease of program verification.

Additional favorable comparisons for STARIS have been obtained with proprietary data supplied by clients, with other riser dynamics computer programs, and with results obtained or published for very sophisticated finite–element programs.

STARIS is an excellent tool for the design and analysis of riser systems. However, like any tool, it has its limitations and demands that the riser analyst use it properly and interpret the calculated results correctly. No riser analysis tool produces the *absolute truth* of riser behavior, except in the simplest of textbook situations. Therefore, STARIS is best used in an engineering environment to increase design confidence and where *relative truth* among various riser design/operation alternatives is recognized, acknowledged, accepted, and appreciated.

H.5 Quality Assurance

To ensure a reliable STARIS software package to all users, a quality assurance program is under development to meet ISO and API requirements.

H.6 Contact Information

For technical information and license arrangements for STARIS, please contact:

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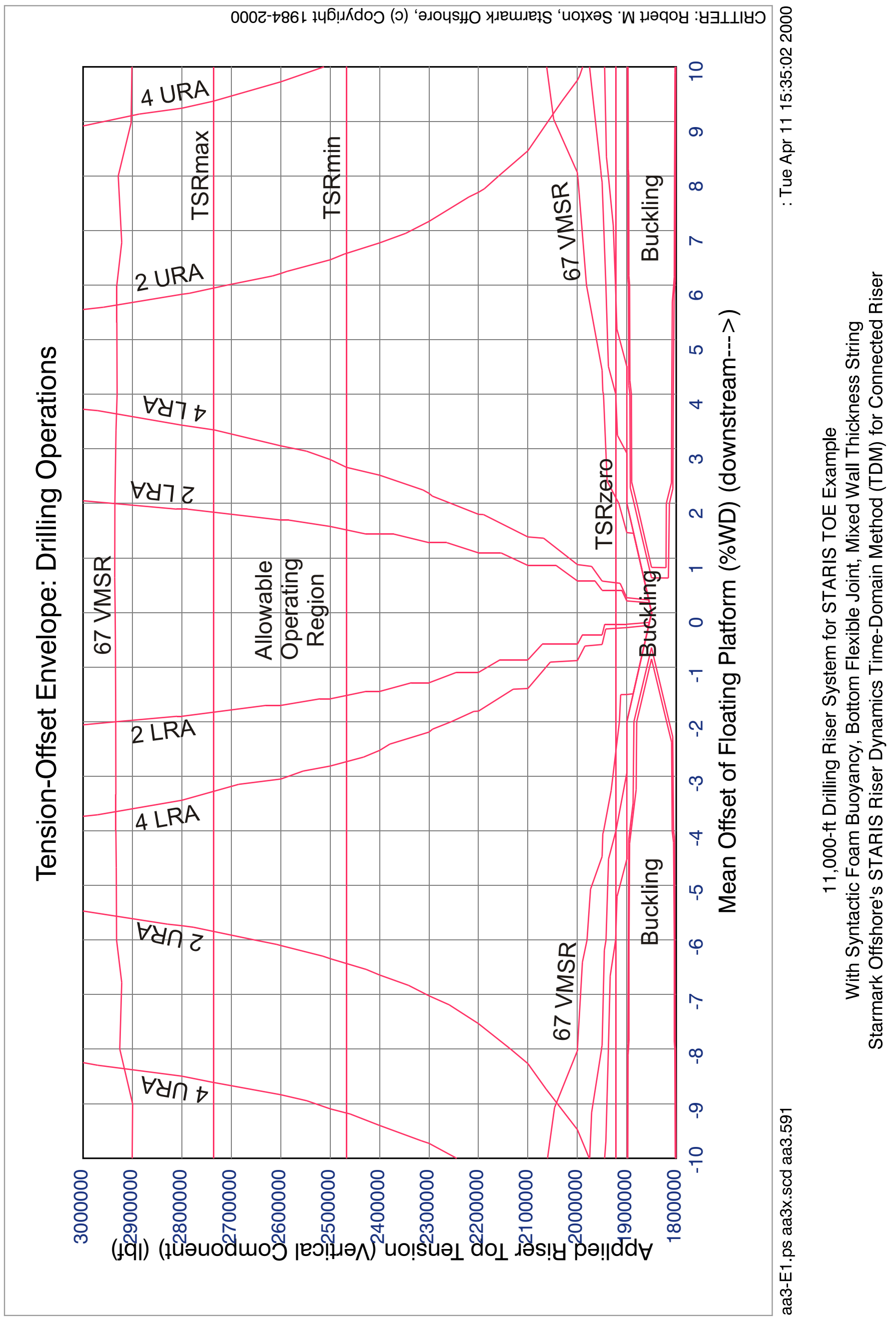

Figure H.1: Example STARIS Tension–Offset Envelope