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SUPPLEMENTAL COMMERCIAL DESIGN GUIDANCE FOR FATIGUE

SHIP STRUCTURE COMMITTEE

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The container ship version of the ABS SafeHull program was used to analyze 10 ships of the U.S. and Canadian Navies. The program, which was developed for commercial ships, was adapted for naval ships, with some shortcomings and limitations associated with this adaptation. In the Phase A module of the SafeHull program, some areas of the structure are not analyzed for fatigue, such as some areas of discontinuity and stress concentration. Phase B of the SafeHull program is intended to deal with such areas through finite element analysis, but limitations of the program prevented its application to naval ships.

Naval ships have a different operating environment and period of service than commercial ships, and adaptation of the program for these differences is limited. A more generalized spectral fatigue procedure must be used to account for such differences in environment and operations.

The Phase A analysis of the midship section of the 10 naval ships indicated that all of the structure was satisfactory for fatigue except for the side longitudinals of some of the ships near the waterline. Operational experience has not shown these areas to be a problem, although some ships have experienced corrosion in the structure near the waterline. The application of Phase A of SafeHull in the early phases of design of a naval ship will provide a basis for improved fatigue life of the ship. However, careful consideration should be made as to the effect of this design method on longitudinal stiffeners near the waterline.

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Rear Admiral, U.S. Coast Guard
Chairman, Ship Structure Committee

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16. Abstract

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The containership version of the ABS SafeHull program was used for the analysis of 10 ships of the U.S. and Canadian Navies. The program, which was developed for commercial ships, was able to be adapted to naval ships, with some shortcomings and limitations associated with this adaptation. In the Phase A module of the SafeHull program, some areas of the structure are not analyzed for fatigue, such as some of the areas of discontinuity and stress concentration on the naval ships. The Phase B of the SafeHull program is intended to deal with such areas through finite element analysis, but limitations of the program prevented its application to the naval ships.

Naval ships have a different operating environment and period of service than commercial ships, and adaptation of the program and its results for these differences is limited. A more generalized spectral fatigue procedure must be used to account for such differences in environment and operations.

The Phase A analysis of the midship section of the 10 naval ships indicated that all of the structure was satisfactory for fatigue except for the side longitudinals of some of the ships near the waterline. Operational experience has not shown these areas to be a problem, although some ships have experienced corrosion in the structure near the waterline.

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CONVERSION FACTORS

(Approximate conversion of common U.S. Customary units used for ship structures to metric or SI units)

To convert from	To	Function	Value
LENGTH			
inches	meters	divide by	39.3701
inches	millimeters	multiply by	25.4000
feet	meters	divide by	3.2808
VOLUME			
cubic feet	cubic meters	divide by	35.3149
cubic inches	cubic meters	divide by	61,024
SECTION MODULUS			
$inches^2$ feet	$centimeters^2$ meters	multiply by	1.9665
$inches^2$ feet	$centimeters^3$	multiply by	196.6448
$inches^3$	$centimeters^3$	multiply by	16.3871
MOMENT OF INERTIA			
$inches^2$ $feet^2$	$centimeters^2$ $meters^2$	divide by	1.6684
$inches^2$ $feet^2$	$centimeters^4$	multiply by	5993.73
$inches^3$	$centimeters^4$	multiply by	41.623
FORCE OR MASS			
long tons	tonnes	multiply by	1.0160
long tons	kilograms	multiply by	1016.047
pounds	tonnes	divide by	2204.62
pounds	kilograms	divide by	2.2046
pounds	Newtons	multiply by	4.4482
PRESSURE OR STRESS			
$pounds/inch^2$	$Newtons/meter^2$ (Pascals)	multiply by	6894.757
kilo $pounds/inch^2$	mega $Newtons/meter^2$ (mega Pascals)	multiply by	6.8947
$pounds/inch^2$	kg/cm^2	divide by	14.2232
kg/cm^2	mega Pascals	multiply by	0.098065
BENDING OR TORQUE			
foot tons	meter tons	divide by	3.2291
foot pounds	kilogram meters	divide by	7.23285
foot pounds	Newton meters	multiply by	1.35582
ENERGY			
foot pounds	Joules	multiply by	1.355826
STRESS INTENSITY			
kilo $pounds/inch^2$ $inch^{1/2}$ (ksi$\sqrt{}$in)	mega Newton $m^{3/2}$	multiply by	1.0998
J-INTEGRAL			
kilo pound/inch	$Joules/mm^2$	multiply by	0.1753
kilo pound/inch	kilo $Joules/m^2$	multiply by	175.3
TEMPERATURE			
Degrees Fahrenheit	Degrees Celsius	subtract & divide by	32 1.8

Executive Summary

This report was prepared for the interagency Ship Structure Committee Current U.S. government ship acquisition directives emphasize the use of commercial practices wherever possible. The objective of this project, in compliance with those directives, was to evaluate commercial methods for analyzing the fatigue loadings on ships over their operational life. The scope of the project included documenting current commercial approaches and practices for the structural design of a ship hull girder for environmental loads. As a minimum, the scope included service life, operating time and area, speed and headings, wave height and whipping probabilities, S-N curves, allowable stress range criteria, hull girder strength, and construction and in-service inspection requirements. It further required that the current commercial design practices for fatigue be applied to 5 past and 5 current Navy Hulls. At the project kick-off meeting the Ship Structure Committee Project Technical Committee SR-1403 agreed upon the 10 U.S. Navy and Canadian Navy ships to be analyzed.

Current methods of fatigue analysis of ship structure for commercial and naval ships were reviewed to develop background for the study. This review included primary and secondary structural loads, ship operational environments, methods of computing hull response to the loads, commercial and naval structural details, and the nominal strength of the hull girder. Structural inspection requirements were reviewed.

There are considerable differences between the documented methods used for fatigue analysis of commercial ships and of military ships. The commercial methods best documented are those of the American Bureau of Shipping (ABS). Specific procedures have been developed and calibrated for three types of ships: containerships, tankers, and bulk carriers. These ABS simplified fatigue analysis procedures have been incorporated into the ABS computer program SafeHull, implementing their classification rules for these types of ships. The ABS philosophy towards fatigue is that the fatigue strength of welded joints and details in highly stressed areas is to be based upon at least 20 years of operation of the ship. Fatigue considerations will increase scantlings above minimum rule requirements, but will not be used to reduce scantlings. Through analysis of a number of ships, ABS developed lifetime fatigue loading spectra for the hull structure that are characterized by a Weibull distribution function [see Glossary for explanation of Weibull distribution]. These fatigue loading spectra are used with the fatigue S-N curves [see Glossary for explanation of S-N curve.] for welded structural details developed by the U.K. Department of Energy (DEN) (UK DEN, 1990), and interpreted for ship structure by ABS. Other ship classification societies have also developed their own procedures for incorporating fatigue analysis into ship structural design.

The U.S. Navy has developed fatigue analysis procedures using a fatigue loading spectrum computed for the assumed operating conditions of each individual ship, using generalized wave response functions from experimental data. The fatigue strength of structural details is obtained from U.S. Navy experimental data supplemented by data developed by the American Association of State Highway Transportation Officials (AASHTO) (AASHTO, 1996).

The Canadian Navy fatigue design procedure is based on the procedures of the U.K. Navy. The procedure uses an exponential frequency distribution function of a maximum lifetime hull girder bending moment developed from static balance of the ship on an 8-meter high wave. Data on fatigue strength of structural details is taken from a British standard that is similar to the U.K. DEN fatigue data (Maddox, 1991).

The differences in the above methods for fatigue analysis are based mostly on historical development and preferences of analysts who developed the methodologies, and not on structural or hydrodynamic differences between commercial and naval ships. Therefore, a methodology developed for a commercial ship should be able to be applied to a naval ship. However, the calibration of the methodology for commercial ships is not necessarily valid for naval ships.

For the purposes of design, all of the above methods develop the lifetime loading spectrum assuming ship operations in the North Atlantic. In defining a 20-year fatigue life, ABS assumes that the ship will spend the majority of its time at sea, specifically, 80 percent of the time for a containership. The U.S. Navy generally assumes that ships will spend only 35 percent of the time at sea, although for a period of 30 or 40 years. Studies of the operations of actual ships show that U.S. Navy ships tend to spend most of their time in a more benign environment than the North Atlantic Ocean, and therefore will have greater fatigue lives than predictions based on North Atlantic operations would indicate.

In developing the loading for fatigue analysis, ABS bases loads on linear ship motion computer programs, supplemented by nonlinear analysis when appropriate. As stated above, the U.S. Navy uses generalized experimental data for developing loading, but is conducting extensive research on methods of nonlinear analysis, as is the Canadian Navy. Such nonlinearities in the response of ships to waves can have a significant effect on predictions of maximum lifetime loads. However, the nonlinearities have less effect on the loads for fatigue analysis because the majority of the loading that causes fatigue damage comes from repeated application of low amplitude loads, which are more linear in nature.

The exception to the statement that nonlinearities are not important for fatigue analysis is wave-induced whipping. This is a nonlinear transient phenomenon caused by the ship slamming into waves that causes hull girder vibration for 5–10 cycles at a frequency of 1–2 Hz, significantly increasing the number of fatigue loading cycles. ABS accounts for slamming by increasing the maximum design bending moment, but the U.S. Navy incorporates whipping cycles into the fatigue loading. The Canadian procedure implicitly includes whipping through the assumed exponential distribution of the fatigue spectrum.

Fatigue damage to the majority of hull structure comes from wave-induced hull girder bending vertical moments. The actual vertical section modulus of the hull will therefore have a strong effect on the actual bending stress incurred in waves, and therefore on the fatigue life of the ship. ABS bases hull girder strength on standards developed by the International Association of Classification Societies (IACS). However, the IACS standards have been supplemented for specific ship types, such as containerships, based on the experience of ABS. For unusual ship types or unusual anticipated operating conditions, additional hydrodynamic analysis may be performed to increase the hull girder strength above the IACS minimum requirements.

The U.S. Navy bases hull girder strength on the traditional naval architectural static balance of the ship on a trochoidal wave, with wave height of 1.1 times the square root of ship length for combatant ships. This wave moment and the associated still water moment are used with somewhat conservative allowable hull girder design stresses to obtain the required hull girder section modulus. As stated above, the Canadian standard for hull girder bending is based on static balance on an 8-meter wave. Allowable stresses are less conservative than those used by the U.S. Navy. The result of these standards is that the Canadian ships have about the same hull girder section modulus as they would have if designed to the ABS standard. However, the section modulus of an otherwise equivalent U.S. Navy ship is 25 percent to 90 percent higher than would be required by ABS.

Secondary loads, such as the varying pressure on the side hull due to wave action and ship motion, have been studied more extensively by ABS than by the U.S. Navy. The standards for fatigue analysis that are based on such loads tend to be higher for ABS, particularly for longitudinal stiffeners in the side shell near the waterline. However, comparison of analytic loads with the limited experimental data available has shown poor correlation, indicating a need for additional studies of these loads.

Standards for in-service inspection and maintenance of ship structure will affect the extent of structural damage that a ship will suffer in service. If a rigorous in-service inspection and maintenance program is in place, then cracks that develop are likely to be discovered and repaired prior to significant damage occurring. Attention to fatigue during design is then taken to reduce maintenance costs rather than to preclude failures of ship structure. The standards of the U.S. Coast Guard for commercial ships and of ABS result in the inspection of ship structure on an annual basis, with more in-depth inspections on a less frequent basis, up to five years between major surveys. The Canadian Navy conducts inspection of critical areas on a 6-month schedule, but other areas of hull structure are inspected on a 5-year schedule. The U.S. Navy requires that every ship be inspected every three years to determine if it is fit for service. The ship's force is required to inspect structure annually, and operational commanders require various levels of inspection on a 2-year cycle and on a 10-year cycle. Both commercial and naval authorities permit underwater survey of structure as an alternative to drydocking for inspection. Therefore, although there are differences in the details, both commercial and naval ships see the same level of inspection of structure.

To demonstrate the applicability of a commercial method of fatigue analysis to naval ships, the containership version of the ABS SafeHull program was used for the analysis of 10 ships of the U.S. and Canadian Navies. Although the program was developed for commercial ships, it was able to be adapted to naval ships. There were some shortcomings and limitations associated with this adaptation. In the Phase A module of the SafeHull program, some areas of the structure, such as some of the areas of discontinuity and stress concentration on the naval ships, are not analyzed for fatigue. The Phase B of the SafeHull program is intended to deal with such areas through finite element analysis, but limitations of the program prevented its application to the naval ships.

The analysis showed that Naval ships have a different operating environment and period of service than commercial ships, and that the ability to adapt the program and its results for these differences is limited. A more generalized spectral fatigue procedure must be used to account for such differences in environment and operations.

The Phase A analysis of the midship section of the 10 naval ships indicated that all of the structure was satisfactory for fatigue except for the side longitudinals of some of the ships near the waterline. Operational experience has not shown these areas to be a problem, although some ships have experienced corrosion in the structure near the waterline.

The analysis of the 10 ships was conducted using the standard operational scenario inherent in the ABS simplified fatigue analysis procedure. The SafeHull output can be modified to account for years of service and for percent of time spent underway. Likewise, modification can be made for use of other fatigue strength data. However, the output can not be directly modified to account for service conditions other than North Atlantic operations. Some modifications to the SafeHull program would make it applicable to a wider range of ship types, including break bulk cargo ships and naval ships. The principal change would be in the development of loads within the program, which could be modified to accept generalized loads on decks, including both live and dead loads.

The application of Phase A of SafeHull in the early phases of design of a naval ship will provide a basis for improved fatigue life of the ship. However, careful consideration should be made as to the effect of this design method on longitudinal stiffeners near the waterline. A more general commercial approach to fatigue analysis of naval ships is available through the ABS Dynamic Loading Approach and the associated Spectral Fatigue approach. This approach should be evaluated for application to typical naval ships in the same manner as SafeHull has been evaluated in this current project.

Glossary of Terms

Classification—The process of establishing and administering standards or Rules. Those seeking classification must adhere to these Rules to gain class.

Fatigue—Failure of material from repeated cyclic application of loads. The number of load cycles in the lifetime of a ship is 10^8 or greater.

Fatigue Loading Spectrum—A representation of the random amplitude loads applied to ship structure from ship operations in a random seaway. A loading spectrum is generally characterized by an exceedance curve, which has the load on the ordinate, and the number of times a load of that magnitude is exceeded during the lifetime of the ship on the abscissa. In a semi-log curve, with the abscissa a logarithmic scale, the exceedance curve is close to a straight line (an exponential distribution), or has a slight curvature to approximate a Weibull distribution.

Linear Cumulative Fatigue Theory—A theory of fatigue failure for loading of variable amplitude. The amount of fatigue damage by all the stress cycles of a particular stress amplitude is the fraction of the number of cycles at that amplitude to the number of cycles to cause failure under constant amplitude loading of that stress amplitude.

Response Amplitude Operator (RAO)—Also known as Frequency Response Functions (FRF) or transfer functions. The amount of response to a unit wave height of some hull response parameter, such as bending moment. The value of the response is determined over the range of all anticipated wave encounter frequencies.

Sea Spectrum—A characterization of the randomly occuring waves at a particular loacation at a particular time. Paramaters used include the low-frequency and high frequency of the significant wave height, modal frequency, and a shape parameter.

Sea State—A characterization of the amplitude of waves at a particular location at a particular time. Sea states are generally characterized by the average of the one-third highest waves. There are several standard tables of probability that the wave height will be within a given range at a particular location in the ocean.

S-N Curve—A graphic representation of the results of a number of fatigue tests on identical specimens tested under repeated loading at the same amplitude of stress. The number of loading cycles (N) is plotted on the abscissa, and the amplitude of the applied stress range (S) is plotted on the ordinate. When the S-N curve is plotted on a logarithmic scale, the shape of the curve through the data points tends to approximate a straight line.

Weibull Distribution—A random distribution with a cumulative distribution function of:

$$F_S(s) = P(S \le s) = 1 - \exp[-(s/S_m)^{\xi}] \ln (N_T)$$

Where:

- S is the stress
- S_m is the design stress
- N_T is the number of times in the lifetime that the stress S_m is exceeded
- ξ is the Weibull shape parameter, generally ranging between 0.7 and 1.3 for hull girder wave loading.

Whipping—Vibration of the hull girder of a ship at its natural frequency, generally 1 to 2 Hz for the first mode of vertical vibration. Excitation is generally from impact of the hull with a wave at the bow. As many as ten cycles of decreasing amplitude will occur from a single impact.

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1. Introduction

1.1 Purpose

This report represents an attempt to apply to naval ships a method developed for the fatigue analysis of commercial ships. All aspects of structural design and construction as well as the operation of the ship at sea have a profound effect on the fatigue life of ship structure. Therefore, a review of these factors, especially as currently applied to the design of commercial and naval ships was undertaken as part of the study. One commercial method, the containership version of the SafeHull program of the American Bureau of Shipping (ABS), was then applied to 10 naval ships. This application was not straightforward, and required modifications to the input of the program, and interpretation of the program output. This effort represents an example of the shortcomings and limitations of such an application of a program developed for one type of ships when applied to a different type.

As part of this study, the literature concerning commercial and naval methods of design for fatigue was reviewed. The documents reviewed are listed in the list of references at the end of the report. The principal subject matters investigated are listed below with a summary of the subject. The subjects will be discussed in further detail in the remaining chapters of this report.

1.2 Commercial Approaches and Practices for the Structural Design of the Ship Hull Girder for Environmental Loads

There are considerable differences between the historical approaches to the structural design of military and commercial ships for environmental loads. These differences have diminished in recent years as the commercial procedures have evolved to structural design based on analytically developed loads and detailed stress analysis. In many regards, particularly in the development of loads, a greater level of sophistication is currently used in the Dynamic Loading Approach (DLA) of the American Bureau of Shipping (ABS) than is currently used by NAVSEA for design. The differences may diminish in the future as the classification societies develop rules for military ships and if the military authorities adopt these rules. The degree of difference cannot be ascertained until ships are designed using the new rules, and the scantlings so developed are compared to equivalent ships designed under the old approach. One important factor relative to fatigue life of structure will be to determine which approach will result in heavier scantlings and thus have an inherently greater fatigue life. In either case, because fatigue assessment has now become standard practice for both commercial and military ship designs, either approach should result in improved fatigue lives.

1.3 Operational Environments Used in Commercial and USN Ship Design Practice

The operating environment clearly influences the fatigue life of ship structure, with some environments far worse than others. The number of operational years for which a ship is designed, and thus, for which avoidance of fatigue damage is necessary, is generally an owner's option. Commercial ships are normally designed for fewer years of operation than naval ships, but spend a greater percentage of that time at sea. The master of a commercial ship is less likely to reduce speed or take a more seakindly heading in heavy weather than the commanding officer of a naval ship will during peacetime, but at time of war, the naval ship is more likely to be driven harder.

The area of operations of a ship has a great effect on fatigue life. A ship that operates throughout the entire Atlantic Ocean will have a fatigue life that is twice as long as a similar ship operating in only the North Atlantic. The more conservative assumption of North Atlantic Operations is generally used for design, but when comparing predictions of fatigue failure with service experience, actual operational conditions should be used.

1.4 Hull Response Methods

The principal issue in the prediction of lifetime bending and torsional moments is the importance of nonlinearities in wave profiles and in the response of ships to waves. They are extremely important in predicting the maximum lifetime response. In fatigue analysis, however, the majority of the fatigue damage occurs at lower sea states where the waves and the response of ships to them are linear. Therefore, consideration of nonlinearities is generally not important for predicting a fatigue loading spectrum, with the exception of slam-induced whipping.

The commercial and military methods of fatigue analysis currently used in design have a deterministic basis, using lower-bound probability fatigue data, but not otherwise considering the stochastic nature of loads, strength or analysis. However, there can be large variability in all of these factors, so that actual fatigue life can vary over a full order of magnitude Thus, calibration of fatigue analysis with operating experience can be difficult, especially if few failure occur in service, making the failure database small.

Issues remain as to the necessary extent of nonlinear analysis methods in moment predictions, and the relative merits of experimental data compared to analytical results. Standardized operating environments may be useful for design, but conditions when it is prudent to deviate from the standard must be determined.

1.5 Commercial Structural Details

In almost all cases of fatigue failure of ship structure, the cracking will originate in a weld. In some instances, the weld that fails will be a simple butt weld, but that is usually true only for defective welds. Welded structural details, such as intersecting stiffeners or changes in geometry, produce local stress concentrations that magnify the effect of discontinuities in welds, and these details are the predominant origin of fatigue cracks.

Considerable data exists on the response of both commercial and military welded ship structural details to fatigue loading. These data are compared in Chapter 5. There are three distinct approaches towards the use of this information. One is to use test data for a structural test specimen that is similar in geometry and in welding procedure to the ship detail being analyzed. The second approach is to use standard fatigue curves published by several different organizations. The third approach is the "hot-spot" approach, which relies on a detailed finite element analysis to predict local stress levels within a detail, and use those stresses with a single standard fatigue curve.

In considering the available database of fatigue data, differentiation must be made between the structural details associated with commercial ships and with naval ships. In the past, commercial ships were generally characterized by less care in design and fabrication compared to naval ships, but there have been changes in recent practice that bring the two types closer together. Furthermore, structural details can frequently be broken down into standard configurations, such as bracket toes and cruciform joints, and these configurations may determine the fatigue strength of the structural detail, whether it is on a commercial or a military ship. In this way, the same database can be used for both ship types. However, issues remain in the interpretation of the databases, such as whether a linear or bilinear S-N curve should be used for design and analysis.

1.6 Nominal Strength of the Hull Girder

Assessment of hull girder strength for commercial ships is an integral part of classification society rules. In past practice, hull girder strength was provided by an overall section modulus approach to hull girder strength, using a standard rule for minimum section modulus. Such methods are still contained in the rules of classification societies. Today, that traditional method is being supplanted by hydrodynamic analysis to determine loads, detailed finite element analysis to determine stress distribution, and failure analysis to determine strength.

Two of the critical items that affect the fatigue strength of the structure are the nominal stress range and stress concentrations. A ship with a high section modulus can have greater global and local stress concentrations and reduced weld quality and still have the same fatigue life as a ship with a lower section modulus but constructed to a higher standard. It is therefore important to understand how various standards for hull girder nominal strength affect the actual section modulus of the ship.

For ships classed by ABS, there are minimum standards for hull girder strength and enhancements to those standards for certain types of ships and to suit special classification requirements of ABS. Owners sometimes require enhancements to the minimum requirements. Likewise, the U.S. Navy and the Canadian

Navy have standards for hull girder strength. It will be shown that these different standards will result in different hull girder section moduli, and therefore different operating stresses for similar ships built to the different standards.

1.7 Secondary Loads Prediction

For critical areas of the hull girder, especially the strength deck and the bottom structure, primary hull girder bending moments are the most important source of alternating stresses that lead to fatigue failure. For other areas of the structure, secondary loads, such as external hydrodynamic pressure on the side shell are more important. The side shell near the waterline is near the neutral axis, and therefore has little stress from vertical hull girder bending, but is frequently subject to great variation in loading due to wave action and ship motion. The technical base for computation of these secondary loads appears to be stronger in commercial practice than in military practice, possibly because of a history of cracking on many commercial ships, particularly single hull tankers.

Other secondary loads of particular interest are tank sloshing loads and bow slam forces. The emphasis in research has been to predict the maximum pressure loads. The spectrum of response to lesser amplitudes of ship motion and lower wave heights for use in fatigue analysis has not been studied as extensively.

1.8 In-service Hull Girder Inspection Requirements

For commercial ships, requirements for inspecting the hull girders of ships in service are provided in governmental regulations and international regulations. For naval ships, the requirements are provided in maintenance policies established by the naval services of their respective countries. In general, hull inspections for commercial ships are carried out by schedules established by authorities such as the U.S. Coast Guard. Underwater hull inspections are accomplished during scheduled and unscheduled drydockings. For naval ships, topside inspections are a part of normal maintenance schedules, which vary depending upon the ship type and the history of problems of different ship classes. Underwater hull inspections have become a routine maintenance item for U.S. Navy ships and an Underwater Husbandry Manual has been developed for this specific purpose. Likewise, under certain circumstances, ABS accepts underwater inspection to inspect hull structure in lieu of drydocking.

1.9 Application of Commercial Methods for Fatigue Analysis of Existing Ships

The ABS fatigue design practices and approaches, as embodied in the SafeHull Phase A program for containerships was used to assess the hull structure of 10 current and past U.S. and Canadian naval vessels. The resulting analysis showed that in most cases the vessels analyzed met the ABS criteria for hull girder structure at midships. The exception occurred with several of the ships for which fatigue failures in side shell longitudinals at or near the waterline were predicted. Although structural failures have not been seen in those ships in service, greater corrosion has been noticed, this may be the result of the breakdown of coatings because of fatigue cracking.

Application of the SafeHull Phase B program module for containerships to one of the naval ships was unsuccessful because the assumptions on hull geometry assumed in that program do not pertain to the particular vessel analyzed, or to similar naval vessels. Therefore, the current Phase B containership version of the SafeHull program is not useful for the fatigue analysis of naval vessels. The tanker version can be used, but the difference in loading for full-form, slow-speed tankers compared to fine-hulled, high-speed naval vessels reduces the viability of that approach.

1.10 Shortcomings/Limitations of the Commercial Approaches

In this project, only one of the variety of commercial methods available for conduct of fatigue analysis of ship structures, the containership version of the SafeHull program developed by ABS, was used to determine the fatigue life of typical naval vessels. Application of a standardized computer program that was developed for a particular type of vessel to an entirely different type for which use was not contemplated is bound to be fraught with difficulties. It should not be surprising then that there were many problems encountered in trying to adapt the Phase A and Phase B modules of SafeHull to the fatigue analysis of naval ships. The ABS SafeHull program can provide a calibrated basis for assessment of fatigue strength of naval vessels. However, the limitations in the program preclude its use for the analysis of all areas of the structure.

1.11 Suggested Modifications to the Commercial Approaches

There are three different categories of modifications to be made: modifications of input by the user, modifications to the SafeHull output by the user, and suggested changes in the SafeHull software that would make such analyses more applicable to naval vessels. The SafeHull suite of programs was developed for the analysis of three very specific types of ships. This project has not used the containership version of SafeHull in the manner in which it was intended to be used. To be able to make the analysis at all, the user had to provide input that did not always correspond to the intended format.

The fatigue analysis results from SafeHull must, in general, be modified when applied to naval vessels for several reasons, such as changes in the years of operation and percentage of time underway, changes in the operating environment, changes in structural details, and differences in fabrication standards.

Use of SafeHull for structural design of a naval ship is inappropriate because the design criteria for naval vessels are significantly different than for commercial ships. However, fatigue analysis is not based on standardized design criteria, but is related to basic engineering principles. Therefore, if modifications were made to the program to accept a more general ship geometry, the program could serve as a useful tool for fatigue analysis of naval ships.

2. Current Commercial Practices for the Structural Design of the Ship Hull Girder for Environmental Loads

2.1 Purpose

The purpose of this chapter is to identify a list of current commercial approaches and practices for the structural design of the ship hull girder for environmental loads and to provide a brief description of each. The following current commercial approaches are addressed:

1. ABS Approach and practice;
2. ABS Rules, SafeHull, and Dynamic Loading Approach (DLA) and the relation between these approaches;
3. Simplified and spectral approaches to fatigue analysis; and
4. ABS benchmarking procedure

2.2 Introduction

Commercial practice for the design of hull structure has evolved over the last few decades from a simple rulebook look-up procedure to the use of detailed load, stress, and failure analysis in conjunction with design for productivity. This process continues to evolve, but is typified by the computer-based design and analysis programs developed by several classification societies, such as the SafeHull suite of programs developed by the American Bureau of Shipping (ABS), and the ShipRight program developed by Lloyds Register of Shipping.

Part of the reason for this evolution has been changes in the ships themselves. As ships began to grow in size, the extrapolation of old experience-based tables of scantlings and other rules for design were not prudent without a reevaluation of loads, analysis methods, and failure modes. New hullforms and ship configurations also developed, and the old rules didn't apply. Designers were also beginning to apply new methods of analysis in design, and the old framework would not accommodate them.

There were also criticisms from several quarters that the well established rules of the classification societies were based too heavily on empirical relationships without a solid basis on principles of engineering science and that they were too prescriptive (Pomeroy, 1999). The societies realized that there was a need for greater transparency in the rules so that the users would have a clearer understanding of the assumptions that underlay their application. An example of that trend is in the commentaries on the rules that ABS is now developing, such as the commentary on the loads for tankers (ABS, 1999).

The primary basis for designing the structure of commercial ships is contained in the rules of various classification societies, of which about 80 exist worldwide. The most significant are those who belong to the International Association of Classification Societies (IACS), namely:

- American Bureau of Shipping (USA)
- Bureau Veritas (France)
- China Classification Society (China)
- Det norske Veritas (Norway)
- Germanischer Lloyd (Germany)
- Korean Register of Shipping (South Korea)
- Lloyds Register of Shipping (UK)
- Nippon Kaiji Kyokai (Japan)
- Registro Italiano Navale (Italy)
- Russian Maritime Register of Shipping (Russia)

IACS also includes the following Associate Members:

- Hrvatski Registar Brodova - Croatian Register of Shipping
- Indian Register Of Shipping
- Polish Register Of Shipping

The technical base of IACS is provided in the IACS Bluebooks, which represent a set of standards that have been developed through cooperation between all the member societies. The standards for ship structure deal principally with the strength of the hull girder. The book contains unified requirements, recommendations, and interpretations for material, hull girder strength, superstructure and deckhouses, equipment (anchors and chain), and rudders. There are also specific requirements for bulk carrier safety similar to those later adopted by the International Maritime Organization (IMO). Each member society in IACS is expected to adopt the unified requirements into their rules. By basing their rules on the IACS standards, the member societies compete on the basis of factors such as the services that they will give to owners and not on the basis of permitting lower structural standards than competing societies. Ship owners cannot go from one IACS member to another looking for lower requirements in critical areas, because they are all the same. However, IACS unified requirements do not cover local criteria for plate, frames or support structure. Therefore, the statement that ship design will not differ between societies is the ideal but not the fact.

The following comparison of design practices, both commercial and military, is somewhat abstract, to a degree. The description of commercial practice is an outsider's view of what classification is and what class does. Without actually applying the requirements to a design and receiving an approval from a classification society, one can not be certain all is completely understood. No set of written rules can cover all situations, especially innovative designs, and much of the classification procedure involves interpretation of the rules, which is the exclusive right of the classification society. Likewise, naval vessels are designed using many other criteria than the written design standards. Besides combat loads, experience from the operation of similar ships has led to unwritten practices, which are not included in the design standards, such as additional stiffening is certain areas. Therefore, the final ship design may be different from what would follow from simple application of design standards.

2.3 ABS Approach and Practice

ABS philosophy toward fatigue design is discussed in the Guide for Dynamic Based Design and Evaluation of Container Structures (ABS, 1996).

> "The fatigue strength of welded joints and details in highly stressed areas, which are important to the safety of the structure, is to be assessed, especially for those constructed of higher strength materials…. The fatigue lives of structures in these areas should generally not be less than 20 years." ABS embodies their requirements for ship structure in their Rules for Building and Classing Steel Vessels (ABS, 2001). The ABS rules are contained in five parts:

1. Classification, Testing and Surveys
2. Materials and Welding
3. Hull Construction and Equipment
4. Machinery Equipment and Systems
5. Specialized Vessels and Services
   - Section 1. Strengthening for Navigation in Ice
   - Section 2. Vessels Intended to Carry Oil in Bulk
   - Section 3. Vessels Intended to Carry Ore or Bulk Cargoes
   - Section 4. Vessels Intended to Carry Liquefied Gases and Chemical Cargoes in Bulk
   - Section 5. Vessels Intended to Carry Passengers
   - Section 6. Vessels Intended to Carry Containers
   - Section 7. Vessels Intended to Carry Vehicles

2.3.1 Typical Rule Requirements

The ABS rules have progressed over the last several decades from being tables of required scantlings based on the size and type of vessel to equations for determining the scantlings of the members. Typical requirements are for the required section modulus of a member, minimum depth of the member, and minimum proportions, such as the ratio of web thickness to depth. The equations for the required section modulus are different for the various types of structural members, such as longitudinal beams (stiffeners). The equations are also different for similar structural members in different types of ships. The rule requirement for the section modulus of a longitudinal stiffener will be different for a general cargo carrier than for an oil tanker or for a container ship. Other parameters included in the equations are shown in the examples below. In the examples, the notation [SafeHull classification notation is required.] is contained in the rules for tankers with length greater than 150 meters. This means that regardless of how the design is developed, a SafeHull Phase A and Phase B analysis is required before the ship will be classed by ABS. The notation [Not included in SafeHull] is made for tankers of length less than 150 meters, as SafeHull does not address such ships, and therefore its use is not a condition of classification.

All of the variables are not defined here, particularly those that cross-reference other sections of the ABS rules. The purpose of this exhibition of the rules is to demonstrate the difference in the format of the rules for similar in different types of ships.

General Cargo Ships

Section 3-2-5/13.7 Longitudinal Frames *(1995)*

The section modulus, SM, of each longitudinal side frame is to be not less than obtained from the following equation:

$$SM = 7.8chsl^2 \ (cm^3) \quad SM = 0.0041chsl^2 \ (in.^3)$$

Where
s = spacing of longitudinal frames in meters or feet
c = .95
h (above 0.5D from the keel) = the vertical distance in m or ft from the longitudinal frame to the bulkhead or freeboard deck, but is not to be taken as less than 2.13 m (7.0 ft).
(at and below 0.5*D* from the keel) = 0.75 times the vertical distance in m or ft from the longitudinal frame to the bulkhead or freeboard deck, but not less than 0.5*D*.

Vessels Intended to Carry Oil in Bulk

Section 5-1-4/9.5 (Ships with length greater than 150 meters)
Deck and Side Longitudinals (1995) [SafeHull classification notation is required.]

The net section modulus of each individual side or deck longitudinal, in association with the effective plating to which it is attached, is to be not less than obtained from the following equation:

$$SM = M/f_b \qquad cm^3 \ (in^3)$$
$$M = 1000psl^2/k \qquad \text{N-cm (kgf-cm, lbf-in.)}$$

where:

k = 12(12, 83.33)
p = nominal pressure in N/cm^2 (kgf/cm^2, lbf/in^2) at the side longitudinal considered as specified in Table 5/2A.3.1.
= nominal pressure in N/cm^2 (kgf/cm^2, lbf/in^2), as defined in Table 5/2A.3.1 for deck longitudinals.
s and *l* are as defined in 5/2A.4.3.3.
f_b = permissible bending stresses, in N/cm^2 (kgf/cm^2 (lbf/in^2)
= $(1.0 - 0.60\ \alpha_2\ SM_{RD}/SM_D)S_m\ f_y$ for deck longitudinals
= $1.0[0.86 - 0.52\ \alpha_1\ (SM_{RB}/SM_B)(y/y_n)]S_m\ f_y \le 0.75\ S_m\ f_y$ for side longitudinals below neutral axis
= $2.0[0.86 - 0.52\ \alpha_2\ (SM_{RD}/SM_D)(y/y_n)]S_m\ f_y \le 0.75S_m\ f_y$ for side longitudinals above neutral axis
$\alpha_2 = S_{m2}f_{y2}/S_m\ f_y$
S_m, f_y and α_1 are as defined in 5/2A.4.3.3.
S_{m2} = strength reduction factor as obtained from 5/2A.4.3.2a for the steel grade of top flange material of the hull girder.
f_{y2} = minimum specified yield point of the top flange material of the hull girder in N/cm^2 (kgf/cm^2, lbf/in^2)

SM_{RD} = reference net hull-girder section modulus based on the material factor of the top flange of the hull girder in cm ^{2}-m (in^2 -ft) = 0.92 *SM*
SM_D = net design hull girder section modulus at the deck in cm^2-m (in^2 -ft)
SM_{RB} and SM_B are as defined in 5/2A.4.3.2a.
y = vertical distance in m (ft) measured from the neutral axis of the section to the longitudinal under consideration at its connection to the associated plate
SM = required hull-girder section modulus in accordance with 3/6.3.4 and 3/6.5.3 based on the material factor of the top flange of the hull-girder in cm^2-m (in^2-ft).
y_n = vertical distance in m (ft) measured from the deck (bottom) to the neutral axis of the section, when the longitudinal under consideration is above (below) the neutral axis.

Section 5-2-2/153/2/1 (Ships with length less than 150 meters) Structural Sections [Not included in SafeHull.]

Each structural section for longitudinal frames, beams, or bulkhead stiffeners, in association with the effective plating to which it is attached, is to have a section modulus, SM, not less than obtained from the following equation:

$$SM = 7.8chsl^2 \text{ (cm}^3) \quad SM = 0.0041chsl^2 \text{ (in.}^3)$$

s = spacing of longitudinal frames in m or ft
c = .95 for side longitudinals
h = distance in m or ft from the longitudinals…to a point located 1.22 m (4 ft) above the deck at side amidships in vessels of 61 m (200 ft) in length, and to a point located 2.44 m (8 ft) above the deck at side amidships in vessels of 122 m (400 ft) in length and above; at intermediate lengths h is to be measures to intermediate height above the side of the vessel.

Vessels Intended to Carry Containers (130 meters to 350 meters in Length)
Section 5-5-4/13.3 Side Longitudinals and Side Frames *(1998)*

The net section modulus of each side longitudinal or side frame, in association with the effective plating is to be not less than obtained from the following equations:

$SM = M/f_b$ cm^3 (in^3)
$M = c\, p\, s\, l^2\, 10^3 /k$ N-cm (kgf-cm, lbf-in.)

where
c = 1.0 without struts
c = 0.65 with effective struts
p = nominal pressure, in N/cm^2 (kgf/cm^2, lbf/in^2), at the side longitudinal considered, as specified in 5-5-3/Table 2, but is not to be taken less than 2.25 N/cm^2 (0.23 kgf/cm^2, 3.27 lbf/in^2). For side frames, pressure is to be taken at the middle of span of side frame.
s = spacing of side longitudinals or side frames, in mm (in.)
l = span of longitudinals or frames between effective supports, as shown in 5-5-4/Figure 8, in m (ft)

k = 12 (12, 83.33)

f_b = permissible bending stresses, in N/cm^2 (kgf/cm^2, lbf/in^2)

= 1.5 [0.835 -0.52 a_2 (SM_{RDS}/SM_D)(y/y_n)]S_m f_y =0.75 S_m f_y for side longitudinals above neutral axis in load case 3-B in 5-5-3/Table 2

= 1.0 [0.835 -0.52 a_1 (SM_{RB}/SM_B)(y/y_n)]S_m f_y =0.75 S_m f_y for side longitudinals below neutral axis

= 1.5 [0.835 -0.52 a_2 (SM_{RD}/SM_D)(y/y_n)]S_m f_y =0.75 S_m f_y for side longitudinals above neutral axis in load case 3-A in 5-5-3/Table 2

= 0.90 S_m f_y for side frames

$a_2 = S_{m2} f_{y2} / S_m f_y$

S_m, f_y and a_1 are as defined in 5-5-4/11.3.1.

S_{m2} = strength reduction factor for the strength deck flange of the hull girder as defined in 5-5-4/11.3.1

f_{y2} = minimum specified yield point of the strength deck flange of the hull girder, in N/cm^2 (kgf/cm^2, lbf/in^2)

SM_D and SM_{RDS} are as defined in 5-5-4/13.1 and SM_{RDS} is to be taken not less than 0.5 SM_{RD}.
SM_{RB} and SM_B are as defined in 5-5-4/11.3.1.

SM_{RD} = reference net hull girder section modulus based on material factor of the strength deck flange of the hull girder, in cm^2-m (in^2-ft)

= 0.95 *SM*

SM = reference gross hull girder section modulus amidships in accordance with 5-5-4/3.1.1, where k w is to be taken as $k_o^{1/2}$ in calculating M_w (sagging and hogging) in 5-5-3/5.1.1 for this purpose, based on material factor of the strength deck flange of the hull girder, in cm^2-m (in^2-ft)

y = vertical distance, in m (ft), measured from the neutral axis of the section to the side longitudinal under consideration at its connection to the associated plate y n = vertical distance, in m (ft), measured from the strength deck (bottom) to the neutral axis of the section, when the longitudinal under consideration is above (below) the neutral axis

y_n = vertical distance, in m (ft), measured from the strength deck (bottom) to the neutral axis of the section, when the longitudinal under consideration is above (below) the neutral axis

Vessels Intended to Carry Containers (Under 130 Meters (427 feet) in Length)

Section 5-6-2 Hull Structure

The design of structure for local loads, in general, is to be the same as required in Section 3-2-5 for general cargo ships.

The above examples are cited to show the degree of specialization within the rules. In some cases, these differences stem from the difference in ship type and service conditions. In other cases, the differences within the rules come from greater emphasis in rule development on various types of ships. The ABS rules have changed radically in recent years for certain types of ships because of the development of the SafeHull system, which will be discussed below. The consistent part between a SafeHull and pre- SafeHull ship or non-SafeHull ship is the minimum hull girder strength. This is an IACS unified requirement applied by all classification societies and does in fact have seakeeping assessment as its basis for the wave induced bending moments and other wave effects assessed in the structure. The current rules for tankers over 150 meters in length, bulk carriers and containerships reflect the developments associated with the SafeHull system.

For tankers of length greater than 150 meters and containerships with length greater than 130 meters, the forms of the design equations are similar. The major differences are in the definition of loads and of allowable stress.

2.3.2. ABS SafeHull and Dynamic Loading Approach

In 1993, ABS released the SafeHull program for the classification of double hull tankers (Chen et al., 1993). This was followed by a version for bulk carriers in 1995, and for containerships in 1997. The SafeHull approach is a follow-on to previous approaches, distinguished in particular for the inclusion of the Dynamic Load Approach (DLA). DLA is a methodology for design whereby the combination of dynamic load components is used to investigate the structural response of a ship and determine those areas of the ship where scantlings must be increased above the minimum rule requirements. All tankers, bulk carriers, and containerships that will be classified by ABS now and in the future will require the use of SafeHull, and will receive the notation SH in their classification. Specific guidance for the DLA approach was provided for tankers in 1993 (ABS, 1993), for Bulk Carriers in 1994 (ABS, 1994), and for Containerships in 1996 (ABS, 1996). The above documents have now been assimilated into the ABS Rules in special sections for these ship types. For other ship types, such a break bulk or Roll-On / Roll-Off ships, no specific guidance is provided, but the basic foundation of the DLA approach remains. That foundation is for the designer to come to a full understanding of all of the loads that will be imposed on the ship during its lifetime, and to understand the response of the structure to those loads, ensuring that the response is reasonable. It is not a fully probabilistic process, because the resistance of the structure to the loads is treated deterministically, but the loads are treated probabilistically, with the general probability of exceedance being 10^{-8}. (ABS, 1999).

If an owner so desires, the use of the DLA notation in classification can still be made with ship types for which no version of SafeHull has been developed. The requirements for such notation is contained in Part 3, Section 2 of ABS rules, and contains the following requirements:

- An acceptable load and structural analysis procedure must be used that will take into consideration the dynamic load components acting on the vessel.
- The dynamic load components include
  - External hydrodynamic pressure loads
  - Dynamic loads from cargo
  - Inertial loads of the hull structure

- The magnitude of the loads and their load components are to be determined from appropriate ship motion response calculations
- The calculations of loads should represent an envelope of maximum dynamically induced stresses in the vessel.
- A finite element analysis of the hull structure is required to ensure the adequacy of the hull structure for all combinations of the dynamic loadings. Although the terminology "dynamic loading" is used, the actual finite element analysis is generally not a dynamic structural analysis, but is a static analysis. Dynamic analysis is only required in certain instances, such as the computation of vibration frequencies for avoidance of resonant conditions.

With the DLA approach, the scantlings obtained from the analysis can only represent increases beyond other requirements in the rules. The analysis can not be used to justify a decrease in scantlings below the basic rule requirements. Ships classed using the Dynamic Load Approach require that consideration be given to fatigue, although a detailed spectral analysis is not always required.

The development of the SafeHull approach to structural criteria for double hull tankers was based on:

- Development of load criteria, including hull girder and local loads
- Review of damage reports to identify problem areas
- Analysis of existing ships for comparison and calibration to successful experience
- Development of strength criteria to determine initial scantlings
- Development of strength assessment criteria
- Verification and calibration of the criteria with theoretical predictions and service experience
- Development of a PC-based suite of computer programs

SafeHull embodies the DLA approach through a 2-phase approach to analysis of the ship. In Phase A, the minimum scantlings are assigned to the structure in accordance with the basic rule requirements, and checks are made of the fatigue strength in specific areas, such as the connections of longitudinal stiffeners to web frames and bulkheads. In Phase B, more detailed analyses of the hull, including finite element analyses, are used to refine the scantlings to meet the structural demands from the loads investigated. The Phase B analysis can include a detailed spectral fatigue analysis of selected areas of the hull structure.. The results of the Phase B analyses are used to increase scantlings above the minimum rule requirements, but are not used to reduce scantlings.

Ships assessed by SafeHull have an integrated approach of defining the loads, establishing the pass / fail criteria, and then requiring an assessment of the total structure using the finite element method. Evaluating prior service and establishing criteria to provide structural requirements to reflect unsatisfactory experiences has developed rules prior to SafeHull. Both the SafeHull approach and the former rules-based approach can provide a suitable ship, but the actual answers will not always be the same (Chen et al., 1993).

The fatigue analysis procedure contained in SafeHull is a continuation of a procedure developed previously that has been used for the assessment of the fatigue strength of tankers (ABS, 1989), but is now contained in the ABS rules for tankers, bulk carriers, and container carriers. During Phase A, guidance is provided for fatigue of structural details in the form of an allowable stress range. This stress range was developed by ABS after analysis of a number of ships considering 20 years operation in the North Atlantic, and deriving an appropriate shape parameter for a Weibull distribution to describe the fatigue-loading spectrum.

During Phase B of the SafeHull analysis, a detailed finite element analysis of the cargo region of the hull is performed using standardized loadings. In addition, detailed 2-dimensional models of components such as web frames and stringers, or areas of stress concentration are made. Analysis of the overall hull model is made using standardized loadings. These loadings are derived from analysis of a number of ships. Nominal design wave-induced hull-girder loads are based on operation for 20 years in the North Atlantic. Internal dynamic tank pressure is determined based on added pressure head due to ship motions and on the inertia force of cargo due to ship accelerations. The external hydrodynamic pressure used in SafeHull was determined from a parametric study of ship motions in waves, and that study was calibrated by model test results. The parametric studies of all loadings that are contained within SafeHull eliminate the requirement for the designer to determine these loads. Note that for a DLA analysis of a ship type that does not have a SafeHull module, the designer is required to perform such hydrodynamic analyses.

SafeHull consists of a suite of computer programs for the ship types and phases of analysis involved. Documentation is provided through a series of manuals (ABS, 2000):

- Getting Started — Instructions for loading the program on a computer
- Phase A User's Guide— Step-by-step instructions for entering the required data
    - Tanker
    - Bulk Carrier
    - Containership
    - Rules Utility
- Phase B User's Guide — Step-by-step instructions for entering the required data
    - Tanker
    - Bulk Carrier
    - Containership
- Finite Element Analysis - Extent of model, basic mesh size, boundary conditions, application of loads, detailed stress analysis, fine-mesh analysis
    - Tanker
    - Bulk Carrier
    - Containership
- Data Reference Manual — Describes each input variable and how it is to be entered.
    - Tanker
    - Bulk Carrier
    - Containership

- ABS Modeler's Users Guide — Manual for the Modeler, which is used to develop NASTRAN finite element models from either the Phase A output or from an AutoCad or IMSA file.
- ABS Rules — The current ABS rules are provided with the SafeHull documentation

2.3.2.1 SafeHull Fatigue Analysis

The wave-induced hull girder loads that are used in SafeHull for fatigue analysis are based on assumed ship operation for 20 years in the North Atlantic. For fatigue analysis, tankers are assumed to operate 100 percent of the time during that 20-year period. For bulk carriers and containerships, an assumption of 70 to 80 percent operability over a 20-year life is made.

The fatigue design approach of SafeHull is documented in the ABS publication "Guide for the Fatigue Strength Assessment of Tankers" (ABS, June 1992). The approach uses cumulative damage theory in conjunction with U.K. Department of Energy (DEN) fatigue data for welded joints (UK DEN, 1990). These curves assume an "endurance limit" at 10^7 cycles, although in use, ABS uses a reduced slope beyond 10^7 cycles, and continues the slope of the curve in a straight line for underwater welds. The UK DEN fatigue data was selected by ABS for several reasons:

- The bureau had used this data for 10 years for ship and offshore classification work, and was therefore familiar with the data and had confidence in its use.
- The UK DEN data appear to be more consistent and offer better coverage of the high-cycle, low-stress regime of interest to ship and offshore structures.
- The data are uniform, providing a consistent reduction in fatigue life with increased severity of weld detail. This avoids a pitfall of using limited experimental data, which could have contrary results because of the variation in experimental data.
- The data offer mathematical convenience because they can be expressed as an exponential function similar to other standard S-N data. (For other standardized curves, see Chapter 5.)
- The data has been used in several worldwide applications, including Lloyds Rules.

The development of the UK DEN data is documented by Stephen J. Maddox of The Welding Institute, which developed the data (Maddox, 1991). Representative data (although not the entire database) is provided to indicate the basis for the curves. It appears that the data is obtained from the testing of small specimens that were produced in a laboratory, and are, therefore, not necessarily indicative of full size structure and standard shipyard quality welds.. Figure 2.1 shows typical data. Note that in this case, the data are for a maximum of 10^7 cycles and so do not substantiate the assumption in the design curves of an endurance limit at 10^7 cycles. Since it is small specimen data, the low-stress, high-cycle regime has not been thoroughly explored.

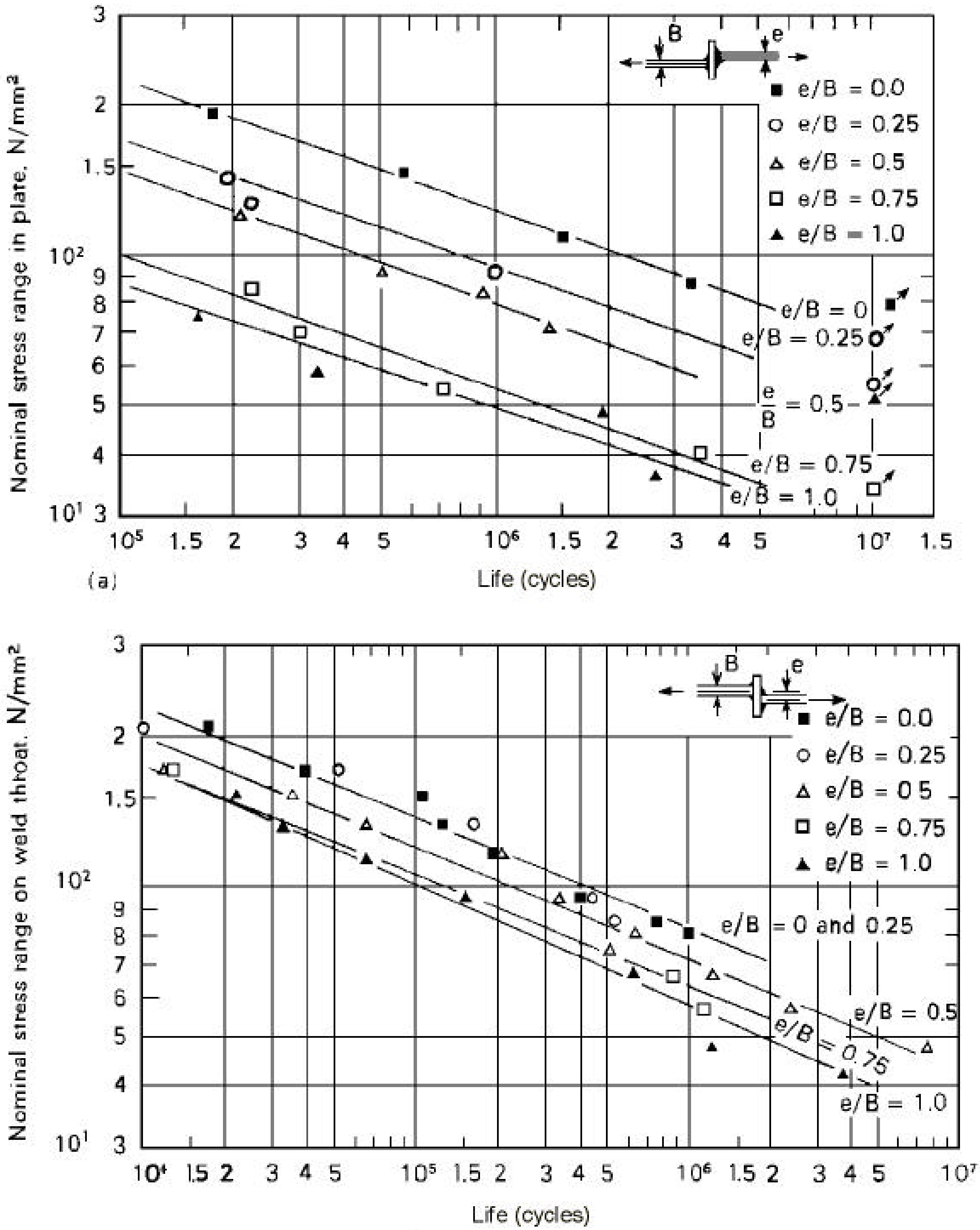


Figure 2.1 Typical Fatigue Data (Maddox, 1991)

Because the data do not represent all possible structural details that will occur in ship structure, weldments that are not represented by the details can be analyzed using a linear elastic finite element analysis that includes a refined mesh in the vicinity of the weld toe. The "hot-spot" stress gradient approach is used to determine the applicable stress range. The ABS hot spot approach uses the stress calculated at a distance 1.5 times the thickness of the member from the weld toe and at 0.5 times the thickness of the member from the weld toe. The stress is then linearly interpolated to the weld toe to determine the adjusted stress range, which is then used with the Class E S-N curve.

The ABS approach to fatigue uses these data, detailed stress analysis, determination of the appropriate stress range probability distribution, and spectral analysis. The spectral approach is the basis for a background parametric analysis that is used to determine a permissible stress range. These permissible stress ranges were determined from a computed maximum lifetime stress range, the number of cycles resulting from a 20-year exposure in the North Atlantic, and an assumed shape factor for a Weibull distribution of the stress spectrum. If the exposure time is different than 20 years, or the operating environment is different from that in the North Atlantic, the Weibull shape parameter and the allowable stress range have to be adjusted. Adjustment is also necessary if the intended operability is different from the assumed operability used in developing the ABS Weibull distribution.

If the stress field is induced by more than one load component, a spectral approach to fatigue analysis is required instead of the Weibull type approach. SafeHull accommodates either approach in determining the appropriate maximum stress range.

A commentary was developed by ABS to document the loads used in SafeHull, particularly the approach used for determining the maximum loadings for tankers (ABS, June 1999). The procedure includes simulation of a ship operating at 70 percent of maximum speed in all headings, varying in 15-degree increments from head seas to stern seas.

The following load components [Dominant Load Parameters (DLP)] are calculated as Frequency Response Functions (FRF), also known as Response Amplitude Operators (RAO), with the ABS/SHIPMOTION computer program:

- External wave pressure at selected surface points at several locations along the ship length
- Accelerations (vertical, lateral, and longitudinal) at the boundary points of the liquid cargo and ballast tanks
- Accelerations at several points along the ship length
- Wave-induced vertical, lateral, and torsional moments and shears along the length of the hull
- Ship motions in roll and pitch

Short-term and long-term response is computed using the H-family (SNAME, 1982) spectral wave data for 20 years in the North Atlantic, corresponding to a probability of exceedance of 10^{-8}. The short-term response is used in determining the fatigue-loading spectrum, since a short time in a particular sea state at a given heading and speed is sufficient to characterize that portion of the fatigue spectrum. Long-term response, on the other hand, represents a longer exposure time in order to determine maximum values of bending moments and other characterizations of response.

Rynn and Morlan (1995) made a summary of the experience of ship designers in using SafeHull. One of the results of using the finite element approach is that the scantlings of the hull become interrelated. In the former rules-based approach, all scantlings were treated separately. Now, a change in one scantling can impact an adjacent scantling, so design becomes an iterative process. Another observation is that intuition in such things as determining which of several adjacent panels would have the greatest susceptibility to buckling can often be wrong, so all panels in a particular area need to be checked.

2.3.3 ABS Fatigue Analysis

Fatigue assessment is required for all ships for which a SafeHull analysis is required. In many instances, a fatigue analysis will be required, even though the ship is not classed using SafeHull. Part 3 Section 2 of the Rules states "The attention of users is drawn to the fact that, when fatigue loading is present, the effective strength of higher-strength steel in a welded construction may not be greater than that of ordinary-strength steel. Precautions against corrosion fatigue may also be necessary." and "The designer is to give consideration to…proportions and thickness of structural members to reduce fatigue response due to engine, propeller, or wave-induced cyclic stresses, particularly for higher-strength steels."

The ABS approach to fatigue is very specific for the ships for which SafeHull modules have been developed, that is, tankers, bulk carriers, and containerships. The procedures are contained in:

- Part 5, Section 2, Appendix 5/2AA of the ABS Rules "Guide for Fatigue Strength Assessment of Tankers",
- Part 5, Section 3, Appendix 5/3AA of the ABS Rules "Guide for Fatigue Strength Assessment of Bulk Carriers"
- Part 5, Section 6, Appendix 5/6AA of the ABS Rules "Guide for Fatigue Strength Assessment of Container Carriers."

The following discussion will focus on containerships because their hullform is closest to that of a combatant ship, generally having a fine hull form, and operating at moderately high speeds (about 20 knots) although some containerships have speeds as high as 33 knots.

The Guide for Fatigue Strength Assessment of Container Carriers provides a permissible stress range for various structural details, which are classified in accordance with the UK DOE classification. The permissible stress range is given in terms of a "long-term distribution parameter," γ. The parameter γ is in turn a function of the location on the ship, and the fullness of the bow.

$$\gamma = m_s \gamma_0$$

where for deck and bottom structures, m_s varies between 1.05 and 1.02 as the "forebody parameter" $A_r d_k$ varies between 155 m^2 and 112 m^2. If $A_r d_k$ is greater than 155 m^2 then m_s is to be calculated by direct calculation, although the rules do not provide the procedure for the calculation. For locations other than the deck and bottom, and for ships where $A_r d_k$ is less than 70 m^2, m_s is equal to 1.0.

$$\gamma_0 = 1.40 - 0.2\,\alpha\, L^{0.2} \qquad \text{for } 130 < L \le 305 \text{ m}$$
$$= 1.54 - 0.245\,\alpha^{0.8}\, L^{0.2} \qquad \text{for } L > 305 \text{ m}$$

where

α = 1.0 for deck structures
0.93 for bottom structures
0.86 for side shell and longitudinal bulkhead stiffeners
0.80 for side frames, vertical stiffeners on longitudinal bulkhead and transverse bulkheads

$A_r d_k$ is defined in Section 5/6A.3.6.2 of the Rules. A_r is the maximum value of a bowflare shape parameter, A_{ri}, calculated for the first 4 hull stations in the forebody. d_k is a nominal half deck width based on the hull stations in the forebody.

$$A_{ri} = (b_{Ti}/H_i)\ S\ [b_j^2 + s_j^2]^{1/2} \quad , j - 1, n \ \ n \ge 4$$

$$d_k = 0.2 \sum_{1}^{4} b_{Ti}$$

b_{ti} and s_i are illustrated in Figure 2.2.

The long-term distribution parameter, γ, is the Weibull distribution shape parameter, and as can be seen from the foregoing, increases with the length of the ship and with the propensity for bow flare slamming.

The guides for fatigue strength assessment of tankers, bulk carriers and for container carriers are similar. The tables of permissible stress range for classes of structural details as a function of the long-term distribution parameter are identical. Between bulk carriers and container carriers, the definition of γ_0 is the same except that the lower limit for length is 150 meters for bulk carriers, compared to 130 meters for container carriers. The definition of m_s is similar between bulk carriers and container carriers, except the definition of the bow flare parameter is different between the two ship types. For tankers, the long-term distribution parameter, γ, is a function of length only, and that definition is different from that of bulk carriers and container carriers.

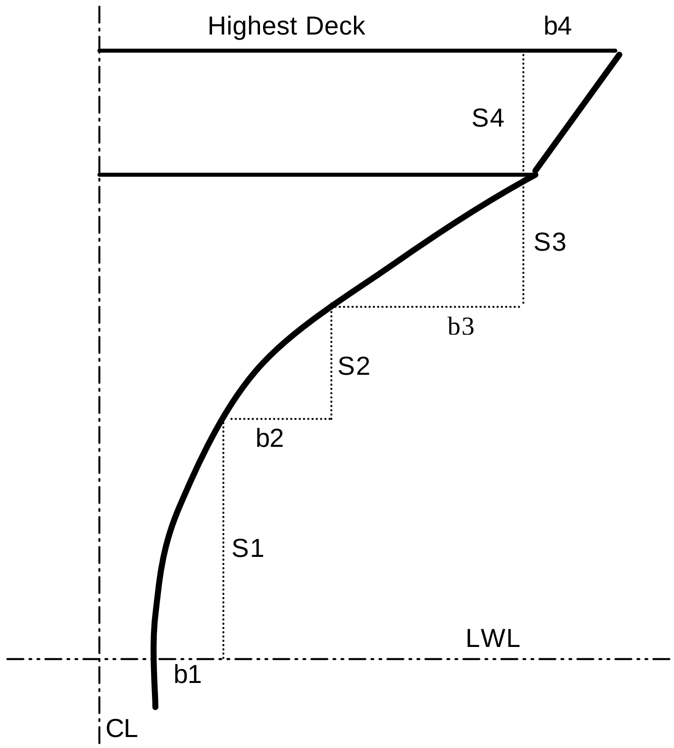


Figure 2.2 Definition of Bow Flare Geometry for Bow Flare Shape Parameter

2.3.4 Relationship between ABS Rules, SafeHull, and DLA

The basic scantlings for all ships are determined by the requirements of the ABS Rules, examples of which are cited above. SafeHull analyses, both Part A and Part B, are required for the classification of all tankers, bulk carriers, and container ships. The DLA approach is an owner's option in classification. With both SafeHull and DLA, the minimum scantlings required by the rules are still required. Use of these advanced procedures can only result in an increase in scantlings, not a reduction. Phase A of SafeHull is a simplified approach to design, providing initial checks on the scantlings, which must be verified by a detailed Phase B analysis, including a finite element analysis of the hull. In general, SafeHull permits a simplified fatigue analysis to be performed, similar to the analysis described in Section 2.3.3. The simplified fatigue analysis using the long-term distribution parameter is contained in SafeHull Phase A and documented in the rules, such as in Part 5, Section 6, Appendix 5/6AA of the ABS Rules "Guide for Fatigue Strength Assessment of Container Carriers." The same answer should result from a manual analysis performed using the rules as a guide as from a SafeHull Phase A analysis. When a critical detail does not meet the simplified criteria, then a full spectral fatigue analysis may be made if the detail is not to be changed. The spectral analysis will also be required if the anticipated operating conditions for the ship are to be different from the 20-year North Atlantic operations assumed for developing the ABS permissible stress ranges. Figure 2.3 illustrates the different approaches.

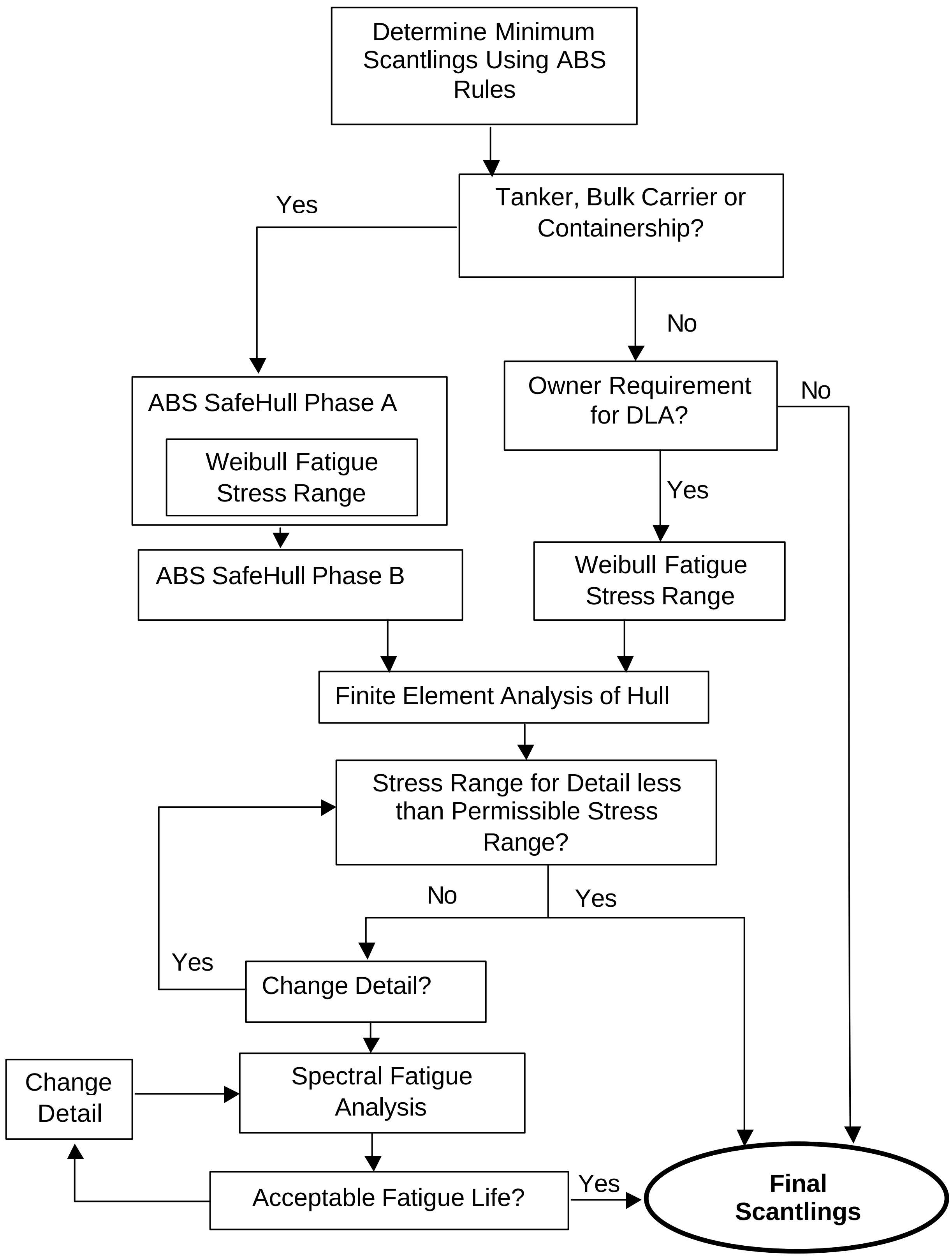


Figure 2.3 Relationship between ABS Rules, SafeHull, and DLA

2.3.5 Simplified and Spectral Approaches to Fatigue

The ABS simplified approach to fatigue, as described above, is based on use of a Weibull distribution for the load exceedance curve. The load exceedance curve is a plot of response parameter, such as bending moment, versus the number of stress cycles that exceed that response level. For example, if a load exceedance curve has a point with an ordinate of 1,000 kiloNewton-meters and abscissa of 10^5 cycles, then there are 10^5 cycles in the load spectrum that have a bending moment of 1,000 kiloNewton-meters or higher. The load exceedance curve is converted to a stress exceedance curve through structural analysis. In some cases, hull girder section modulus can be used to determine the stress from a bending moment load spectrum, but in other cases, a finite element analysis is needed. When several load conditions are acting simultaneously, some assumption must be made concerning the phasing between the different loads in order to combine them in one stress spectrum.

The use of a Weibull distribution to characterize the fatigue loading spectrum for ships was first reported by Nordenström (1973). This approach is well documented, such as in the Ship Structure Committee Report SSC-318, Fatigue Characterization of Fabricated Ship Details for Design (Munse et al., 1982). Munse used this closed-form approach to the fatigue-loading spectrum in order to develop a relationship between maximum design stress and fatigue life for a particular structural detail using information on both the probabilities of the fatigue loading spectrum and the S-N data for the structural detail. The probability is introduced through a reliability factor defined by Munse. A similar approach was taken by Wirsching (Mansour, 1990). The Wirsching approach uses a slightly different form of the reliability factor, but both approaches provide for direct recognition of the inherent randomness and uncertainty in the loading, the analysis procedure, and the fatigue strength of the structure. This approach was taken by ABS in developing their simplified fatigue approach (Chen, 1998).

$$D = \frac{N_T S^m}{A\left[\ln(N)\right]^{m/\xi}} \Gamma\left(1 + \frac{m}{\xi}\right)$$

where:

- D = The Palgren-Miner cumulative damage, taken as D = 1
- N_T = the total number of loading cycles in the life of the ship
- S = the maximum stress range
- m = the slope of the S-N curve in the relationship $N = A/S^m$
- ξ = the Weibull shape parameter
- Γ= the Gamma function

In some instances, such as when the simplified approach indicates a possible fatigue problem and additional factors need to be considered, ABS will use a direct spectral approach to fatigue life calculation. The advantage is that through development of a fatigue loading spectrum for a specific ship, the actual design assumptions such as percent of operability, preferred headings and speeds in differing sea states, area of operation and consequent probability of occurrence of different wave heights and modal periods, and the response amplitude operators (RAOs) for the particular ship can be readily used to derive a fatigue loading spectrum that makes no assumption on shape of the distribution function. The fatigue loading spectrum can also be easily augmented with loading cycles from slam-induced hull girder whipping.

If a fatigue loading spectrum is developed, then the hull girder bending moments by which the spectrum are characterized can be converted to stress at various structural details through analysis of varying levels of sophistication, although the approach must assume a linear relationship between bending moments and stress. The resulting stress spectrum is used with the S-N data for the structural detail being investigated to determine the fatigue life. The fatigue damage computation in this case must be deterministic, assuming fixed values of parameters, such as characterization of the S-N curve. Typically, S-N data with a high probability of exceedance, such as a lower 95 percent bound, is used to characterize the fatigue data.

When different loads are acting simultaneously, they can be combined by either assuming some phasing between them, or a "stress RAO" approach can be used. In the latter, the RAOs for load effects such as vertical and horizontal bending are converted to stress and then used with the wave encounter spectrum to obtain a stress spectrum.

The trade-off (other than reduced computational time) between the use of a "simplified" fatigue approach based on a Weibull loading spectrum and a direct analysis using a fatigue spectrum is then between a reliability based approach and a deterministic approach to fatigue life. As implemented in SafeHull, however, the probability of exceedance is not directly calculated.

ABS provides general guidance for performing a spectral analysis in the SafeHull Load Criteria for Tanker Structures, Commentary on Load Criteria (ABS 1999). Response is to be computed at 15 degree increments of heading for response in regular waves at a speed equal to 75 percent of maximum ship speed. A sea spectrum appropriate for the anticipated operating conditions for the ship is used to determine the response spectrum. In most cases, the default is 20 years operation in the North Atlantic, but alternative sea conditions and service lives can be used.

2.3.6 ABS Benchmarking of the Fatigue Design Procedure

The SafeHull fatigue analysis was compared to the service experience of six different tankers that had service experience of 5 to 19 years (ABS, 1992). The number of ships examined was limited because of a lack of well-documented damage history of ships in service. In general, the actual time for crack initiation of the ships in service was less than the predicted fatigue life when the life was 11 years or less. However, when the predicted service life was 30 years or more, there were no reported instances of cracking. Table 2.1 summarizes that comparison. The ratio of the actual stress range for a structural detail, f_R, is compared to the computed allowable stress range, P_S. A value higher than 1.0 implies a greater than 5% probability of cracking in 20 years.

Table 2.1 ABS Comparison of Predicted Fatigue Damage with Service Experience (ABS, 1993)

SHIP	A	B-1	B-2	C	D	E
Year Built	1977	1986	1988	1975	1977	1974
f_R / P_S	1.23–1.99	1.14–1.35	1.24–1.79	0.77–1.18	0.86–1.04	0.60–1.17
Predicted Fatigue Life (years)	3–11	8–14	3.5–11	12–>30	18–>30	12–>30
Actual Years to Damage	2–4	2–5	N.D.	N.D.	5–7	12–14

Note:
Data is for side longitudinals of single hull tankers in the region between 0.33 of draft to 1.15 of draft.
N.D. — No fatigue damage was reported.

The data in Table 2.1 do not show as strong a correlation between actual and predicted behavior as might be desired. The fatigue behavior of other areas of the structure was also examined, and in general, no fatigue damage was reported in areas where the ratio f_R / P_S was less than 1.0. For that reason, ABS feels that use of the fatigue method provides a reasonable basis for design.

2.4 Design Criteria for U.S. Navy Ships

The basic description of the procedure for designing the structure of U.S. Navy ships is contained in the Structural Design Manual for Naval Surface Ships (NAVSEC, 1976). That manual represents a documentation of U.S. Navy approach as of 1976, and there have been few significant changes since that time.

One of the most important considerations in the U.S. Navy approach is the standardized approach to loads. Hull girder bending moments are based on a static balance of the ship on a trochoidal wave of the same length as the ship, and with a height equal to 1.1 times the square root of the length. Loads on the side and bottom of the ship are based on the head to the design waterline plus a factor times the square root of the length of the ship. For combatant ships, that factor is 0.675, but for noncombatant ships, it is 0.55. Loads on the side and bottom are also determined by computing the static head to the design waterline with the ship heeled to some maximum angle. That angle will vary with the size of the ship, but for ships of the size of cruisers or destroyers, it is 30 degrees. A wave slap loading of 500 pounds per square foot is taken on side plating above the waterline. In the forward area of the hull, allowance is made for slamming loads by taking a design head to a given height above the weather deck at the forward perpendicular, and tapering linearly to the design waterline amidships. That height varies from 8 to 12 feet, depending on the size of the ship.

With the standardized method for calculating hull girder bending moments, the allowable stress is 7.5 tsi for medium steel ships, 8.5 tsi for high strength steel, and 9.5 tsi for HY-80 or

HSLA-80 steel. The section modulus at all points along the hull must be sufficient so that the allowable hull girder bending stress is not exceeded.

In the design of longitudinal members, the stress computed from the local loading is added to the stress from hull girder bending using an interaction formula. For longitudinal stiffeners, the interaction formula is for combined compressive and bending load is:

$$\frac{f_b}{F_b} + \frac{f_c}{K_s F_c} \leq 1.0$$

where:

f_b is the compressive bending stress in the member computed using the design load.

F_b is the allowable bending stress, equal to 27 ksi for medium steel ships, 40 ksi for high strength steel, and 55 ksi for HY-80 or HSLA-80 steel.

f_c is the assumed hull girder compressive bending stress, equal to the allowable stress increased by a margin of 1.0 tsi. This stress is taken as the maximum at the strength deck and keel, and for shell plating, tapered to one-half the maximum at the neutral axis.

K_s is a slenderness coefficient

F_c is the buckling strength of the member.

The U.S. Navy approach is nearly a “first principles” approach, except that the design loads are less than the maximum loads and a high factor of safety is used to compensate for the reduced loads. It was estimated (Sikora et al., 1983) that the standard bending moments will be less than the maximum lifetime hull girder bending moments by a factor ranging from 0.430 to 0.916, with an average value of 0.73. On that basis, the allowable hull girder bending stress for an average medium steel ship would be $7.5 \div 0.73 = 10.3$ tsi., with a range between 8.2 and 17.4 tsi. The design wave loads on the side of the ship are similarly less than the lifetime maximum loads. Therefore, the allowable bending stress for stiffeners is significantly less than the yield strength.

One of the greatest changes in U.S. Navy design practice since the writing of the design manual has been the use of the finite element method. In 1976, this method of structural analysis was only beginning to be used in ship structural design, but it has since become standard practice, particularly for the design of transverse members. In finite element analysis, the standard loads are still used in conjunction with the standard design allowable stresses. The justification for this approach is that the former methods of stress analysis did attempt to replicate the exact response of the structure to a given load. For example, when a longitudinal stiffener is supported by uniformly spaced transverse frames and subject to a uniform load, the bending moments will be the same as for a fixed end beam, which was used in analysis. Likewise, approximate methods of analysis of transverse frames, such as the Hardy-Cross moment distribution method were also used to estimate bending moments and shears.

Recently, combatant loads, such as hull girder whipping moments and fatigue effects have been used for design of U.S. Navy ships, particularly the LPD-17 Class (Sieve et al., 1997). That analysis was conducted assuming 40 years of operations in the NATO North Atlantic sea spectrum, with 35 percent of the lifetime spent at sea. The Ochi 6-Parameter wave spectrum was used. The Response Amplitude Operators (RAOs) used were the NSWCCD "universal" RAOs contained in the computer program SPECTRA (Sikora, 1999), including whipping moments. The S-N curves used were from the standard American Association of State Highway and Transportation Officials (ASSHTO), using a linear plot with no endurance limit. With this analysis, an allowable stress range was determined and used for the design of ship structural details.

Additionally, there is currently an effort underway to develop a Load and Resistance Factor Design (LRFD) approach for naval ship structures. This effort will produce separate factors for loads and for strength of members, so that computed maximum lifetime loads can be used in conjunction with strength computations in a reliability-based design.

2.5 Canadian Navy Structural Design Criteria

The current approach for the ships of the Canadian Forces is based on the standard of the Navy of the U.K. (SSCP23, 1988).

2.5.1 Longitudinal Strength

The standard wave bending moment for U.K. combatant ships is computed by conducting a static balance on a trochoidal wave of length equal to the length of the ship and with a height of 8 meters. This standard was derived by analyzing several combatant ships in the 100 to 200 meter length range. Computations were performed for wave encounters in all of the areas where British ships normally operated, and determining the maximum vertical bending moment expected to occur with a 1 percent probability of exceedance in 3×10^7 wave encounters. Design bending moments are then derived as:

$$M_{ds} = M_{SW} + 1.54\,(M_s - M_{SW})$$
$$M_{dh} = M_{SW} + 1.54\,(M_h - M_{SW})$$

where M_{ds}, M_{dh} = the design sagging and hogging moments
M_{SW} = the still water bending moment
M_s, M_h = sagging and hogging moments calculated by static balance on an 8-m trochoidal wave

The maximum bending moment at midships computed in this manner is then distributed along the length of the ship using a standard method. The maximum moment is carried forward of midship for 0.15 of the ship length, and then reduced linearly to zero at the forward perpendicular. The moments are carried aft of midships using the shape of the computed moments. Neither lateral bending nor torsional bending is considered except when the ship has large openings in the strength deck.

Wave loading on the side and bottom plating is the greatest of the following:

- a 5 meter (16.4 foot) minimum head
- the head to the design waterline plus 0.3 √L (L in meters)
- a head to 1.1 √L at the forward perpendicular, tapering to the design waterline amidships.(L in meters)

The allowable hull girder bending stress is a function of the yield strength of the material and the breadth-to-thickness ratio of plating in the strength deck and shell, as shown in Table 2.2

Table 2.2. UK MOD Allowable Hull Girder Stress (percent of yield strength)

	Allowable Stress / Yield Strength		**Allowable Stress for Mild Steel (tsi)**	
Breadth/thickness (b/t)	Strength Deck	Bottom	Strength Deck	Bottom
b/t < 60	0.65	0.54	10.1	8.4
90 > b/t > 60	0.57	0.43	8.9	6.7
b/t > 90	0.43	-	6.7	-

Note that it has been the British practice to use only mild steel for hull structure. Critical areas, such as crack arrestor strakes, use tougher materials, but higher strength steel is not used to reduce weight because of concerns for buckling and fatigue.

The allowable primary hull girder stress is greater for the strength deck than for the bottom structure because the effects of pressure loading are included when assessing strength. In the design of deck plating and longitudinals, only the calculated primary hull girder bending stress is considered. The maximum bending moment is divided by the actual hull girder section modulus to determine the compressive stress in the deck. Various methods are given in SSCP23 for computing the strength of the members, including load-shortening curves and grillage strength methods to determine the collapse strength of the structure. The recommendation is made that in later stages of design finite element analyses should be conducted to calculate the strength of the structure more accurately. Because a maximum lifetime load is used, no factor of safety should be taken.

2.5.2 Side and Bottom Shell

For the design of stiffeners in the bottom shell, the computed primary bending stress is added to the secondary stress from stiffener bending. This combined stress is used in the buckling calculations without a factor of safety for assessing structural adequacy. Likewise, longitudinals on the side shell are designed similar to those on the bottom, with the primary hull girder bending stress reduced based on the distance from the neutral axis. Again, no factor of safety is used in computing structural adequacy.

2.5.3 Fatigue

SSCP23 –Vol. 1 chapter 13, includes calculation of a permissible design stress range. The bending moment exceedance curve is assumed to be exponential, which is equivalent to a Weibull distribution with a shape parameter of 1.0. The exponential distribution is combined with linear cumulative fatigue damage and the BS 5400 S-N curves to obtain permissible stress ranges for each detail class. This approach was validated by comparison of the predicted mean fatigue life for several details with the actual performance of several ship classes that had experienced cracking during 20 years of operation.

2.6 Commercial Rules for Military Ships

Some classification societies have developed or are developing rules for the design of military ships. Lloyds released their provisional rules in July 1999 (Lloyds, 1999). Lloyds intended to update these in January 2000 following initial evaluation by users. Det norske Veritas had announced their intention to release rules for military ships in the Autumn of 1999 (Majumdar, 1998), but that effort has apparently been delayed. Likewise, ABS is working with the Naval Sea Systems Command to develop rules for military ships.

The Lloyds Rules represent a complete departure from the previous design practice of the Royal Navy. For example, hull girder bending moments are determined using the basic equations that are required by all classification societies who are members of IACS. However, for determination of the extreme vertical wave bending moment, the formula is multiplied by a factor of 1.5. This increase in design moments implicitly increases fatigue life by increasing section modulus, and thus decreases nominal field stress in the hull. The rules also contain definition of sea conditions for the direct computation of extreme hull girder bending moments. Fatigue analysis procedures under the new rules are the same as contained in Lloyds Register Structural Detail Design Guide. Military loads, such as underwater shock or missile blast loads, are dealt with as additional design considerations by which scantlings are increased above the minimum rule requirements. Provision is also made for the use of the Lloyds Total Load Analysis (TLA). TLA uses the rule-based loads, but combines the effects of various loads, such as hull girder bending and pressure loads, on the side shell using load combination factors that allow for the phasing between the various loads. Structural analysis is based on closed-form solutions for various structural elements rather than a global finite element analysis as required by the ABS Dynamic Load Analysis (DLA).

2.7 Naval Ship Assessment by the SafeHull System

SafeHull is a system for analysis of Tankers, Bulk Carriers and Container Ships. Development of SafeHull required definition of loads, response and failure criteria. The strength of the hull girder is in accordance with unified requirements of IACS (International Association of Classification Societies). The development of the unified requirement for hull girder strength is based on operation in the North Atlantic. The route is from Northern Europe to the Northeast United States (Rotterdam to New York).

The loads on the hull and structural elements (plate and stiffening) are determined from operating on this route. The comparison of the structural response to failure criteria selected is calibrated to defined failures. When studying naval ships using SafeHull it is necessary to have structural failures to calibrate the results. Although naval ships operate in the North Atlantic, operation will also include other areas. This will require modification of the SafeHull System to account for the naval ship operation scenario.

The essential elements considered by ABS in developing SafeHull are:

1- LOADS- The loads from the external environment, and the internal loads from cargo and ballast including inertial loads.
2- RESPONSE- Structure must be analyzed in a consistent method for the imposed loads to establish the response.
3- ASSESSMENT- The response (stresses) are to be determined to be within properly calibrated failure criteria for yielding, buckling and fatigue.
4- VALIDATION- SafeHull criteria has been validated by using known failures to establish the limits for yielding, buckling and fatigue.
5- CRITERIA- Without known failures to calibrate the structure of a ship type against, a rigorous method for assessment of the ship type such as Dynamic Load Approach (DLA), a system based on first principles must be used. The design of naval ships presently uses methods of this type. Commercial ships are also at times designed to such a system and for this, ABS would apply SH-DLA.
6- FAILURE- Naval ships in general are found to be more robust than commercial ships due to extensive assessment during the design development which includes evaluation to first principles. Efforts to reduce the rigor in design require proper definition of the loads, response and failure criteria to apply.

2.8 Summary

There is a considerable difference between the historical approaches to the structural design of military and commercial ships for environmental loads. These differences have diminished in recent years as the commercial procedures have evolved to include structural design based on analytically developed loads and detailed stress analysis. Both the ABS DLA approach and the current NAVSEA approach use definition of loads made by analysis of typical ships, and generalize the results for future designs. The approaches, in general, provide for direct computation of ship response and for differences in assumed operational profiles. The differences between procedures may diminish in the future as the classification societies develop rules for military ships and the military authorities adopt these rules. The degree of difference will not be able to be ascertained until ships are designed using the new rules, and the scantlings so developed are compared to equivalent ships designed under the old approach. The approach that results in heavier scantlings should have an inherently greater fatigue life. Because fatigue assessment has now become standard practice for both commercial and military ship design, either approach should result in improved fatigue lives. Table 2.3 summarizes the differences in the approaches for fatigue assessment.

Table 2.3 Comparison of Commercial and Naval Approaches for Fatigue Assessment

	ABS Simplified	ABS Spectral	U.S. Navy SPECTRA Program	U.S. Navy Detailed Analysis	Canadian
Method	Weibull Distribution	Spectral Analysis	Spectral Analysis	Spectral Analysis	Exponential Distribution
Application	Assessment	Assessment	Design	Assessment	Design
Philosophy	Prevent fatigue cracking (in general)	Prevent fatigue cracking (in general)	Prevent fatigue cracking (safe life)	Prevent fatigue cracking (safe life)	Prevent fatigue cracking (safe life)
Practice	Assess details in highly stressed areas important to safety	Assess details in highly stressed areas important to safety	Limit nominal stress and stress concentrations	Limit nominal stress and stress concentrations	Limit nominal stress and stress concentrations
Hull Girder Bending and Shear	Maximum response from standard equations	Hydrodynamic analysis	Response from generalized algorithms	Response from model tests and full-scale ship instrumentation	Static Balance on 8-meter wave
External Hydrodynamic Pressure	Range of standard design loads	Hydrodynamic analysis including ship motion	Not considered	Not considered	Function of ship length
Internal Tank Loads	From Rules	Ship motion and Sloshing analysis	Can be included Simplistically	Can be included Simplistically	Not considered
Longitudinal Distribution of Bending Moments	Trapezoidal	Computed	Sinusoidal (1-cosine)	Sinusoidal (1-cosine)	Trapezoidal
Wave height probabilities	H-Series North Atlantic	H-Series North Atlantic or from applicable shipping route	NATO North Atlantic	NATO North Atlantic or applicable alternative	NATO North Atlantic
Lateral/Torsional Bending	Rule Moments	Seakeeping Analysis	Considered separately	Can be combined to suit applications	Not considered
Ship Heading probabilities	Not applicable	Equal probability of all headings	*f*(ship type, speed, wave height)	*f*(ship type, speed, wave height)	Head Sea, (L_W=LBP)
Ship Speed	Not applicable	75% maximum	Various	Various	Not considered
Wave Cells	Not applicable	16 wave heights x 11 modal periods = 176	16 wave heights x 11 modal periods = 176	Various; Can be Application Specific	Not considered
Wave Spectra	Not applicable	2-parameter scatter	Ochi 6-Parameter	Various types available	Not considered
Method of Hull Stress Analysis	Hull beam bending	Finite Element Analysis	Hull beam bending	Finite Element Analysis	Hull beam bending
Stiffener bending analysis	Bending plus torsion	If finite element model has sufficient detail	Not considered	If finite element model has sufficient detail	Not considered

	ABS Simplified	ABS Spectral	U.S. Navy SPECTRA Program	U.S. Navy Detailed Analysis	Canadian
Fatigue Load Spectrum	Weibull distribution	Spectral analysis considering all sea conditions to be encountered	Spectral analysis considering all sea conditions to be encountered	Spectral analysis considering all sea conditions to be encountered	Exponential distribution
Whipping	Bow flare increment to loads	Not considered if linear seakeeping used	Empirical from trial data	Model or ship data	Implicit in ship calibration data
Fatigue Analysis	Linear cumulative damage based on UK DEN bilinear S-N curves	Linear cumulative damage based on any widely recognized S-N curves	Linear cumulative damage based on AASHTO linear S-N curves	Linear cumulative damage based on any appropriate S-N curves	Linear cumulative damage based on BS 5400 bilinear S-N curves
Design Life	20 years at 70% – 80% operability for container ships	Owner requirements	30–40 years at 35%–60% operability	Ship/Application Specific	20 years at 100% operability
Total Days Operation	5110–5840	Owner requirements	3830–8760	Ship/Application Specific	7300
Operating area	North Atlantic	Anticipated shipping route or unrestricted service	North Atlantic	Actual operating area or unrestricted service	North Atlantic
Supporting test data/reports for S-N curves	UK DEN Reports	As appropriate	NCHRP reports available	As appropriate	Maddox (1991)
Permissible Stress Range	*f*(detail)	*f*(detail)	*f*(service life, detail, ship type)	*f*(service life, detail, ship type)	*f*(detail)
Corrosion	Considered	Considered	Not Considered	Not Considered	Not Considered
Analysis time and cost	Minimal	Significant	Minimal	Significant	Minimal
Computer Program Used	SafeHull/ Empirical	FLECS	SPECTRA	SPECTRA	-

3. Operational Environments Used in Commercial and USN Ship Design Practice

3.1 Purpose

This chapter identifies and lists commercial ship design operating environments. It also addresses the operational environmental factors considered during the design of ships for the U.S. Navy and Canadian Navy. For each of the identified design practices, the following aspects are discussed:

1) Service Life
2) Assumptions about total years of operation and percent of at-sea time
3) Operating areas and associated wave spectra applied

3.2 Introduction

The operating environments for commercial ships will vary with the area of operations, type of service, and anticipated service life. A cruise ship operating in the Caribbean will experience a more benign environment than will a containership operating in trans-Atlantic service. Moreover, the cruise ship will take greater efforts to avoid rough weather than will the containership. However, these differences are not reflected in the rules for developing the scantlings of commercial ships. The assumption is made that even if a ship is intended by its owners to operate in restrictive service, future owners may operate the ship in an entirely different manner.

The general assumption in developing the design loads for commercial ships is that the vessel will operate for 20 years in a harsh environment, such as the North Atlantic (ABS, 1999). The loads so derived are assumed to have a probability of exceedance of 10^{-8}. Only if it is known that a more severe environment is to be expected, such as a tanker operating on the West Coast to Alaska (TAPS) trade, will more severe environments be used for determining the design loads. Table 3.1 illustrates this difference between the probability of occurrence of different wave heights in the North Atlantic and the TAPS trade as developed for two commercial ships operating on these routes (Glen et al., 1999). This information was developed by plotting the course of two ships operating on these routes and summing the different sea states encountered, using data from global wave statistics (Hogben et al., 1986).

Table 3.1 Wave Height Probabilities for Different Operating Areas (Glen et al., 1999)

NATO Sea State	North Atlantic		California to Alaska (TAPS Trade)	
	Eastbound	Westbound	Northbound	Southbound
1	0.0148	0.1005	0.0484	0.1120
2	0.0620	0.1128	0.1258	0.1537
3	0.1906	0.1803	0.1928	0.1880
4	0.1804	0.1525	0.1644	0.1472
5	0.2526	0.2667	0.1999	0.1886
6	0.2996	0.1818	0.2679	0.2070
7	0.0000	0.0054	0.0013	0.0035

In special cases where a ship is to operate only in benign conditions, reduced loading can be used for fatigue assessments. In most cases, the fatigue assessment performed during design represents an owner's requirement so that maintenance costs can be reduced. A fatigue assessment is used to increase scantlings and fatigue classifications of structural details above the minimum rule requirements, and the extent of such increases is often a decision made by the owner, not the classification society. One area where the classification societies reduce the loading requirements is in the number of fatigue cycles assumed during the lifetime of the ship. For fatigue analysis, ABS assumes that tankers operate 100 percent of the time during a 20-year lifetime. For bulk carriers and containerships, a 70 to 80 percent operability over a 20-year life is assumed. ABS also assumes that the ship will take headings relative to waves of equal probability, and that the ship will be operated at 75 percent of maximum ship speed.

The actual operating conditions of ships may vary from the assumptions made by classification societies or military design authorities. In a study made for the Ship Structure Committee (Glen et al., 1999), information was gathered from commercial ship owners and the U.S. Coast Guard on actual operational conditions that ships encountered over a period of time. This information is somewhat limited in that the commercial ship data was limited to 3 ships operating over an average of 1.7 years for a total of 5 ship years of operation. It should therefore not be considered as typical for all commercial ships, only indicative of what operational profiles might actually be. The report includes data from a high-speed container ship operating on a regular route in the North Atlantic, a tanker operating between California and Alaska, a tramp bulk carrier, and a U.S. Coast Guard cutter. In all cases, it was shown that an assumption of random speeds and headings relative to the direction of waves in different sea states is not valid. However, the relationship between speed, heading, and sea state varied depending on the ship size and type. The report provides such probabilities for the ships analyzed, but does not generalize the results for use with other ships. Most importantly, the report did not assess the difference in fatigue life prediction that results from the use of specific operational profiles compared to random operational profiles.

The percent of time at sea of the four ships studied is shown in Table 3.2. Also shown in Table 3.2 is data on the operation of 86 combatant ships of the U.S. Navy. This data was taken from the U.S. Navy Visibility and Management of Operating and Support Costs (VAMOSC) database, and will be discussed below.

Table 3.2. Percentage of Time at Sea of Ships (Glen et al., 1999, VAMOSC)

Ship	Percent of Time at Sea
Container Ship, Europe to United States[1]	53
Tanker, California to Alaska[1]	65
Tramp Bulk Carrier[1]	59
U.S. Coast Guard Cutter[1]	40
U.S. Navy Aircraft Carrier[2]	56
U.S. Navy Cruiser[2]	52
U.S. Navy Amphibious Transport Ship[2]	54

[1] (SSC SR-1388)
[2] VAMOSC Data, October 1997 — September 1998, maximum operations for ship class

For the fatigue analysis that was performed during the study, a ship life of 20 years was assumed because the data gathered represented only a portion of the lives of the ships, ranging from one to three years. The operating profile for the tanker in the full-laden southbound leg of its voyage is shown in the Table 3.3. Table 3.3 gives the probability of a combination of speed, heading, and sea state on the given route. By contrast, the operational profile of naval combatants is shown in Table 3.4 (Michaelson, 1996). Table 3.4 is more general than Table 3.2. It gives the conditional probability that a ship will operate at a particular combination of speed and heading, given that it is in a particular sea state. The operational profile in Table 3.4 is a recommended profile that was based on the analysis of 15 years of operations of 20 naval combatants. It is important to note that the operational profile represents 300 ship years of operation.

Table 3.3. Sample Tanker Operating Profile *(Glen et al., 1999)*
(1000 x Probability of combination of speed, heading, and sea state)

Speed (knots)	Sea State 1					Sea State 2				
	Head	Bow	Beam	Quart.	Follow.	Head	Bow	Beam	Quart.	Follow.
0–6	0.109	0.301	0.364	0.542	0.126	0.000	0.000	0.000	0.000	0.000
6–10	0.214	0.594	0.717	1.067	0.248	0.086	0.246	0.283	0.443	0.103
10–14	0.493	1.367	1.650	2.457	0.571	0.613	1.749	2.009	3.144	0.730
14–18	3.447	9.564	11.546	17.192	3.998	3.504	10.004	11.492	17.986	4.175
Sum	**4.3**	**11.8**	**14.3**	**21.3**	**4.9**	**4.2**	**12.0**	**13.8**	**21.6**	**5.0**

Speed (knots)	Sea State 3					Sea State 4				
	Head	Bow	Beam	Quart.	Follow.	Head	Bow	Beam	Quart.	Follow.
0–6	0.125	0.286	0.330	0.548	0.123	0.000	0.000	0.000	0.000	0.000
6–10	0.467	1.066	1.232	2.045	0.461	1.285	2.968	3.568	5.686	1.293
10–14	7.089	16.186	18.702	31.036	6.990	5.956	13.757	19.538	26.351	5.991
14–18	18.637	42.549	49.163	81.588	18.376	15.857	36.628	44.032	70.159	15.950
Sum	**26.3**	**60.1**	**69.4**	**115.2**	**26.0**	**23.1**	**53.4**	**64.1**	**101.2**	**23.2**

Speed (knots)	Sea State 5					Sea State 6				
	Head	Bow	Beam	Quart.	Follow.	Head	Bow	Beam	Quart.	Follow.
0–6	0.000	0.000	0.000	0.000	0.000	0.061	0.103	0.137	0.221	0.049
6–10	0.639	1.530	1.818	15.035	3.428	5.663	9.540	12.669	20.388	4.490
10–14	3.317	7.940	9.430	15.035	3.428	5.633	9.540	12669	20.388	4.490
14–18	9.891	23.676	28.121	44.833	10.223	6.085	10.306	13.686	22.024	4.850
Sum	**13.8**	**33.1**	**39.4**	**62.8**	**14.3**	**13.4**	**22.7**	**30.2**	**48.6**	**10.7**

Speed (knots)	Sea State 7				
	Head	Bow	Beam	Quart.	Follow.
0–6	0.941	0.843	1.651	2.268	0.456
6–10	1.254	1.125	2.201	3.024	0.608
10–14	2.509	2.249	4.402	6.049	1.216
14–18	0.627	0.562	1.100	1.512	0.304
Sum	**5.3**	**4.8**	**9.4**	**12.9**	**2.6**

Table 3.4 Operational Profile for Combatants (Michaelson, 1996)
(Probability of speed and heading in given sea state)

Speed (knots)	0–3 Meter Have Height					3–6 Meter Wave Height				
	Head	Bow	Beam	Quart.	Follow.	Head	Bow	Beam	Quart.	Follow.
0–10	.06884	.09032	.06641	.07458	.04791	.06131	.09045	.04422	.04422	.02714
10–20	.10590	.15724	.10414	.13127	.07297	.14975	.19698	.13970	.09447	.06131
>20	.01583	.02168	.01473	.01815	.01004	.01809	.02714	.01307	.02412	.00804
Sum	**0.1905**	**0.2692**	**0.1852**	**0.2240**	**0.1309**	**0.2291**	**0.3145**	**0.1969**	**0.1628**	**0.0964**

Speed (knots)	>6 Meter Wave Height				
	Head	Bow	Beam	Quart.	Follow.
0–10	.11111	.08642	.08642	.02469	.02469
10–20	.16049	.16049	.09877	.08642	.04938
>20	.00000	.01235	.02469	.01235	.06173
Sum	**0.2716**	**0.2592**	**0.2098**	**0.1234**	**0.1358**

Many commercial ship owners and operators are installing hull response monitoring systems (over 200 by 1997) to measure and display key ship motions and hull structural responses. A study of such systems was made by the Ship Structure Committee (Slaughter et al., 1997). The information provided by such systems is helpful in making fatigue analyses of the ships monitored. Because the owners generally consider such information proprietary, there has been no effort to date to systematically analyze this data in the development of typical fatigue spectra for commercial ships. However, it does represent one commercial approach to fatigue analysis.

3.3 ABS Fatigue Analysis

Chen and Thayamballi (1991) gave a discussion of the approach being taken by ABS to develop a fatigue analysis procedure. They developed the parameters “response severity” (RS), “fatigue severity” (FS) and “fatigue vulnerability” (FV), defined as:

$$RS = MPEV/[MPEV]_N$$

$$FS = D / D_N$$

$$FV = FS / RS^m$$

MPEV is the most probable extreme value of the wave height that will occur in a particular environment, and $[MPEV]_N$ is the most probable extreme value on a standardized route, Rotterdam to New York. D is the Palmgren-Miner cumulative damage summation for a ship operating in a particular environment, and D_N is the damage summation for the standardized route. The coefficient m is the slope of the S-N curve for a structural detail being analyzed. The FV parameter measures how vulnerable a structure is to fatigue damage in a given wave environment. Using these parameters, they demonstrated that the most severe wave environment does not always represent the most severe environment for a particular ship on the basis of fatigue. Chen and Thayamballi then ranked 104 ocean zones on the basis of the three parameters, clearly showing that the operating area of the ship influences the extent of fatigue damage. The fatigue vulnerability ranged from a value of 0.1 for the most benign to 3.4 for the most severe. The results for a few environments and routes are shown in Table 3.5.

Table 3.5. Variation of Severity Parameters with Respect to Wave Environment (Chen and Thayamballi, 1991)

Region	Response Severity (RS)	Fatigue Severity (FS)	Fatigue Vulnerability (FV)
Grid Point 128	1.030	1.587	1.454
Gulf of Alaska	1.151	2.314	1.518
Alaska to California	1.087	1.329	1.035
Alaska to Yokohama	1.069	1.585	1.296
Europe to New York	1.000	1.000	1.000

Chen and Shin (1997) discuss the ABS approach to loads analysis. The H-family of spectral wave data (ABS, 1980) that was developed for strength assessment is used by ABS. The ABS H-family of North Atlantic measured wave spectra consists of 5 weather groups of significant wave heights of 3, 6, 9, 12, and 14.69 meters. Each weather group is represented by

10 wave spectra, except for the 14.69-meter group, which contains 12. An H-family group for the 10-meter significant wave height case is shown in Figure 3.1

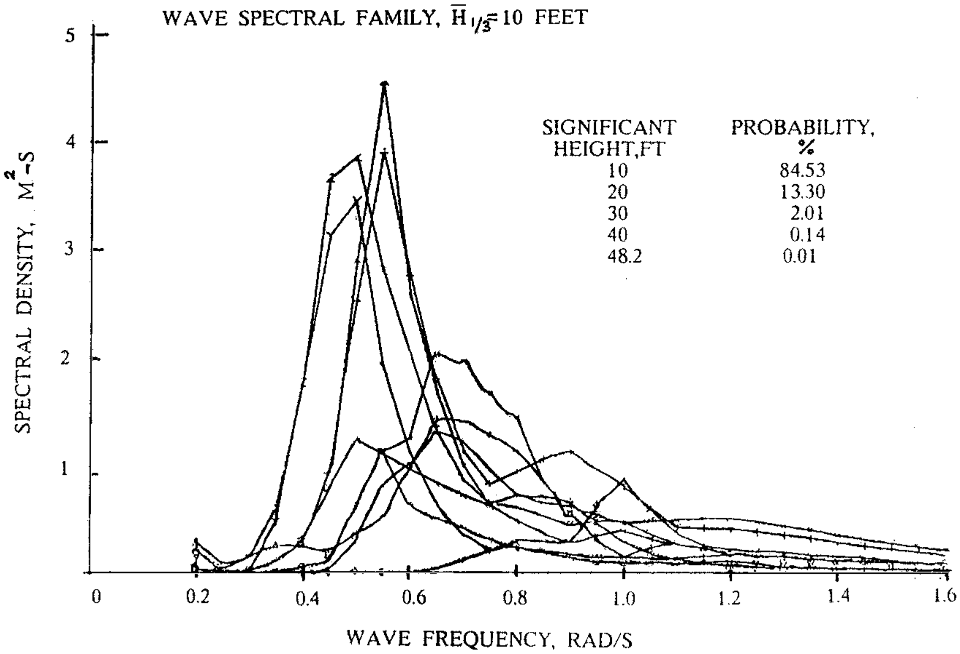


Figure 3.1 ABS H-family of wave spectra for 3 meter Significant Wave Height (Thayamballi et al., 1987)

In assessing strength, the emphasis is on the highest waves, which are characterized by the tails of the probability density functions. However, for fatigue assessment, all wave occurrences are important. The wave spectrum used should have an unbiased joint probability of characteristic period and significant wave height.

The approach to load determination as used by SafeHull is given by ABS (1999). This documents the approach used in deriving the design loads for tankers. The assumption is made that the ship will operate in the North Atlantic for 20 years, with random headings and at 75 percent of full speed.

3.4 U.S. Navy Fatigue Analysis

In performing fatigue analyses, the U.S. Navy uses the computer program SPECTRA to develop the fatigue loading spectrum. This program was described by Sikora et al. (1983), later by Sikora and Beach (1986), and most recently by Sikora (1998). The computer program is capable of developing a fatigue spectrum for any ship operating for any length of time in any wave environment, four of which are incorporated into the program. The characteristics of the ship are described by linear response amplitude operators (RAOs), which may be either default values or separately input by the user. The default values are based on the testing of instrumented models in the David Taylor Model Basin at Carderock, Maryland. The user input RAOs would be obtained either from model or full-scale measurements. Since these RAOs are ship specific, they would reflect the best estimate of ship response. If unavailable, a normalized general empirically based RAO can be derived given the heading, speed and principal dimensions of the ship. The RAO's are differentiated as to ship type:

- Commercial and Naval Auxiliaries
- Amphibious Assault
- Aircraft Carriers
- Frigate
- Destroyers and Cruisers

Other than this differentiation by ship type, a particular vessel is characterized only by length and beam. From this information, RAOs are developed for a variety of ship headings and speeds. The probability of a ship taking a particular heading and speed during differing wave conditions is also characterized by standard tables built into the program for different ship types, although the operator has the option of inputting a different set of probabilities.

The SPECTRA program includes prediction of slam-induced hull girder whipping. Model test data and at-sea measurements of vertical and lateral whipping were analyzed and an exponential distribution was developed. The rate of slamming is taken as proportional to the encounter frequency, and inversely proportional to the length of the ship.

Tables 3.6 through 3.8 shows the operating profiles used for U.S. Navy ships in fatigue analyses in the SPECTRA program.

Table 3.6 U.S. Navy Standard Operational Profiles for Frigates, Destroyers, and Cruisers

Speed (knots)	**Heading**	**Significant Wave Height (meters)**		
		0–5	**5–10**	**>10**
5	Head	.0125	.0250	.0000
	Bow	.0250	.3750	.8075
	Beam	.0250	.0250	.0000
	Quarter	.0250	.0500	.0425
	Follow	.0125	.0250	.0000
15	Head	.0875	.0225	.0000
	Bow	.1750	.3375	.1420
	Beam	.1750	.0225	.0000
	Quarter	.1750	.0450	.0080
	Follow	.0875	.0225	.0000
25	Head	.0250	.0025	.0000
	Bow	.0500	.0375	.0000
	Beam	.0500	.0025	.0000
	Quarter	.0500	.0050	.0000
	Follow	.0250	.0025	.0000

Table 3.7 U.S. Navy Standard Operational Profiles for Aircraft Carriers and High Speed Cargo Ships

Speed (knots)	Heading	Significant Wave Height (meters)		
		0–5	5–10	>10
5	Head	.0100	.1250	.1750
	Bow	.0200	.1250	.1750
	Beam	.0200	.0625	.0875
	Quarter	.0200	.1250	.1750
	Follow	.0100	.0625	.0875
15	Head	.0963	.1150	.0750
	Bow	.1925	.1150	.0750
	Beam	.1925	.0575	.0375
	Quarter	.1925	.1150	.0750
	Follow	.0963	.0575	.0375
25	Head	.0188	.0100	.0000
	Bow	.0375	.0100	.0000
	Beam	.0375	.0050	.0000
	Quarter	.0375	.0100	.0000
	Follow	.0188	.0050	.0000

Table 3.8 U.S. Navy Standard Operational Profiles for Auxiliaries and Commercial Cargo Ships

Speed (knots)	Heading	Significant Wave Height (meters)		
		0–5	5–10	>10
5	Head	.0100	.1250	.1750
	Bow	.0200	.1250	.1750
	Beam	.0200	.0625	.0875
	Quarter	.0200	.1250	.1750
	Follow	.0100	.0625	.0875
15	Head	.1150	.1250	.0750
	Bow	.2300	.1250	.0750
	Beam	.2300	.0625	.0375
	Quarter	.2300	.1250	.0750
	Follow	.1150	.0625	.0375

In the SPECTRA program, the wave environment can be represented by one of four environments, General North Atlantic, NATO North Atlantic, Ochi North Atlantic, or General Pacific. The probability of wave height occurrence of each environment is shown in Table 3.9. The user also has the option of inputting the statistics of a different wave environment. The sea spectrum in these environments can be a Pierson-Moskowitz, Bretschneider, Ochi 6-Parameter, or North Atlantic 2-Parameter. The program also computes slam induced whipping and adds that response to the fatigue loading spectrum.

Table 3.9 Sea State Probabilities

Significant Wave Height (meters)	Frequency of Occurrence			
	General North Atlantic	NATO North Atlantic	Ochi North Atlantic	General Pacific
<1	.03920	.0870	.05030	.22540
1–2	.33000	.1920	.26650	.38490
2–3	.14800	.2200	.26030	.23050
3–4	.07230	.1570	.17570	.09450
4–5	.03550	.1240	.10140	.03033
5–6	.01810	.0800	.05890	.01735
6–7	.01100	.0520	.03460	.00675
7–8	.00660	.0390	.02090	.00390
8–9	.00360	.0250	.01200	.00312
9–10	.00247	.0130	.00790	.00177
10–11	.00138	.0070	.00540	.00058
11–12	.00074	.0040	.00290	.00031
12–13	.00040	.0000	.00160	.00031
13–14	.00019	.0000	.00074	.00010
14–15	.00012	.0000	.00045	.00001
>15	.00010	.0000	.00041	.000001

The standard practice for the U.S. Navy, such as (Kihl, 1991), is to use the default values of the RAOs and operating probabilities during ship design. The Ochi 6-Parameter sea spectrum is used with NATO North Atlantic wave probabilities. In the study by Kihl, that spectrum and that probability table were used to determine the average fatigue life of various structural details. The design life and operability were first defined and used to generate the fatigue load spectrum. Critical details such as frame and bulkhead penetrations, openings, and transverse butt welds over the entire ship were then analyzed to determine the fatigue life of each detail. The ship that he analyzed had been designed using the standard U.S. Navy design procedures, which did not include fatigue analysis at that time. Recent U.S. Navy practice is to include fatigue analysis as part of the structural design of ships, such as the Amphibious Transport Dock LPD 17 (Sieve et al., 1997). This ship class was evaluated for fatigue using SafeHull Phase A (See Chapter 9). The SafeHull Phase A analysis indicated no areas in the midship section that were inadequate for fatigue. This comparison illustrates the suitability of this commercial method when used in naval ship design. The SafeHull comparison was made after the design was completed using the naval procedure, but is shows that an existing commercial method can be used to screen details for further assessment by methods that are more exact. The fatigue design of the LPD 17 Class by the U.S. Navy was based on the default RAOs of SPECTRA, the operating profile for aircraft carriers and high speed cargo ships, the Ochi 6 parameter sea spectrum, General Atlantic wave height probabilities, and 50 percent operability over a 40-year service life.

Data available from the U.S. Navy Visibility and Management of Operating and Support Costs (VAMOSC) database indicates the number of days that U.S. Navy ships actually are at sea during a year. It is important to note that the data represents 230 ship years of operation and that similar data for commercial ships in the reference (Glen et al., 1999) is limited to 5 ship years. The assumption of 35 percent operability is borne out by data provided by the VAMOSC database as shown in Figure 3.2 for Ship G of this study. The average time underway for all ships of the class from Fiscal Year 1986 to FY 1998 is 34.1 percent. However, the trend has been one of decreasing operations during the 1990s, going from a peak of 41.4 percent in FY 1991 to 28.7 percent in FY 1998. If future operations are at this reduced tempo, then predictions of fatigue life based on 35 percent operability will be conservative. On the other hand, there is considerable variability within the VAMOSC data. The standard deviation of the operability over the years recorded is 939 hours, so that the mean minus two standard deviations is 5.8 percent operability, and the mean plus two standard deviations is 55.5 percent operability.

Between ship classes and within ship classes, there is considerable variability. One aircraft carrier operated for 5,757 hours and 4,129 hours in FY 80 and 81, respectively, which represents 56 percent operability. However, all aircraft carriers of that class averaged 34 percent operability over a 20-year period. One cruiser operated for 5,208 hours and 3,960 hours in FY 91 and FY 92, respectively, which represents 52 percent operability, although the 10-year average for that class was 34 percent operability. One amphibious transport ship operated for 4,699 hours in FY 91, which represents 54 percent operability, although the 18-year average for that class of ships was 26 percent operability.

A study was made of the actual operational profiles of U.S. Navy ships by Michaelson (1996). Weather observations made by 40 naval ships over 15 years were examined in order to create ship operational profiles. These ships included a variety of ship types to reveal any differences in their operating characteristics. The data included the ship speed, ship heading and wave height and direction. The data was grouped in the following categories:

- Aircraft carriers
- Combatant ships
- Amphibious ships
- Auxiliary ships

Table 3.4 above shows the resulting operational profile for naval combatant ships.

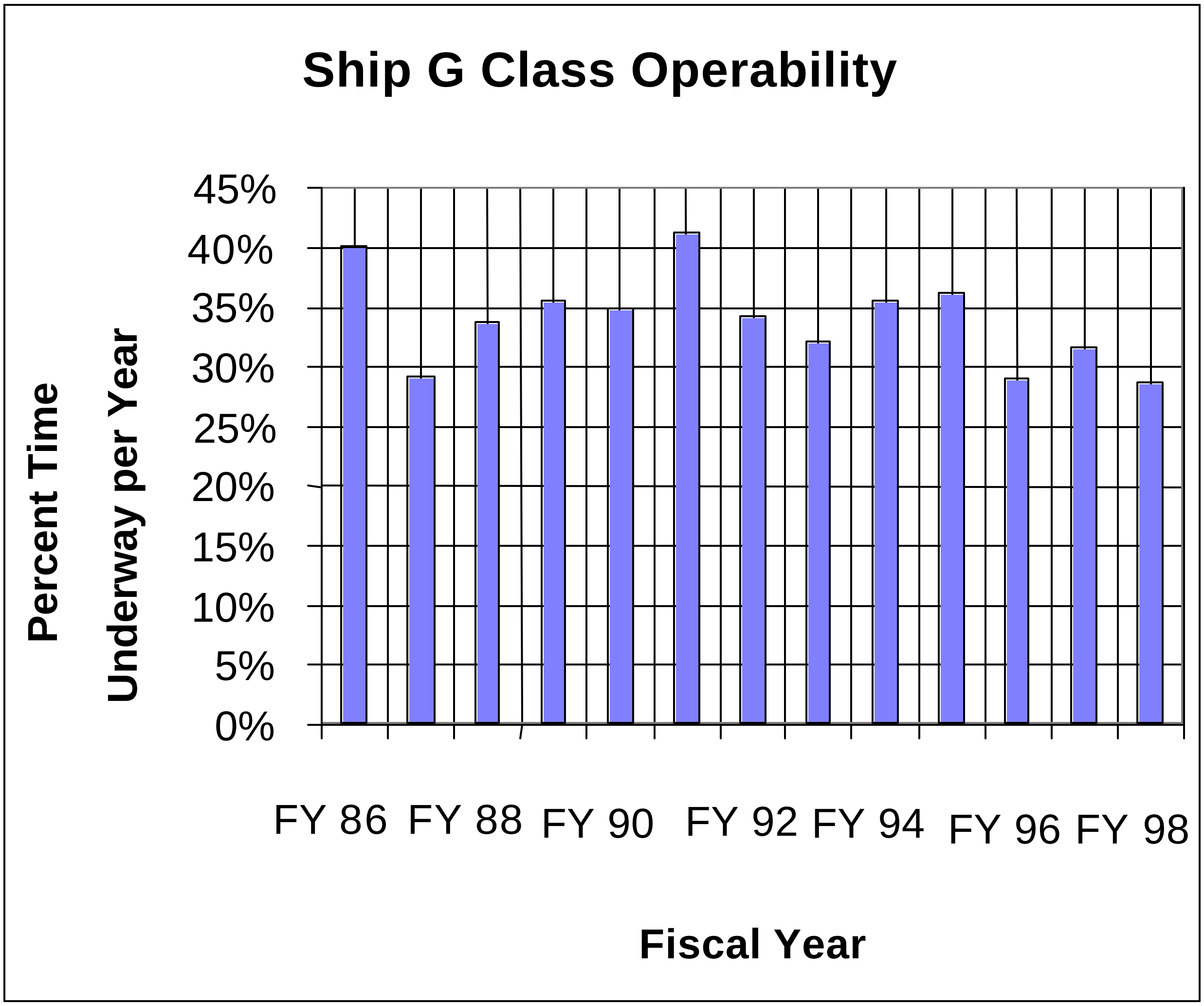


Figure 3.2: Percent of Time Underway for Ship G

Because the wave height and direction are based on visual observations, the accuracy of the information could be questioned. Common judgment is that wave height observations tend to approximate the average for the one-third highest waves ($H_{1/3}$). For that reason, $H_{1/3}$ is called the significant wave height. However, there is some indication (such as Ochi, 1978) that if the observers are mariners, they will tend to underestimate the height of the higher waves. A different conclusion was reached by Nordenström (SNAME, 1989) that trained wave observers tend to underestimate the height of the lower waves, and to overestimate the height of the higher waves. Ochi developed the relationship

$$H_{1/3} = H_V^{1.08} \text{ (meters)}$$

where H_V is the reported wave height.

However, Nordenström developed the relationship

$$H_{1/3} = 1.68\ H_V^{0.75}\ \text{(meters)}$$

If the significant wave height is 10 meters, both of the above formulas yield the same result; namely, that the observer would report the height as 8 meters. A significant wave height of 17 meters would be recorded as 14 meters if the Ochi correction is correct, and as 12 meters with the Nordenström correction.

Because the data analyzed is from the observations of mariners, it would seem more proper to use the Ochi correction, although the observers on some ships, such as aircraft carriers, are trained meteorologists, and their perceptions could be different. Furthermore, there is the difference of height of eye between different ship types, which was not accounted for in either comparison of observed and measured wave heights. An observer on the bridge of a combatant ship would be only 5 to 10 meters above the water, on an auxiliary or merchant ship 20 to 40 meters above the water, and on an aircraft carrier 50 meters above the water. The difference in height of eye would make a significant difference in the way that the observer would see the waves, and thus make different judgments about wave height. The study by Michaelson discounted these corrections, and made all of the analysis of data on the basis of the observed wave height

One of the important conclusions of the Michaelson study is that the spectrum of the observed waves is significantly less than that of standard wave spectra. For example, there were less than 1 percent of the recorded observations for wave heights of 4 meters, but the North Atlantic wave data indicate a 10 percent probability of encounter. This difference is more than can be accounted for by the difference between observed and recorded data. The analysis showed that the naval ships tend to operate mostly in coastal waters, and little in the open ocean. The assumption of operation solely in the North Atlantic is therefore extremely conservative for naval ships.

Another result of the Michaelson study is that even in lower sea states, the heading is not random, but ships tend to favor head seas. Michaelson commented that the forward motion of an observer might tend to skew observations toward head seas. However, it is also likely that ships on training missions would tend to favor the most sea kindly heading so as to maximize crew performance during training exercises. Michaelson did not compare the predicted fatigue lives using previous assumptions to the lives that would be predicted using the new data, but a significant increase in life would result from the lowered sea states. The report did provide recommended profiles of ship headings and speeds in various sea states that can be used for the development of fatigue loading spectra, particularly with the NSWCCD program SPECTRA.

To determine the impact of different probability of sea states and operational profile within a sea state, a fatigue analysis of a typical naval vessel was made using the U.S. Navy SPECTRA program with two different sea state probabilities. The probabilities were those from Table 3.9 for NATO North Atlantic and for General Atlantic. The latter is the more benign environment, and as can be seen in Table 3.10, results in fatigue lives approximately twice as long as when the NATO North Atlantic probabilities are used.

The fatigue lives shown in Table 3.10 for the NATO North Atlantic Sea Spectrum should be comparable to results for a detailed SafeHull Phase B analysis using 3-dimensional finite element analysis because ABS assumes operations in the North Atlantic. Other differences, such as the S-N curves of the welded structural details, and assumed headings and speeds could produce other changes in the results. It would be informative to see what fatigue lives such an analysis would predict, although such a comparison was beyond the scope of this study.

Table 3.10: Effect of Sea Spectrum and Operational Profiles on Predicted Fatigue Lives

Location	Fatigue Life Using NATO North Atlantic Sea Spectrum and Table 3.6 Operational Profile		Fatigue Life Using General Atlantic Sea Spectrum and Modified Operational Profile for Michaelson (1996)	
	Mean S-N Data	Lower Limit S-N Data	Mean S-N Data	Lower Limit S-N Data
Ship G, Fr. 129 Dk. Edge	92	33.6	210	77
Ship G, Fr. 136 Dk. Edge	16.6	6.1	38.1	13.9
Ship G, Fr. 129 Dk. Edge	13.0	4.7	30.3	11.1
Ship G, Fr. 136 Dk. Edge Modified	7.9	2.9	18.6	6.8

3.5 Summary

The operating environment clearly influences the fatigue life of ship structure, with some environments far worse than others. The actual area of operation can have a significant effect on fatigue life. There is a significant difference between the amount of operability data used in this study for commercial and military ships, and so comparisons made on percentage of operability are questionable. The number of operational years for which a ship is designed to avoid fatigue damage is generally an owner's option. However, consistency is needed in defining years of operation in terms of the percent of time the ship will actually be at sea. Likewise, assumptions on actions taken by a master to reduce damage or make the ship ride more kindly in various sea states need to be considered. There is a definite trend shown by existing data that headings that are more favorable and reduced speeds will be taken during heavier weather, and this information should be included in a fatigue assessment. This is true for both commercial ships and military ships operating in peacetime. However, when designing military ships, caution must be used in considering the experience of peacetime operations. During extended military operations, it may not be possible to change course and reduce speed to meet mission objectives. Therefore, more severe service may occur during wartime than during peacetime.

4. Commercial Methods for Predicting Ship Lifetime Bending and Torsional Moments

4.1 Purpose

This chapter describes the commercial methods used to predict the lifetime bending and torsional moments of ships during their design phases.

4.2 Introduction

A number of methods, both military and commercial, are used to predict the maximum bending and torsional moments to which ships are subjected over their operational life and to develop applicable loads spectra for them. Some of the considerations associated with these methods are:

- Software codes used
- Wave height and whipping probabilities
- Longitudinal distribution of moments
- Ship heading probabilities
- Ship speeds
- Wave cells
- RAOs
- Wave spectra
- RAO and wave spectra domains

These and other factors have been reviewed to determine their effect on design for fatigue.

4.3 Software Codes

4.3.1. SafeHull and other ABS Computer Programs

The design program of the American Bureau of Shipping (ABS), SafeHull, imbeds the ABS loading approach for fatigue analysis in the Phase B analysis. The program has been developed only for tankers, bulk carriers, and containerships, although some applications of the program have been made for the analysis of other types of ships. This is possible in the Phase B part of SafeHull because it is an analysis program, not a strict application of set rules. With SafeHull, loadings are developed from a series of maximum wave events and applied to a finite element model of the cargo section of the hull. These loadings represent a distillation of experience and analysis of a number of hulls (ABS, 1999).

For either a simplified fatigue analysis or the Phase A SafeHull fatigue analysis, the loads used are the rule bending moments, shears, and torsional moments. More sophistication is required for SafeHull Phase B and a Dynamic Load Analysis (DLA). The ABS approach to loads determination for a Phase B SafeHull or a DLA analysis is based on a suite of computer programs ranging from linear strip theory to advanced 3-dimensional nonlinear time domain analysis (Shin et al., 1997). Several methods are included in the current system for ship motions, wave loads, and impact analysis. The combination of these methods can result in a capable multi-level computation and simulation system for ship design and analysis. The following methods are available at ABS:

2-D Linear Frequency Domain Analysis: ABS/SHIPMOTION (1980) is used as a base level for exploring the entire design domain. It is a traditional frequency-domain linear strip-theory computer code, based on the theory developed by Salvesen, Tuck and Faltinsen (1970). Once the linear transfer functions are calculated, short term and long term extreme value analyses are performed to establish the extreme value and its probability distribution using linear spectral analysis. The design value of the critical load then can be determined at the probability level corresponding to the lifetime of the ship. Because most fatigue damage of ship structure occurs from low-stress, high-frequency loading, the linear analysis from ABS/SHIPMOTION is applicable for fatigue calculation, including the computation of vertical, lateral, and torsional bending moments. However, other computer programs are necessary for computing maximum loads, as well as for evaluating unusual hull forms, such as catamarans and SWATH vessels. This program does not compute whipping response. This response is currently addressed in the rules for bulk carriers, Section 3A of the ABS Rules.

3-D Linear Frequency Domain Approach: This linear theory used in the development of the computer program PRECAL is similar to 2-D linear theory but 3-D effects near bow, transom and overhanging stem can be correctly accounted for in the local pressure calculation. The ship is modeled as a number of 3-D panels and hydrodynamics is solved by a 3-D source distribution.

Quadratic Strip Theory for weakly non-linear system: Non-linear quadratic theory has been developed by Jensen, et al. (1979) and successfully applied to the analysis of non-linear vertical bending moments for a container ship with a large bow flare. Short term and long term values and probability distribution can be determined separately for hogging and sagging bending moments.

Two-dimensional quasi-linear time domain approach for wave and impact induced responses: Kaplan (1993) developed QLSLAM (Quasi-Linear SLAM) using a 2-D strip approach to predict the wave impact on the ship motion and hull girder load. This simplified analysis can be used effectively as a screening tool to identify the critical event for maximum hull girder load (vertical, horizontal and torsional) including bow flare and bottom slamming. The numerical solution is very stable and efficient.

Non-linear time domain approach: LAMP-1, LAMP-2, and LAMP-4 are part of the LAMP (Large Amplitude Motion Program) system. This system of programs was developed by SAIC Corporation, Annapolis, Maryland, mostly under U.S. Navy funding. LAMP development is based on time-domain formulation and 3-D hydrodynamics. LAMP-1 is the linear version, whereas LAMP-2 and LAMP-4 are nonlinear codes with different degrees of sophistication. The LAMP code system includes the prediction of impact loads and the resulting whipping responses (Lin, et al., 1994). LAMP has been expanded to a complete analysis system with model generation, impact analysis and structural load interface for analysis using the finite element method. A top-level diagram of the LAMP system is given in Figure 4.1. The LAMP system of programs will be discussed more fully below.

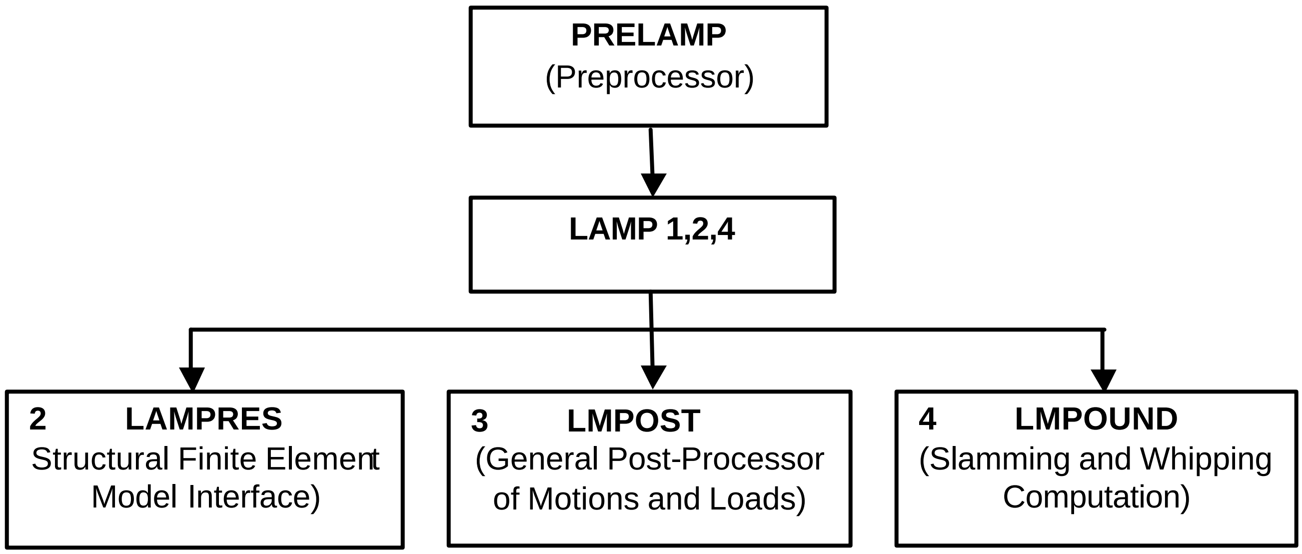


Figure 4.1 LAMP Based Load Analysis System

All of the above computer programs are available within ABS for spectral analysis of loading. In general, a linear analysis using ABS/SHIPMOTION is used except where nonlinear response is anticipated.

During the development of the SafeHull criteria, ship motions and loads were calculated by using the ABS/SHIPMOTION program. Linear response is computed in regular waves as Frequency Response Functions (FRF), which are also called transfer functions or Response Amplitude Operators (RAO). Motion and load RAOs are calculated for a number of wave headings and wave frequencies. These RAOs are used with a variety of sea states to determine the long-term extreme values of load components and for computing the phase angles between various load components that are applied to the finite element model in Phase B of a SafeHull analysis.

The paper by Shin et al. (1997) provides some of the background theory behind the LAMP suite of programs, and compares the results that were computed for a typical containership. In the comparisons, it is shown that the nonlinear effects are important in assessing the vertical and horizontal bending moments for the ships analyzed.

The nonlinear programs described above, QLSLAM, DYNRES, and LAMP, are useful in fatigue analysis for defining nonlinear response, such as response to maximum lifetime wave events and for response to slamming. Because of the computational effort involved, none except QSLAM are suitable for generating a fatigue-loading spectrum, and even that program has its limitations and can be effectively used only in simulation of a fraction of a ship's lifetime. The primary basis for developing a lifetime loading spectrum remains linear computations using RAOs to compute the response to a variety of sea states at multiple headings and speeds.

The ABS process for developing a fatigue-loading spectrum is similar in principle to the U.S. Navy approach shown in Figure 4.2. Principal differences are:

- RAOs are determined analytically for the hull form
- Slam induced whipping is determined with an algorithm that includes a factor based on the form of the forebody above the waterline
- The ABS H-Family of sea spectra are used, assuming operation in the North Atlantic
- Ship operation is assumed for 90 percent of the time over 20 years.
- Response is computed in 15 degree increments of heading
- Operation at all headings is assumed to be equally probable
- Speed is taken as 75 percent of maximum ship speed

4.3.2. U.S. Navy Hull Response Methods

The principal U.S. Navy method for developing a fatigue loading spectrum (and maximum lifetime moments) is the computer program SPECTRA (Sikora, 1998), described previously in Chapters 2 and 3. The structure of the program is shown in Figure 4.2.

The Ship Motions Program (SMP) is the linear strip-theory ship motions program developed by the Naval Surface Warfare Center, Carderock Division. It was developed in the late 1970s by Salvesen and others (Salvesen et al., 1970), and has received several updates since that time. The emphasis in the development of the program was in predicting ship motions and powering. Structural loads were a secondary consideration. Therefore, the program only computes vertical bending moments and shears. Lateral and torsional bending and pressure loads are not calculated.

SMP is commercially available as the suite of tools, VisualSMP. Included in VisualSMP is the SMP95 strip theory based frequency domain seakeeping program, the SEP96 seakeeping analysis program, the STH97 time history program, and the SWMP96 SWATH seakeeping program, all developed by the U.S. Navy. The U.S. Navy has selected Proteus Engineering to distribute these tools commercially, and Proteus has used its experience in seakeeping analysis and software development to integrate and extend them, resulting in VisualSMP. VisualSMP adds a graphical pre- and post-processor, together with tools to simulate and visualize the motion of the ship in a seaway.

The U.S. Navy uses a number of codes for seakeeping and wave load analyses, especially to support its reliability initiative. The relationship of the programs is shown in Figure 4.3. The combination of these codes can result in a capable multi-level computation and simulation system for naval ship design. A brief description of each of these codes is given in the following paragraphs.

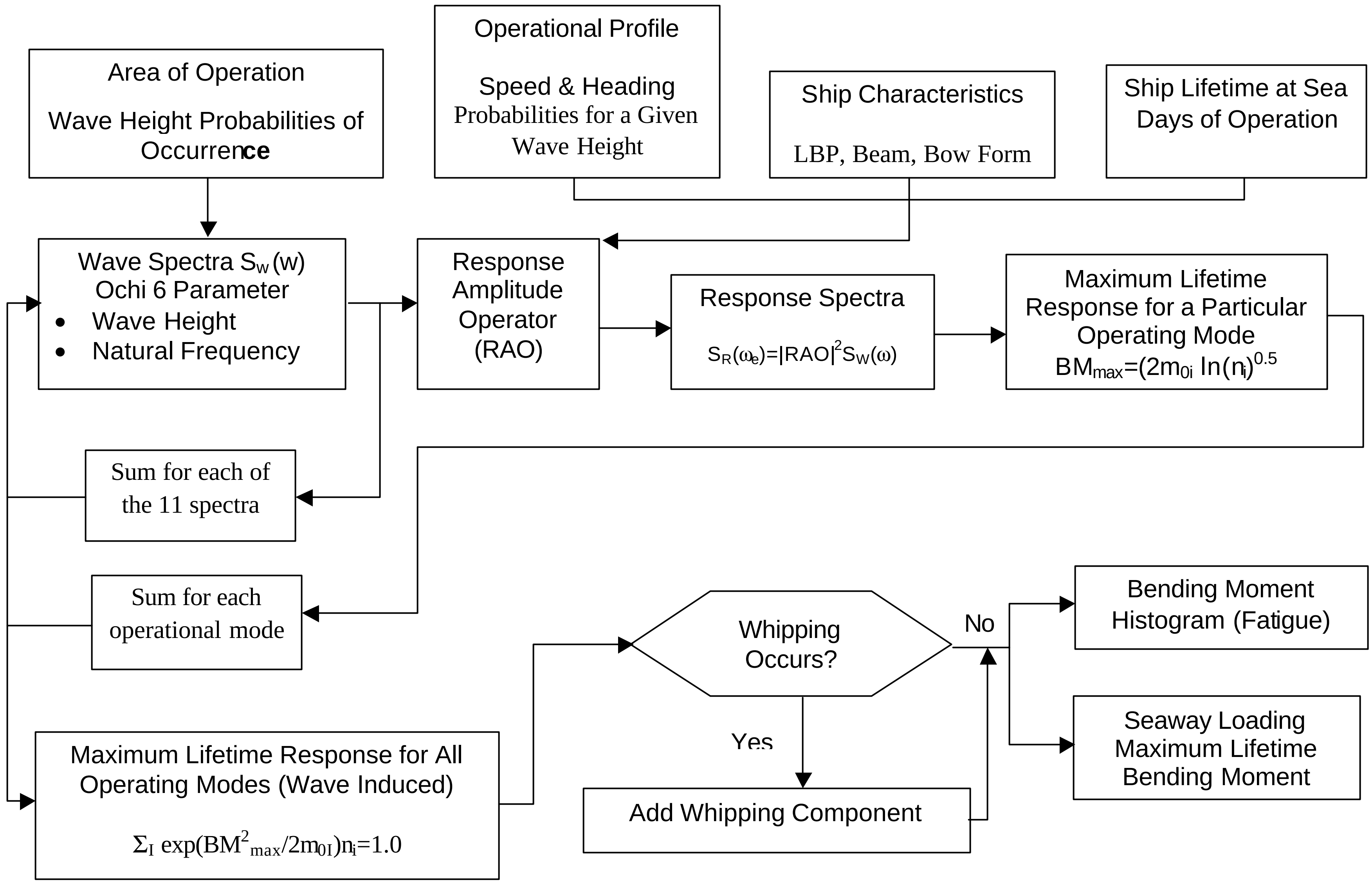


Figure 4.2 Organization of SPECTRA Program for Computing Lifetime Bending Moments

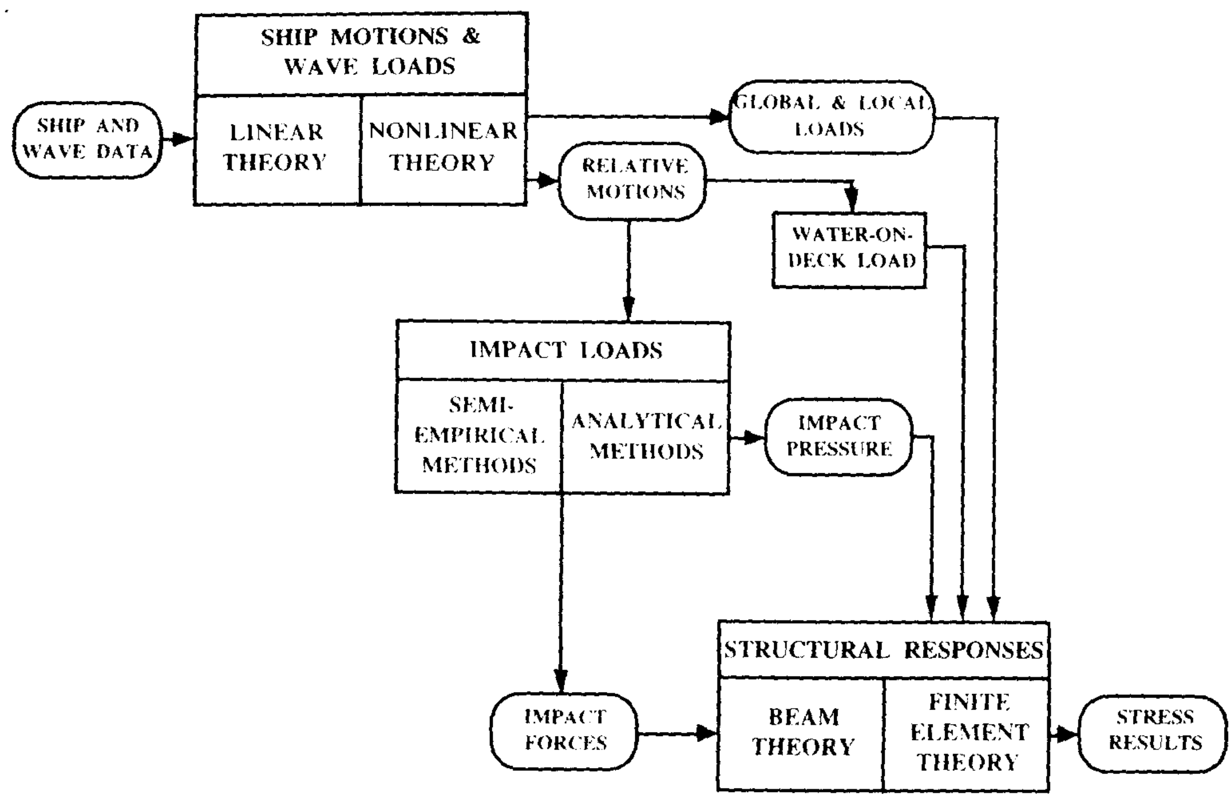


Figure 4.3. Prediction System for Ship Motions, Wave Loads, and Structural Responses. (Engle et al., 1997)

SMP, described above, is used as a base level code for exploring the entire design domain.

QLSLAM, described above, is used as a post processor to the SCORES 11 strip theory program. SCORES 11 is used to predict the relative motions between the ship and the waves as well as immersion-dependent added mass and hydrostatic corrections for use in QLSLAM. QLSLAM uses this information to predict impact loads, which in turn are used to excite a uniform beam model (Kaplan and Dalzell, 1993).

DYNRES is a 2-D large amplitude strip theory program. The program calculates frequency and independent hydrodynamic coefficients as a function of instantaneous immersion of a section. The resulting coefficients are then used to compute hydrodynamic loads in the time domain (DYNRES, 1994).

LAMP-1, -2, and -4 are part of the LAMP (Large Amplitude Motion Program) code system described above. The LAMP nonlinear seakeeping program has also been used for the analysis of the loads on a naval combatant ship (Engle et al., 1997). In the comparison of results, experimental data were compared to the results of computations using LAMP. In the head sea condition, the linear program LAMP-1 accurately predicted both pitch and heave response. The vertical bending moments, however, were significantly underpredicted, especially the sagging response, which was less than half of the maximum experimental value. The LAMP-2 nonlinear program computed the vertical response in head seas far more accurately, even computing slam induced whipping moments. In the case of LAMP-4, the more sophisticated program failed to predict accurately slamming response because the current developmental version of the program can not model cases of bow emergence.

In oblique seas, the LAMP-2 program accurately predicted pitch motions and vertical bending moments. However, the comparison was not good between experimental and predicted heave motions, even worse for roll motions, and inadequate for horizontal bending moments. The inaccuracy of the computed horizontal bending is partially due to the lack of a capability for computing lateral whipping response in the current version of LAMP-2. This situation is being corrected as the LAMP suite of programs is developed.

The U.S. Navy, recognizing the extensive resources needed to develop and validate nonlinear ship motions and loads programs, is now participating in several international cooperative programs for the development of such computer programs. One such program is PRECAL, which is a 3-dimensional linear ship motion program that includes the computation of pressures on the side and bottom shell, and is also used by ABS and the Canadian Navy.

4.3.3 Canadian Navy Hull Response Methods

The primary loads program used by the Defence Research Establishment, Atlantic (DREA) is the program SHIPMO (McTaggart, 1997). This is a linear strip-theory program developed by DREA. It has been licensed to Fleet Technology, Ltd. for marketing, and Fleet has added a Windows shell for running the code. One unusual feature of SHIPMO is the linking with the computer program VSHIP, which has the capability of visualization of the ship in regular and directionally irregular seas, including the finite element model on which the loads are imposed. DREA is also a member of the international group that is sponsoring the development of PRECAL, which can also be linked to VSHIP.

4.3.4. Other programs

A comparison of six different nonlinear time-domain strip-theory ship motion programs was made by the Loads Committee of the International Ship and Offshore Structures Congress (ISSC, 1997). The subject was discussed in further detail by Watanabe and Guedes Soares (1999). The organizations participating that used their own programs were:

- University of Newcastle
- Instituto Superior Técnico
- Det norske Veritas
- China Ship Scientific Research Center
- Kanazawa Institute of Technology
- Ship Research Institute

The S-178 containership was selected as a model for this comparative study because information on the hull form and experimental data were available from an earlier study by the International Towing Tank Conference (ITTC). The ship design has 175 meters length, 25.4 meters beam, 9.5 meters draft, and 28,000 metric tonnes displacement. The response of this ship was computed in regular head seas. Figure 4.4 compares the vertical bending moments at midships as computed by four of the programs, with the identities of the contributing organizations made anonymous by using only letters to identify the program used. The results of these nonlinear programs are also compared to the results from a linear strip-theory ship motions program. The abscissa is the wave height in meters. At low wave heights, all of the programs agree fairly well, but there is a considerable difference in the results at the higher wave heights because of the treatment of slam-induced whipping, which significantly increases the calculated bending moments in most of the programs. Note that the response is computed at different wave heights, and so the results can not be directly compared to design moments such as those of ABS or the U.S. Navy. The ABS design moments are based on the maximum response over a variety of sea spectra, and the U.S. Navy design moment is based on static response to a wave with height equal to 1.1 $\sqrt{L}$.

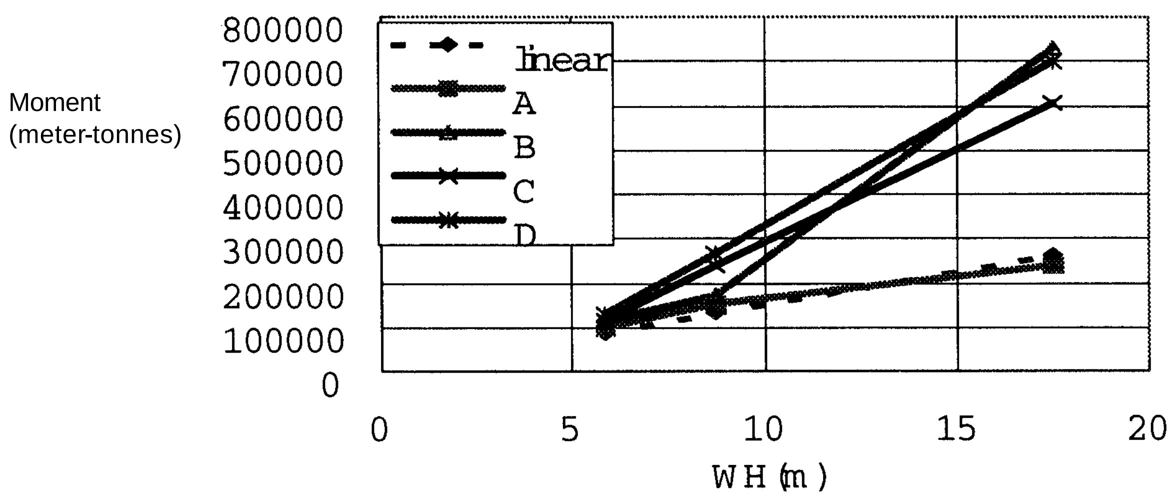


Figure 4.4. Comparison of Computed Bending Moments Midships (ISSC, 1997)

4.4 Longitudinal Distribution of Moments

ABS uses a standard distribution of the rule bending moments. The maximum vertical bending moment is carried to a point 0.45 of the length of the ship from the forward perpendicular, varying linearly from that point forward to zero at the forward perpendicular. Similarly, the midship moment is carried aft to a point 0.4 L from the after perpendicular, varying linearly from that point aft to zero at the after perpendicular. For containerships, the lateral bending moment is carried to points 0.1 L forward and after midships, tapering linearly to zero at the ends. The vertical whipping moment, as computed in section 5/3A.3.6.1c of the ABS Rules (Bulk Carriers) has the profile shown in Table 4.1.

Table 4.1 ABS Longitudinal Distribution of Slam Induced Vertical Bending Moments (ABS Rules 5.3A.3.61c)

Distance from F.P.	.2	.3	.35	.4	.5	.6	.7	.8
Factor	2.05	2.510	2.35	2.21	1.84	1.84	2.16	1.56

The U.S. Navy approach for the distribution of bending moments is to use a 1 minus cosine distribution of moments for both wave bending and slam-induced whipping moments. This distribution was determined by evaluation of model and full scale data.

The longitudinal distribution of the maximum hogging and sagging moments computed by the different programs compared by the ISSC Loads Committee varies significantly. Figure 4.5 shows the maximum computed moments during one wave encounter cycle. There is significant variation not only in the amplitude, as was shown in Figure 4.4, but the shape of the distribution of the moments also varies significantly. The response in Figure 4.5 was computed for comparative purposes on a wave with length equal to the length of the ship and height 1/30 the length. Therefore the magnitude of the response should not be compared to standard bending moments, such as the IACS standard moment or the NAVSEA 1.1 $\sqrt{L}$ design moment.

The ISSC comparison of the results from different nonlinear programs did not compare the results with experimental data. Therefore, it is difficult to determine which is the correct response. The conclusion that can be drawn is that the current state-of-the-art for nonlinear seakeeping programs computing hull girder bending moments is not advanced to the point that repeatability of results can be shown. The significance of this for fatigue analysis is that reliance cannot be placed on computed slam-induced whipping moments unless the program used has been validated by comparison with experimental data for the ship type being analyzed.

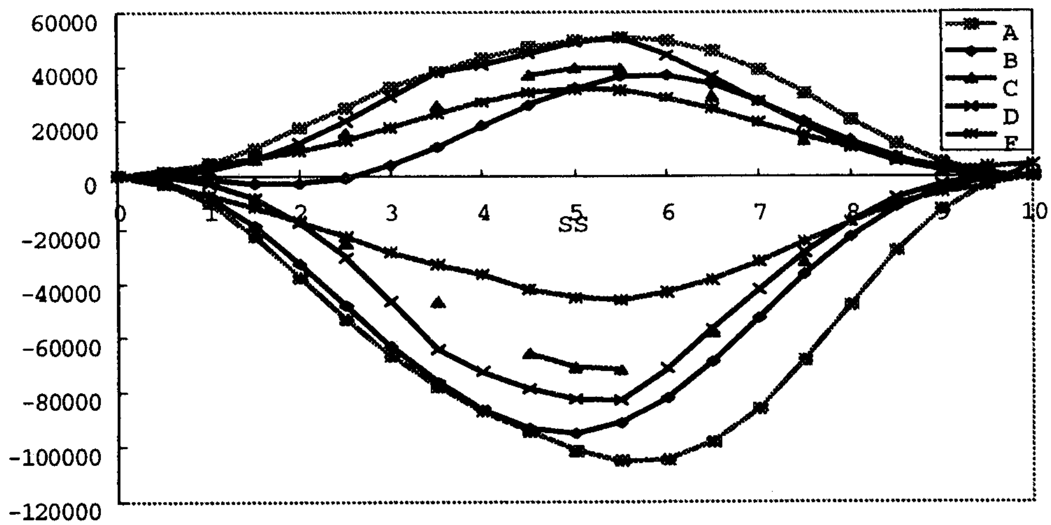


Figure 4.5. Comparison of the Longitudinal Distribution of the Maximum Computed Bending Vertical Moments (Station 10 is the FP) (ISSC, 1997)

4.5 Ship Speed and Heading Probabilities

An essential difference in the ABS and U.S. Navy approach to determination of loads is the use of speed-heading probabilities in the program SPECTRA used by the U.S. Navy to develop both maximum lifetime bending moments and lifetime fatigue load spectra (Sikora, 1998). The subject of speed and headings was discussed in Chapter 3, considering their effects on the ship operating environment. Instead of using different probabilities of speed and heading in various sea states as the U.S. Navy does, ABS assumes all headings to be equally probable, and that the speed will be 75 percent of maximum speed. For computation of a fatigue spectrum, assumptions on speed will affect the magnitude of the linear response amplitude operators (RAOs) and the wave encounter frequency. Figure 4.6 shows the measured RAOs for vertical bending midships from full-scale trials of a military ship. The dependence of response on speed is not apparent, or at least is overshadowed by other variability in the trials, such as small changes in sea state from the beginning of the time of measurement to the end. The peak RAO is at 10 knots, and the 25 knot data does not appear to be significantly greater than the data at any other speeds, including 5 knots.

Ship speed does have an effect on slam occurrence and the subsequent slam-induced whipping moments. However, none of the methods in use today for predicting whipping moments make direct calculations on which speed would have an effect. Rather, data on the probability of slam occurrence in particular sea states is used, and the effect of speed (and heading) is inherent in those assumptions.

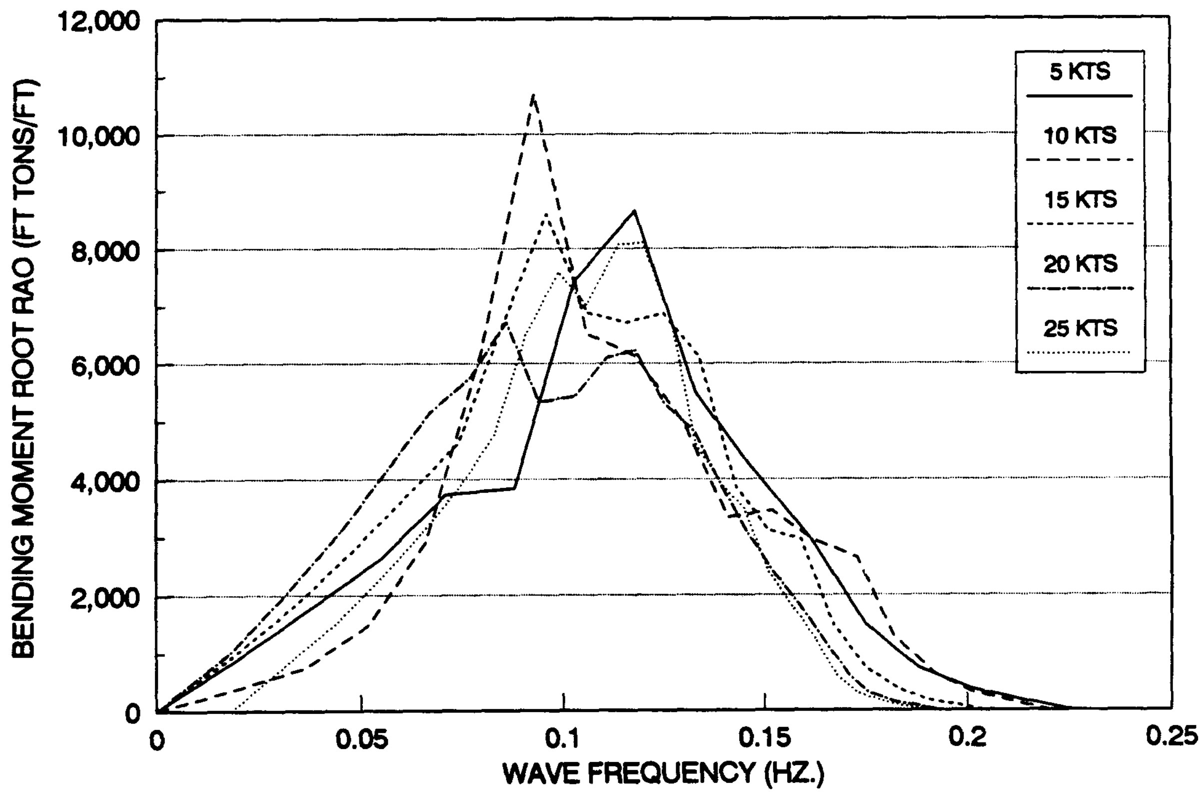


Figure 4.6. Vertical Bending Moment Square Root RAO of Military Ship in Head Seas

4.6 Wave Cells

Both the ABS and the U.S. Navy approach to development of maximum lifetime loads and fatigue spectra use the concept of "cells," where the response is computed at a variety of sea states, headings and speeds. The principal difference is that the ABS approach is to use only one speed, and to assume equal probability of headings. However, ABS computes the response in headings of 15-degree increments from head to following seas, while the U.S. Navy usually only uses 45-degree increments. In contrast to this, SSCP23 used by Canada does not use "cells" but provides a "fixed" fatigue spectra scaled by the design bending moment. This spectrum is based on long term strain measurements on Royal Navy warships.

4.7 Response Amplitude Operators

A significant difference in the approach to load determination between ABS and the U.S. Navy is the use of computed RAOs by ABS, and experimental RAOs by the U.S. Navy. The approaches also differ in the sea spectra used, as discussed in section 4.8. However, both approaches determine the RAOs in the encounter frequency domain. This is important to note, as significant errors can be made if the sea spectrum is not converted to an encounter spectrum for each ship heading and speed. As shown above, analytically determined RAOs are questionable in higher sea states because of nonlinear effects. On the other hand, experimental RAOs can have both bias and randomness from observational methods. Figure 4.7 shows typical experimental data on which loads are determined in the U.S. Navy computer program SPECTRA (Sikora, 1998).

The vertical RAOs have considerable scatter in their values, especially compared to the mean value that is used by the RAO algorithm in SPECTRA. Even for one ship, the data for the bending moments shows considerable experimental variability.

Whether experimental or measured RAOs are used for computing loads, both bias and variability will occur. Neither the approach used by ABS nor by the U.S. Navy implicitly includes these probabilistic factors in the computations, especially for fatigue life predictions. Such consideration should be made whatever method is used. If proper usage of the randomness in the prediction methods is used, then the benefits of efforts to make more exacting measurements or calculations will be easier to estimate. For example, a greater coefficient of variation in loads should be taken if the standard RAO in SPECTRA is used instead of measured data from a model of the ship being designed. If the greater confidence that comes from use of a model can reduce the variability in predicted fatigue life, then higher design stresses can be permitted with the associated decrease in weight of structure.

4.8 Wave Spectra

A variety of sea states are available for development of maximum lifetime loads and fatigue spectra. These sea states define the probability of occurrence of the wave height in a particular geographical domain and season. The sea state defined by NATO (1983) is used by the U.S. Navy. ABS uses the SNAME H-Family of sea states (SNAME, 1982) for maximum lifetime load predictions, as was discussed in Chapter 3. This family of sea states was developed on North Atlantic data, and although it represents that area well, does not model developing seas that are more typical of coastal areas.

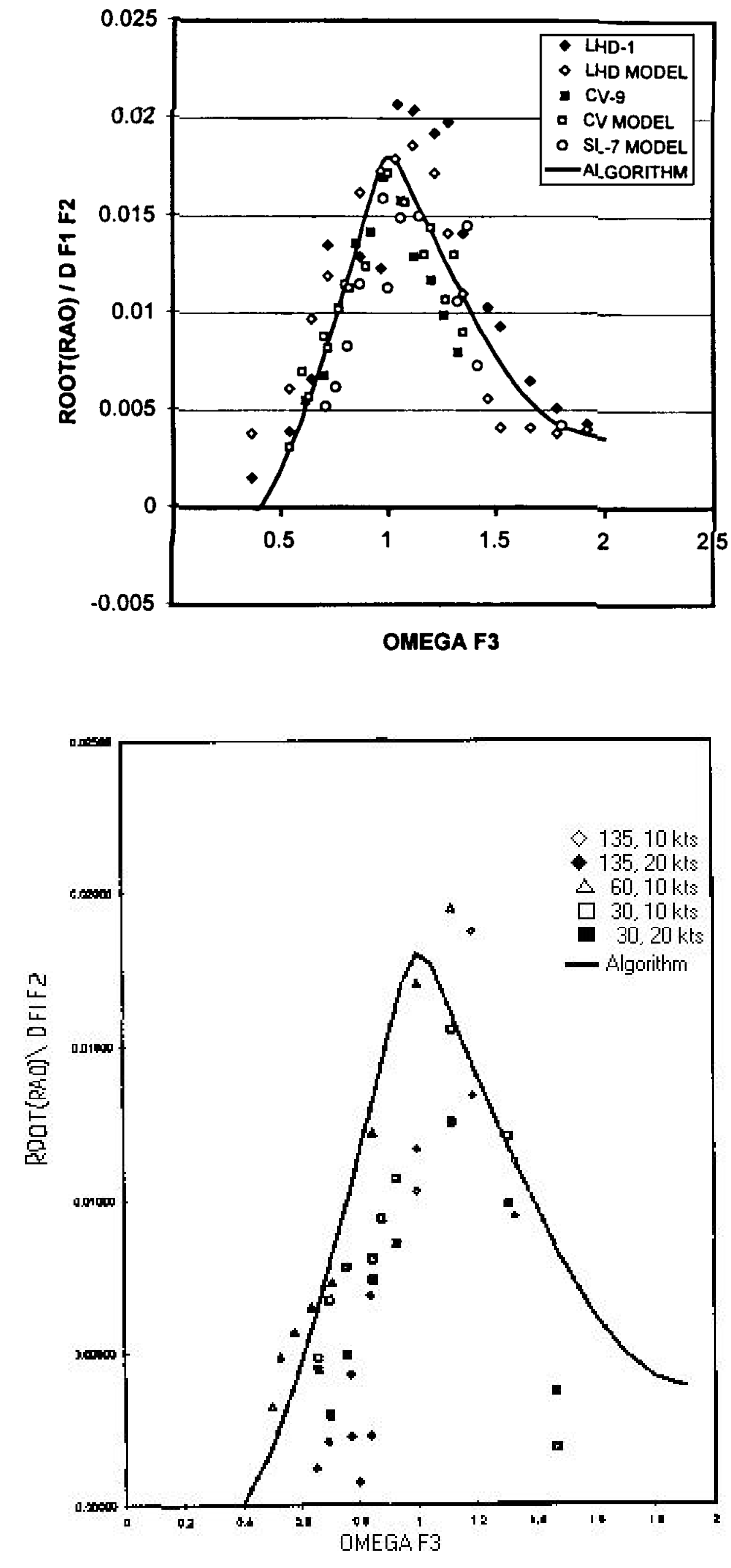


Figure 4.7. Vertical and Lateral RAOs from Experimental Data (Sikora, 1998)

The U.S. Navy uses the Ochi 6-parameter sea spectra (Ochi, 1978) for developing the fatigue load spectrum. The 6-parameters describe the low-frequency and high frequency of the significant wave height, modal frequency, and a shape parameter. This approach reflects the difference between developing and fully-developed seas, and thus can accurately describe wave spectra in both open ocean and coastal waters. Because the sea spectrum is described in the wave frequency domain for use with a moving ship, it must be transformed into the encounter frequency domain in order to reflect the frequency and phasing of bending moment RAOs, which are computed in the encounter frequency domain.

The assumptions on spectra generally have little influence on maximum responses, as the probability of exceedance of the largest response will not change significantly after about an hour's exposure to a particular sea condition. However, there is a more significant effect on fatigue life, as shown by Chen and Thayamballi (1991). The important issue is whether or not fatigue spectra should be developed for the specific operations intended for a ship design, or if a general approach should be taken, with only more severe conditions used if they are anticipated.

4.9 Summary

The principal issue in the prediction of lifetime bending and torsional moments is the importance of nonlinearities. They are extremely important in predicting the maximum lifetime response, but are generally not important for predicting a fatigue loading spectrum, with the exception of slam-induced whipping. In the commercial approach used by ABS, vertical, lateral, and torsional hull girder moments are generally computed using a linear seakeeping program, and therefore do not include nonlinear wave response or slam-induced whipping moments. The U.S. Navy uses experimental means to obtain these same moments, thereby including nonlinear effects in the determination of the response. However, the fatigue loading spectra developed by the U.S. Navy using the SPECTRA program is based on linear response amplitude operators, and therefore does not include nonlinear wave response, only whipping moments.

In comparing different approaches to determining ship response to a sea environment, either computational or experimental approaches are used. To be able to place values on the relative merits of alternative approaches, a probabilistic approach to fatigue life prediction should be used.

Fatigue life predictions are extremely dependent on assumed operating conditions. A decision needs to be made as to whether on not a standardized operating environment should be used as a basis for design.

5. Fatigue Data for Ship Structural Details

5.1 Purpose

This chapter identifies and lists the commercial structural details and the S-N curves used to define fatigue strength of the details. It addresses U.S. Navy and the Canadian Navy Design Practices, and American Bureau of Shipping classification practices for fatigue analysis. It also addresses the applicability of linear and bilinear S-N curves in fatigue analysis of ship structure.

5.2 Introduction

Among the many items of required information for the fatigue analysis of ship structure is knowledge of the fatigue characteristics of structural details. Structural details are the most important areas of ship structure for fatigue analysis because they will always involve a stress concentration and include welds, both of which lower the fatigue strength compared to homogeneous base metal.

Fatigue strength is generally characterized by the S-N curve, which is a plot of the number of cycles to failure (N) of the detail when alternating stress (S) is applied. A typical S-N curve was shown as Figure 2.1. When S-N curves are plotted on a log-log scale, they tend to be linear. Sometimes there is a break point in the curves, making the curves bilinear. The S-N relationship is taken as:

$$N = A\,S^{B} \qquad (5.1)$$

where

A is a coefficient, sometimes expressed as the base 10 logarithm.

B is the slope of the curve. The slope is sometimes expressed as m, in which case m is the negative value of the slope.

The S-N curves for structural details are in three different formats:

- Either test data for the structural detail exists, or an experimental program is undertaken to produce an S-N curve for the detail.
- Standard S-N curves for a variety of details are referred to, using the standard curve for details with geometry close to the geometry of the detail in question
- Finite element analysis is used to develop stress concentrations, which are used in conjunction with “hot-spot” S-N curves.

S-N curves for a number of structural details used on commercial and military ships exist to enable use of the test data approach, and are described below. Because of the variety of details for which the data exists, data from details that are close in geometry to most details used in ship construction can generally be used for the fatigue analysis of most structural details. Special test data will generally not be required unless the detail in question is identified as having a marginal fatigue life and cannot be easily modified to improve that life. Extensive testing is also justified if a sufficient number of the same detail is repeatedly used in construction and has marginal fatigue life. This approach is desirable if special weld procedures are used that have a possible effect on fatigue life.

In a sense, the other means of gathering S-N data is a subset of the test data approach, because S-N curves cannot be developed analytically, but rely on some fatigue data base. An important difference is in the amount of data available. S-N curves typically show as much as a full order of magnitude of scatter in the test results for the fatigue life of a detail at a particular stress range. A large number of test points are necessary to describe fully the fatigue characteristics of a particular detail. This can be very time consuming and expensive, especially as testing is required at 10^6 to 10^7 cycles and greater. Often, testing at these higher cycles is omitted, and sufficient data is obtained to describe only the mean value of the fatigue strength. Assumptions may be necessary to estimate the probability distribution function and the coefficient of variation of the data. The tendency in limited data is to overestimate the slope of the S-N curve.

To overcome the need for extensive testing, the data on a variety of test specimens has been collected by various agencies into several different standard S-N curves. Studies have been conducted to show their applicability to a number of typical ship structural details, both military and commercial, and are described below. This approach simplifies the process of obtaining S-N data, and overcomes some of the limitations of using test data, which will be discussed below. This approach has the disadvantage of not addressing the specific geometry or weld procedure used for a specific detail.

When designing structure, it is often necessary to use an unusual structural detail for which no data exists, and finite element analysis is used to determine the stress concentrations associated with the detail. In addition, detailed finite element analyses are frequently conducted to develop design modifications to improve the fatigue life of structural details that have a low predicted fatigue life. In the conduct of a linear elastic finite element analysis, computed stress gradients become extremely high at changes in geometry at a structural detail, such as an intersection of two members. Using a finer finite element mesh does not resolve the problem. In general, the calculated stress concentration continues to rise as the finite element mesh size is reduced. To resolve this dilemma, the stress is determined at some standard point distant from the stress concentration, such as one-half the thickness of the intersecting member. The stress at this point is used in the fatigue analysis in conjunction with S-N data from specimens with which the stress is similarly defined. This method is known as the hot-spot stress approach.

5.3 Commercial Structural Details

Several reports by the Ship Structure Committee list a number of the structural details used in ship construction. Report SSC-266, Review of Ship Structural Details (Glasfeld et al;, 1977), catalogues common structural ship details, lists some of their damage history, and suggests some detail improvements. This document also lists some existing guidelines for given details from American Bureau of Shipping (ABS), Bureau Veritas (BV), Det norske Veritas (DnV), Germanisher Lloyd (GL), Lloyd's Register of Shipping (LR), and Nippon Kaiji Kyokai

(NKK). Report SSC-272, In-Service Performance of Structural Details (Jordan and Cochran, 1978), records the performance of specific families of details from different ship types. However, this report does not relate the service performance of the details to the service condition of the detail. For example, the service performance of openings with square corners and with rounded corners is reported in a manner that could suggest that square corners have a fatigue life similar to rounded corners.

Report SSC-318, Fatigue Characterization of Fabricated Ship Details for Design (Munse et al., 1982), documents a simple design procedure for fatigue referred to as the Munse Fatigue Design Procedure (MFDP). This report also contains some fatigue data (S-N curves) for typical details and the mean fatigue data from the AISC fatigue provisions. The MFDP includes adjustment factors for the loading distribution (Weibull shape), random loading, and reliability.

Report SSC-346, Fatigue Characterization of Fabricated Ship Details—Phase 2 (Park and Lawrence, 1990), was Phase II for SSC 318. This task generated five additional constant-amplitude S-N diagrams. This report also provides some additional factors to account for thickness and mean stress in the Munse Fatigue Design Procedure (MFDP).

An example of the use of finite element analysis to improve fatigue performance of structural details is contained in SSC-374, Effect of High Strength Steels on Strength Considerations of Design and Construction Details of Ships (Heyburn and Riker, 1994.) In this report developed by Gibbs & Cox, Inc., several structural details used in a naval combatant and a single hull tanker were analyzed to determine the probability of fatigue cracking. These details were redesigned to reduce the probability of cracking, which would increase with the use of higher stress levels for design with high strength steel.

Report SSC-395, Classification of Critical Structural Details in Tankers (Bea and Schulte-Strathaus, 1997), involved developing an expert system for the selection of the S-N curves for a given detail. The report also details the development of finite element models for structural details to calibrate S-N curves.

Report SSC-400, Weld Detail Fatigue Life Improvement Techniques (Kirkhope et. al., 1997), makes recommendations to improve the fatigue strength of welds, including post-weld improvement techniques.

The Tanker Structure Cooperative Forum (TSCF), which was discussed more fully in Chapter 2, is an international organization of owners and operators of commercial tankers and of classification societies. Reports of the TSCF provide information on the service performance of structural details used in the structure of commercial tankers. The Guidance Manual for Inspection and Condition Assessment of Tanker Structures (TSCF, 1986) provides information on many commercial structural details, including those that have had poor fatigue performance. The report Condition Evaluation and Maintenance of Tanker Structures, (TSCF, 1992) provides information on more commercial structural details, including those that have had poor fatigue performance.

ABS has provided information on commercial structural details in several reports as well as in their Rules for Building and Classing Steel Vessels. The information from two of these reports, ABS Guide 75, Improvement for Structural Connections and Sample Structural Details–Service Experience and Modifications for Tankers, and ABS Guide 77, Improvement for Structural Connections and Sample Structural Details–Service Experience and Modifications for Bulk Carriers has been included in the rules. The fatigue data provided in the ABS rules is based on S-N curves from the UK Department of Energy, Offshore Installation: Guidance on Design, Construction, and Certification. ABS, in the Guide for Dynamic Based Design and Evaluation of Container Carrier Structures, 1996, allows the use of "widely recognized design data, such as those recommended by AWS, API, and U.K. DEN." It also requires that if other fatigue data are used, the background and supporting data are to be submitted for review. The ABS fatigue analysis assumes 20-year design life with linear accumulative damage, ignores mean stress affects, uses nominal stresses (P/A, M/SM), and uses the Weibull probability distribution parameter.

5.4 Structural Details on Military Ships

The U.S. Navy fatigue analysis procedure is documented in the report "DDG-51 Whole Ship Fatigue Analysis" (Kihl, 1991). The approach uses the SPECTRA program, which was described previously in Chapters 2, 3, and 4, to develop the fatigue loading spectrum using standard response amplitude operators (RAO). The SUMDAM program (Kihl et al., 1988) is used to compute the time to failure using linear cumulative damage. The fatigue analyses are based on the use of mean data S-N curves that were generated from specific test data. A more comprehensive study on fatigue of structural details used in military ships was made by Kihl (1999). This report provides data for the assessment of fatigue life. Mean minus two sigma S-N curves for a variety of ship details are compiled in this report. This report also compares the S-N curves from the following codes: AASHTO, BS 5400, DnV, and Eurocode. Both the mean and mean minus two sigma strength ratios for each of these codes can be found in Appendix J of that report. It is worth noting that (Kihl, 1991- Appendix A) and (Kihl, 1999) reports fatigue life predictions based on linear (vice bi-linear) S-N curves, which correspond more closely to (more ship-like) random and variable amplitude test results.

In recent U.S. Navy design for the LPD 17 Class, the AASHTO curves were used (Sieve et al., 1997). The LPD 17 fatigue design was based on linear, mean minus 2 sigma S-N curves. The design allowable stress range was computed using the ASSHTO curve for a Class E detail, which is described as a non-load carrying attachment longer than 100 mm and less than 25 mm thick, as well as load carrying attachments less than 25 mm thick (ASSHTO, 1990). This class of detail was viewed for the LPD 17 Class design as being typical of deck to transverse bulkhead connections, and was selected as the critical structural detail for design. An ASSHTO Class E detail is comparable to a BS 5400 Class F2 detail. Information on the development of the AASHTO fatigue curves is given in a report of the National Cooperative Highway Research Program (NCHRP), report 299.

The Canadian Navy uses the design documentation of the Royal Navy for ship design and analysis. The U.K. Sea Systems Controllerate Publication No. 23 (SSCP23), Design of Surface

Ship Structures, covers fatigue in Chapter 13. Mean minus two sigma fatigue data is tabulated for the different classes of details using S-N curves from BS 5400. The fatigue data has a stress ratio of zero. The guide uses linear cumulative fatigue damage for fatigue design. It recommends a 5 percent stress reduction for frigates and destroyers to account for slam induced whipping. SSCP23 ignores the endurance limits in BS 5400 and uses linear S-N curves. Information on the development of the UK DoE BS 5400 curves is given by Maddox (1991), who describes some of the testing database used to develop the curves.

5.5 Other Fatigue Data

Appendix B, Table B3 of the AISC steel manual contains fatigue allowable stress ranges for specific detail categories (AISC, 1980). This information can be used for comparison with ship structural details.

The American Association of State Highway and Transportation Officials (AASHTO) provides fatigue data for stress ranges in section 10.3 of the standard specifications. The data is divided into two categories: redundant load path structure and non-redundant load path structure. It also includes a reduction for unpainted weathering steel. These curves are the basis for many other standardized approaches to fatigue data. The AASHTO curves are based on full scale test data documented in National Cooperative Highway Research Program (NCHRP) reports 102, 147, 188, 206, 227, 267, and 286.

5.6 Evaluation

The above reports provide S-N curves for specific details. These curves may represent some the same structural detail but the bases for these S-N curves are not consistent such as:

- Stress: nominal vs. hot-spot,
- Stress ratio (stress_minimum/stress_maximum): R=0 vs. R=-1,
- Slope: linear vs. bi-linear.
- Deviation: mean versus. mean minus two sigma

ABS rules use a nominal stress approach for standard details, but uses the hot-spot stress approach when linear elastic finite element analysis is used to determine stress concentrations. ABS defines the hot spot stress at one-half the thickness of the intersecting member from the weld toe, and uses fatigue curve E with that stress.

SSCP23 also uses the hot-spot stress approach. For a SSCP23 (BS 5400) Class F detail, the stress used in fatigue computations is that determined at a distance of ten plate thicknesses from the stress concentration. For a SSCP23 (BS 5400) Class D detail, the stress is to be taken at a distance of two-thirds to one plate thickness from the stress concentration. To help clarify the differences of the various design codes for fatigue, a comparison of several such codes is shown in Table 5.1 and Figure 5.1 through Figure 5.4 (NSWCCD, 1998).

Table 5.1 Design Code S-N Curves (NSWCCD, 1998)

Detail Category		Design Code				U.S. Navy[2] (mean – 2 σ)
		ECCS	BS 5400[1]	AASHTO	DnV[1]	
Benign	Designation	90	E	C	D	Non-Load Carrying Fillet Weld
	Log(A), ksi	9.648	9.500	9.653	9.667	10.1561
	B, slope	-3	-3	-3	-3.5	-3.2096
Moderate	Designation	71	F	D	F	As-Welded Component
	Log(A), ksi	9.342	9.287	9.336	9.286	9.6830
	B, slope	-3	-3	-3	-3	-3.2238
Severe	Designation	56	F2	E	F2	
	Log(A), ksi	9.031	9.120	9.031	9.120	
	B, slope	-3	-3	-3	-3	

Notes: 1. BS 5400 and DnV are the same curves except for benign details.
2. From Kihl (1991)

By way of comparison with the design codes, Table 5.1 includes experimental data that the U.S. Navy has used for evaluation of existing ship structures. The data points indicated represent the lower bound fatigue strength, mean minus two standard deviations, which is comparable with the design codes. The non-load carrying fillet welds are from welded cruciform specimens, and the as-welded components are from details of the intersection of a longitudinal stiffener with a transverse bulkhead stiffener. These data have longer fatigue lives than comparable data in the design codes.

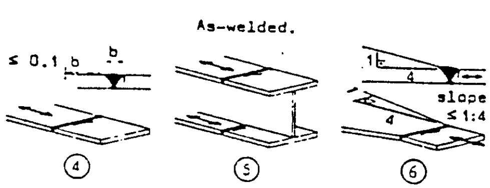
In the curves shown in Figure 5.4, only the linear portions are shown. There is a difference between the curves as to where the break point is taken. For the BS 5400, the break is at 10^7 cycles. Use of a bi-linear curve is unconservative compared to a linear curve, resulting in a slightly longer lifetime prediction with a bi-linear curve. However, the difference is not great, because spectral fatigue analyses of ship structure usually show the greatest fatigue damage from stress levels that occur between 10^5 and 10^7 cycles. The stress levels that occur more than 10^7 times during the life of a ship are generally low enough that little computed fatigue damage will occur from them, even if a linear S-N curve is used.

All of these guides for fatigue analysis during structural design are consistent in recommending the use of mean minus 2 sigma S-N curves. Others, such as Munse (1982), recommend the use of the mean S-N curves, and use the statistical distributions of the S-N data and other variables, including the loads, to compute the probability of fatigue failure. Others, such as Kihl (1991), use the mean S-N data for analysis. In most design codes, the mean stress level (stress ratio) is ignored for fatigue analysis of welded details.

Benign detail severity is that associated with details such as as-welded transversely loaded butt welds or longitudinally loaded fillet welds. Although there is some degree of overlap in detail classification within and between design codes, the following are felt to be representative. Parentheses indicate detail category used in analysis.

ECCS: detail categories (90) and 100

90



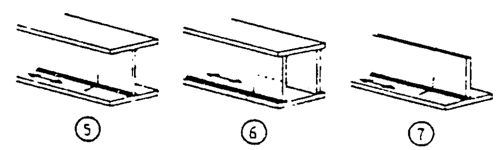
(4) Transverse splices of plates or flats.

(5) Transverse splices of rolled sections or welded plate girders.

(6) Transverse splices in plates or flats tapered in width or in thickness where the slope is not greater than 1:4.

Requirements for details (4), (5) and (6) :
- The height of the weld reinforcement to be not greater than 10 % of the weld width with smooth transitions to the plate surface.
- Welds made in flat position.

100



(5) Manual fillet or butt welds.

(6) Manual or automatic butt welds carried out from one side only, particularly for box girders. A very good fit between the flange and web plates is essential. Prepare the web edge such that the root face is adequate for the achievement of regular root penetration without breakout.

(7) Repaired automatic or manual fillet or butt welds. Improvement methods which are adequately verified may restore the original Category.

BS5400: detail categories D and (E)

Full penetration butt weld joining plates of any width or thickness, with changes tapered to < 1 in 4 slope, except that up to 15% thickness change can be accommodated in the weld profile without taper.	Shop welds made from both sides in the flat position either manually or by automatic process other than submerged-arc.	4.2	D	Welds made positionally, on-site or by submerged-arc process tend to have poor overfill shapes. Hence they are down-graded from D to E unless a favourable weld profile can be produced. Welds designed to Class D which fail to meet the criteria stated should be dressed flush in the regions affected. Plate thickness design penalty applicable.
	Welds made by any means from both sides or from one side onto consumable insert or temporary non-fusible backing.			
	Overfill profile θ > 150°	4.3	D	
	Overfill profile θ < 150°	4.4	E	

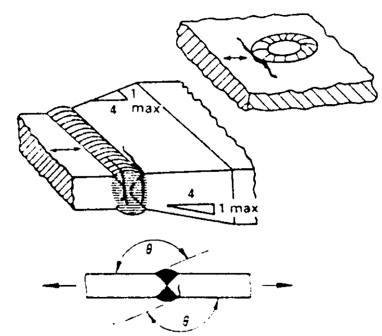
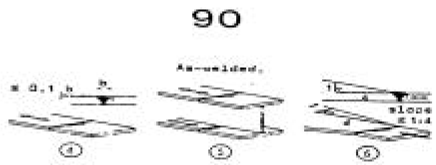


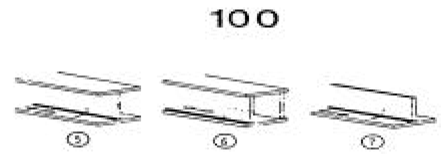
Figure 5.1. Benign Structural Detail Categories (NSWCCD, 1998) (Continued)

ECCS: detail categories (90) and 100



(4) Transverse splices of plates or flats.
(5) Transverse splices of rolled sections or welded plate girders.
(6) Transverse splices in plates or flats tapered in width or in thickness where the slope is not greater than 1:4.

Requirements for details (4), (5) and (6):
- The height of the weld reinforcement to be not greater than 10 % of the weld width with smooth transitions to the plate surface.
- Welds made in flat position.



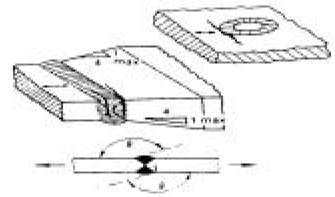
(5) Manual fillet or butt welds.
(6) Manual or automatic butt welds carried out from one side only, particularly for box girders. A very good fit between the flange and web plates is essential. Prepare the web edge such that the root face is adequate for the achievement of regular root penetration without break-out.
(7) Repaired automatic or manual fillet or butt welds. Improvement methods which are adequately verified may restore the original Category.

BS5400: detail categories D and (E)

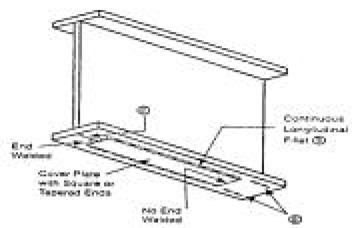
Full penetration butt weld joining plates of any width or thickness, with changes tapered to ≤ 1 in 4 slope, except that up to 15% thickness change can be accommodated in the weld profile without taper.

Shop welds made from both sides in the flat position either manually or by automatic process other than submerged-arc.	4.2	D	
Welds made by any means from both sides or from one side onto consumable insert or temporary non-fusible backing.			
Overfill profile θ ≥ 150°	4.3	D	
Overfill profile θ < 150°	4.4	E	

Welds made positionally, on-site or by submerged-arc process tend to have poor overfill shapes. Hence they are down-graded from D to E unless a favourable weld profile can be produced. Welds designed to Class D which fail to meet the criteria stated should be dressed flush in the regions affected. Plate thickness design penalty applicable.



AASHTO: detail categories B and (C)



DnV: detail categories (D) and E

3.1 Parent metal adjacent to, or weld metal in, full penetration butt joints welded from both sides between plates of equal width and thickness or where differences in width and thickness are machined to a smooth transition not steeper than 1 in 4

Note that this includes butt welds which do not completely traverse the member, such as circular welds used for inserting infilling plates into temporary holes

(a) With the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination — C

The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects

(b) With the welds made in the shop, either manually or by an automatic process other than submerged-arc, provided all runs are made in the flat position — D

(c) Welds made other than in (a) or (b) — E

In general welds made positionally, or on site, or by the submerged-arc process tend to have a poor reinforcement shape, from the point of view of fatigue strength. Hence such welds are downgraded from D to E

In both (b) and (c) the corners of the cross-section of the stressed element at the weld toes should be dressed to a smooth profile

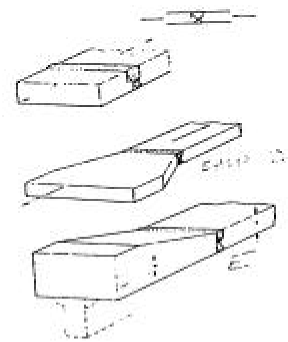
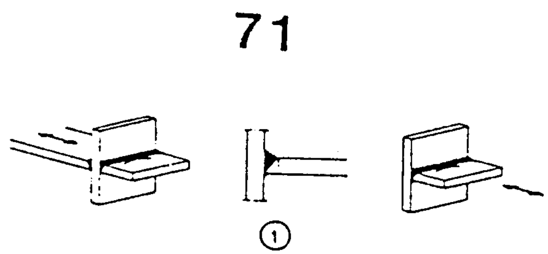


Figure 5.1. Benign Structural Detail Categories (NSWCCD, 1998) (Concluded)

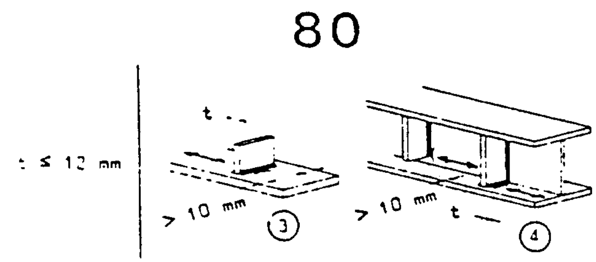
Moderate detail severity is that associated with details such as welded attachments to load carrying members, full penetration welded members, intermittent welds, and welds around cope holes. Although there is some degree of overlap in detail classification within and between design codes, the following are felt to be representative. Parentheses indicate detail category used in analyses.

ECCS: detail categories (71) and 80



Cruciform joints

(1) Full penetration weld. Inspected free of detectable discontinuities, see Appendix B3.



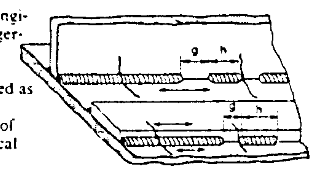
Transverse attachments

(3) The end of the weld more than 10 mm from the edge of the plate.

(4) Vertical stiffeners welded to a beam or plate girder. The stress range should be calculated using principal stresses if the stiffener terminates in the web.

BS5400: detail categories E and (F)

Intermittent fillet welds with: g/h <2.5 g/h >2.5	 3.3 3.4	 E F	Limiting gap ratio g/h applies even though adjacent welds may be on opposite sides of a narrow attachment (e.g. longitudinal stiffener with staggered fillet welds). Long gaps between intermittent fillet welds are not recommended as they increase the risk of corrosion and, in the case of compression members, local buckling.
Fillet weld at a cope hole, for weld continuing around plate ends or not.	3.5	F	Note that the existence of the cope hole is allowed for in the joint classification; it should not be regarded as an additional stress concentration in relation to fatigue cracking in the flange. For situation in web, see detail type 5.2.



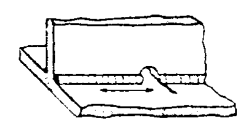
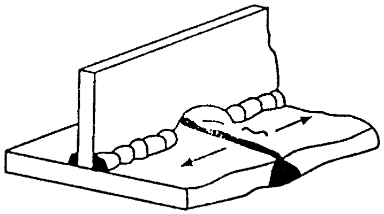
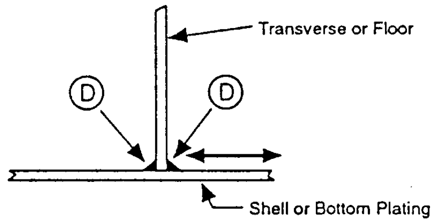


Figure 5.2. Moderate Structural Detail Categories (NSWCCD, 1998) (Continued)

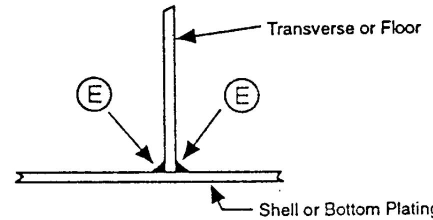
AASHTO: detail categories C, (D) and E



(a) Cope Hole, Category D if Well Excuted, Category E if Uncertain Quality



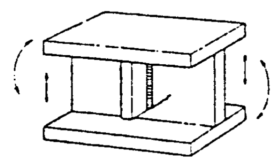
Ends of Transverse or Floor in Shell, Deck, or Bottom Plating
Classification for the Stress in the Shell is Categroy D

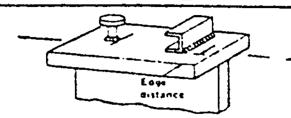


End of Transverse or Floor in Shell Deck or Bottom Plating
Classification for the Stress in the Discontinuous Plate is Category E

DnV: detail categories E and (F)

6.2	Parent metal at the end of a weld connecting a stiffener, diaphragm, etc. to a girder web in a region of combined bending and shear	E	This classification includes all attachments to girder webs
6.3	Parent metal adjacent to welded shear connectors		
(a)	Edge distance ≥ 10mm	F	
(b)	Edge distance < 10mm (see Type 4.2)	G	
6.6	(a) Parent metal adjacent to the ends of discontinuous welds, e.g. intermittent web/flange welds, tack welds unless subsequently buried in continuous runs	E	This also includes tack welds which are not subsequently buried in a continuous weld. This may be particularly relevant in tack welded backing strips
	(b) Same as (a) but adjacent to cope holes	F	Note that the existence of the cope hole is allowed for in the joint classification; it should not be regarded as an additional stress concentration





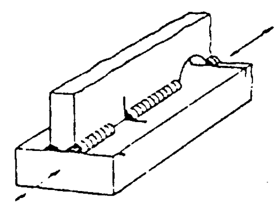
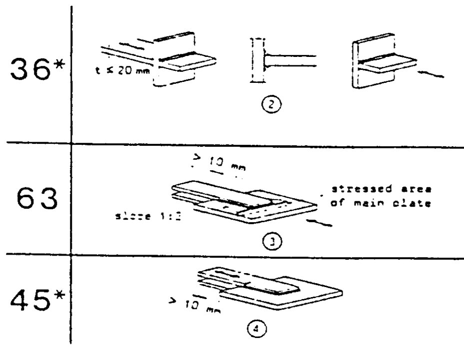


Figure 5.2. Moderate Structural Detail Categories (NSWCCD, 1998) (Concluded)

Severe detail severity is that associated with details such as partial penetration load carrying welds, one-sided welds made without backing bars, and welded load carrying lap joints. Although there is some degree of overlap in detail classification within and between design codes, the following are felt to be representative. Parentheses indicate detail category used in analyses.

ECCS: detail categories 63, (56), 50, 45 and 36



(2) Fillet welded connection. Two fatigue assessments are required. Firstly, root cracking is evaluated by determining the stress range in the weld throat area, Category 36*. Secondly, toe cracking is evaluated by determining the stress range in the load-carrying plates, Category 71.

Requirements for details (1) and (2) :
- The maximum misalignment of the load-carrying plates should be less than 15 % of the thickness of the intermediate plate.

Overlapped welded joints

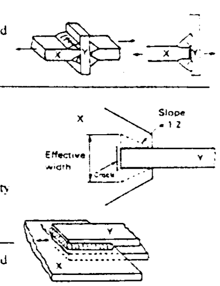
(3) Fillet welded lap joint. Stress in the main plate to be calculated on the basis of area shown in the sketch.

(4) Fillet welded lap joint. Stress calculated in the overlapping elements.

Requirements for details (3) and (4) :
- Weld terminations more than 10 mm from plate edge.
- Shear cracking in the weld should be verified using detail (7).

BS5400: detail categories (F2), G and W

		6.3	W	Based on stress range on weld throat area, assuming that none of the load is carried in bearing between the plates.
Fillet welded lap joints between plates or sections.	Lap joint on both surfaces of member X symmetrically.	6.4	F_2	Where narrow attachment transfers the entire load out of a wider member, assume that all load in that member acts over effective width shown.
	Lap joint on only one surface of member X.	6.5	G	Plate thickness design penalty applicable. For failure in attachment plate, see joint type 6.7.
	Any lap joint.	6.6	W	Based on stress range on weld throat area.



Attachments of any shape with surface in contact with stressed member.	Fillet weld continuous around ends or not: L < 160 mm, W < 55mm.	8.4	F	Plate thickness design penalty applicable.
	L > 160 mm, W < 55 mm.	8.5	F_2	
	L > 160 mm, W > 55 mm.	8.6	G	Classification includes stress concentration arising from normal eccentricities in the thickness direction.
	Cover plate of any length and wider than girder flange.	8.7	G	Not recommended due to likelihood of undercutting flange edge. Weld returns across corner should be avoided. Plate thickness design penalty applicable.
Attachments of any shape on or close to the edge of a stressed member.	Any size of butt or fillet welded attachment with weld continuous around ends or not.	8.8	G	Avoid undercut on corners or grind it out to a smooth profile should it occur. Weld returns across a corner should be avoided. Note that the classification applies to all sizes of attachments. It would therefore include for example the junction of two flanges at right angles. In such situations a

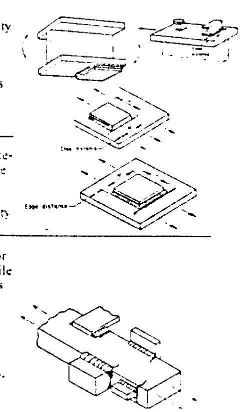
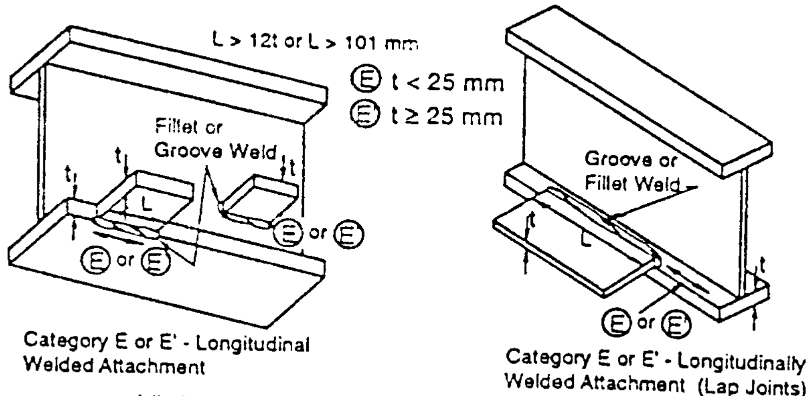


Figure 5.3. Severe Structural Detail Categories (NSWCCD, 1998) (Continued)

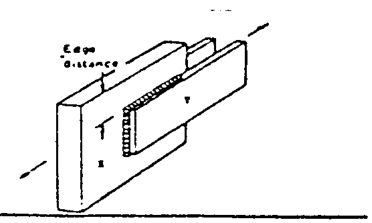
AASHTO: detail categories (E) and E'



(d) Most Attachments are Category E Details

DnV: detail categories (F2), G and W

5.2	Parent metal adjacent to the toe of load-carrying fillet welds which are essentially transverse to the direction of applied stress (member X in sketch)		The relevant stress in member X should be calculated on the assumption that its effective width is the same as the width of member Y
(a)	Edge distance ≥ 10mm	F2	These classifications also apply to joints with longitudinal welds only
(b)	Edge distance < 10mm	G	
5.3	Parent metal at the ends of load-carrying fillet welds which are essentially parallel to the direction of applied stress, with the weld end on plate edge (member Y in sketch)	G	
5.4	Weld metal in load-carrying joints made with fillet or partial penetration welds, with the welds either transverse or parallel to the direction of applied stress (based on nominal shear stress on the minimum weld throat area)	W	This includes joints in which a pulsating load may be carried in bearing, such as the connection of bearing stiffeners to flanges. In such examples the welds should be designed on the assumption that none of the load is carried in bearing



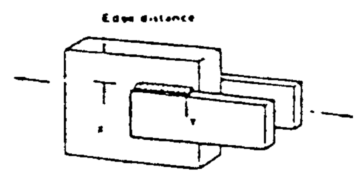


Figure 5.3. Severe Structural Detail Categories (NSWCCD, 1998) (Concluded)

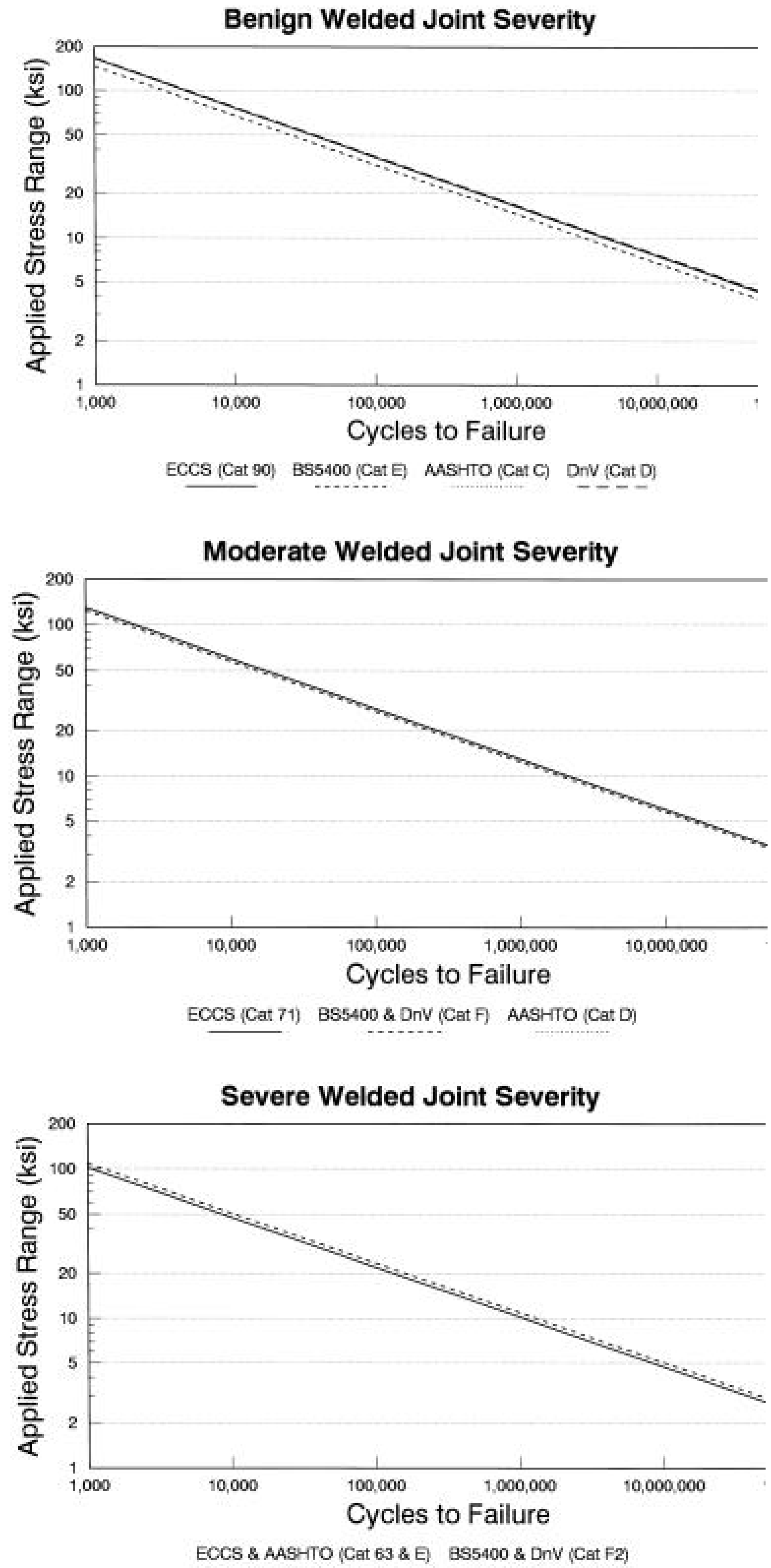


Figure 5.4. Design Code S/N Curves (2.3% Probability of Failure) (NSWCCD, 1998)

5.7 Nonlinear Analysis and Fracture Mechanics Analysis

The discussion of fatigue data has focused on the S-N approach to crack initiation and on linear analysis of stress and stress concentration. There are other methods of fatigue analysis, including the use of fracture mechanics to predict crack growth rates. This approach can also be used to predict crack initiation, especially in welded structures. Welds will always have flaws associated with them, although sometimes microscopic in size. Cracks in welded structure begin at these initial flaws, and grow under repeated loading until they are of a detectable size. Fracture mechanics analysis can be used to evaluate observable cracks and determine their rate of growth until they reach a size where complete failure will occur. Such analyses are useful in determining maintenance schedules and doing damage assessments.

The analysis of stress concentrations at welds can be done through nonlinear analysis rather than through the empirical hot-spot approach. In an analysis that accounts for material yielding, the high computed stresses, which are an anomaly of linear analysis, do not occur. Such analysis can be used to predict fatigue crack initiation if the fatigue data are developed in terms of strain cycles instead of stress cycles.

5.8 Summary

There exists a considerable fatigue database on the fatigue of welded ship structural details, both commercial and military. There are three distinct approaches towards the use of this information. One is to use test data for a structural detail that is as close in geometry to the actual detail as possible. With this approach, testing may be required to evaluate an unusual detail. The other approach is to use standard fatigue curves published by several different organizations. A particular structural detail being analyzed is placed in one of several categories, depending on its similarity to the details tested to develop the standard curves. The third approach is the hot-spot approach, which relies on a detailed finite element analysis of the detail. All of the approaches have their advantages and disadvantages in design. A simplified approach may be expedient to determine if a particular detail requires further analysis. Rigorous approaches must be validated, however, so that the unusual circumstance can be handled in design with confidence.

6. The Nominal Strength of the Hull Girder

6.1 Purpose

This chapter identifies and lists the commercial approaches for determining the nominal strength of the hull girder. It addresses U.S. Navy and Canadian Navy Design Practices, and American Bureau of Shipping classification practices for determining the nominal strength of the hull girder. It also addresses the various approaches used by different organizations for determining structure that are effective and ineffective in longitudinal strength.

6.2 Introduction

Assessment of hull girder strength for commercial ships is an integral part of classification society rules. In past practice, it was provided only by an overall section modulus approach to hull girder strength, using a standard rule for minimum section modulus. Such methods are still contained in the rules of classification societies, particularly those that are members of the International Association of Classification Societies (IACS), although computation of the ultimate strength of the hull girder is now becoming a part of these commercial design practices. A variety of methods for computation of ultimate strength are available and documented in the rules, including those of ABS, Lloyds, and Det norske Veritas. A major item of interpretation is the effect that openings and other discontinuities have on hull girder strength. There are different rules for evaluating ineffective areas, including the use of detailed finite element analysis for strength determination. All of these methods of the major classification societies for evaluating both nominal and ultimate hull girder strength have been identified, listed, and compared, especially those contained within commercial design procedures such as SafeHull.

Two of the critical items that affect the fatigue strength of the structure are the nominal stress range and stress concentrations. The wave encounter spectrum that a ship sees over its lifetime will result in a bending moment spectrum that is dependent on design and operational factors such as hull form and the speed and heading taken in various sea states. Given a bending moment loading spectrum, the stress spectrum for a detail is determined by the nominal stress range and global and local stress concentration factors. The nominal stress range for hull structure is determined using simple beam theory with the hull girder bending moment range divided by the section modulus.

Large openings and major discontinuities such as deckhouses cause global stress concentration factors. These factors cause the overall stress distribution to depart from the stress distribution given by simple beam theory. The design of structural details, such as the radius of corners, local reinforcement, and local discontinuities of structure cause local stress concentration factors. Of course, fabrication factors such as weld quality will also affect fatigue life. For the same fatigue life, a ship with a higher section modulus can have greater global and local stress concentrations, and conversely, a ship with a lower section modulus will be less tolerant of global and local stress concentrations and of poor weld quality. It is therefore important to understand how various standards for hull girder nominal strength affect the actual section modulus of the ship.

A comparison is shown below of the actual as-built section modulus of the naval ships that have been investigated in this study compared to the section modulus that would have been required had they been built to the IACS standard. As will be seen, many of the the naval ships have greater section moduli than the rule requirement, and should, therefore, have a lesser nominal stress range in a particular sea condition than a commercial counterpart.

6.3 ABS Methods for Determining Hull Girder Nominal Strength

For ships classed by ABS, there are minimum standards for hull girder strength, and enhancements to those standards for certain types of ships and to suit owners' special requirements.

6.3.1 Primary ABS Standard

The primary standard for longitudinal strength of ships classified by ABS is the standard established by the International Association of Classification Societies (IACS). The wave sagging moment, M_{WS}, and the wave hogging moment, M_{WH}, are given by the equations

$$M_{WS} = k_1 C_1 L^2 B (C_b + 0.7) \times 10^{-3}$$

$$M_{WH} = k_2 C_1 L^2 B (C_b + 0.7) \times 10^{-3}$$

where:

k_1 = 110 (SI units), 1.026 (feet, long tons)
k_2 = 190 (SI units), 1.772 (feet, long tons)
$C_1 = 10.75 - [(300 - L)/100]^{1.5}$ (SI units), $= 10.75 - [(984 - L)/328]^{1.5}$ (feet, long tons)
L = the rule length of the ship, generally 0.97 of the length on the waterline
B = beam of the ship at the waterline
C_b = block coefficient, defined using the rule length, but not to be taken as less than 0.60.

The total hull girder bending moment is the sum of these wave bending moments and the still water bending moments computed from a variety of loading conditions. The required section modulus is obtained by dividing the maximum hull girder bending moment by the allowable stress, which is 17.5 kN/cm^2 (11.33 tsi) for mild steel, and 24.3 kN/cm^2 (15.74 tsi) for higher strength steel

The section modulus must be equal to or greater than the minimum section modulus SM_M

$$SM_M = C_1 C_2 L^2 B (C_b + 0.7) \text{ m-cm}^2 \text{ (in}^2 - \text{ft)}$$

where:

C_1, L, B, and C_b are as defined above, and

C_2 = 0.01 (SI units), 1.44 x 10^{-4} (U.S. units)

For ships with longitudinally continuous deckhouses, the deckhouse is to be included in the section modulus calculation, with the top of the deckhouse designated as the strength deck. In computing the cross sectional area of material effective in longitudinal strength, openings may be ignored as long as the openings and the shadow area of other openings across the beam of the ship do not reduce the section modulus by more than 3 percent. Shadow areas are determined by tangential lines from the openings intersecting at an included angle of 30 degrees, as shown in Figure 6.1.

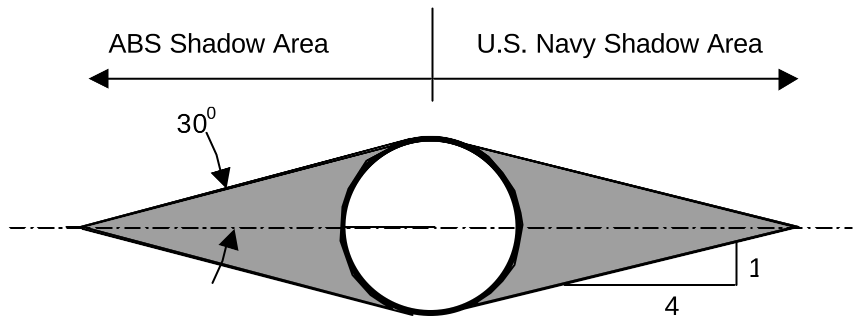


Figure 6.1 Ineffective Area in Longitudinal Strength Calculation

6.3.2 ABS Dynamic Loading Analysis (DLA) Approach

The above methods provide for the minimum ABS scantlings. If an owner desires, a ship may be classed using the Dynamic Loading Analysis (DLA) approach, as was discussed in Chapter 2. DLA usually results in an increase of scantlings above the rule minima, providing greater buckling strength of members, and assurance that unusual loading conditions or hull form parameters are considered in determination of design bending moments. DLA does not require a fatigue analysis, but an owner may request the ABS Spectral Fatigue Analysis as part of ABS classification, which can result in better structural details and improved fatigue life for the structure.

The DLA approach is implicit in the SafeHull procedure, which is mandatory for all double-hull tankers, bulk carriers, and containerships. Strength assessment is an integral part of the DLA design process. The assessment consists of analyses that are pursued to verify the suitability of the initial design established using the principles described in the previous sections against the specified failure criteria. The probable failure modes of the hull structure, relevant to the vessel type considered, are yielding, buckling, fatigue, and ultimate hull-girder strength in the intact and assumed damaged condition. These identified failure modes encompass a wide spectrum of failure scenarios spanning from global failure to local failures, and local failures that may develop into catastrophic global failure. Structural assessment uses the “net-ship” concept, which explicitly accounts for deterioration in structural strength due to corrosion. When assessing structural strength with the net-ship concept, all scantlings are reduced by the corrosion allowance, which is different for various structural members. The allowance is sometimes an absolute reduction, such as 1 mm, or is taken as a percentage deduction, such as 10 percent. This approach is also used by the Canadian and U.K. navies, but is not generally used by the U.S. Navy for design.

Yielding Criterion — This failure criterion is expressed on the basis of the von Mises stress obtained from a finite element analysis of the entire ship structure. The von Mises stress is not to exceed the material yield strength, f_y, multiplied by a strength reduction factor, S_m (≤ 1).

The factor S_m is a measure of the modeling uncertainty, accounting for the possible incompatibility between the designed structural details and the expected stress field for structures constructed of higher strength steels such as HS-32 and HS-36. The specified value of S_m is obtained from service experience and is expressed as a function of the material grade.

Consideration is also given to the least-plastic behavior of plating in local bending, with the formation of the first plastic hinge adopted as the plate's bending limit.

Buckling and Ultimate Strength Criteria — The problem of structural instability is treated at both the level of classical, bifurcation type buckling and the level of ultimate strength. Elastic buckling of plates, when treated with the classical bifurcation buckling analysis, is never a catastrophic phenomenon because of the post-buckling rise of strength in plates. For this reason, plate buckling (between stiffeners) in the elastic range is considered acceptable in the proposed formulation. It may, however, be relevant in the context of serviceability.

The ABS DLA approach requires checking that stresses do not exceed the minimum ultimate strengths of plate panels (between stiffeners), stiffeners themselves, and the stiffened panel. The stiffener can be modeled as a beam-column having the whole of the stiffener plus certain portion of the plating that is effective. Such requirements have been calibrated with experimental data.

In assessing the compressive strength of plate and stiffened panels, an interaction unity-check equation is given for the combined effect of the interacting biaxial loads and shear. Torsional instability (tripping) of stiffeners is included in the assessment of buckling strength. This mode of instability often turns out to be, with high degree of realism, the weakest for some non-symmetric longitudinal stiffener designs.

Fatigue Criteria — The ABS approach to fatigue assessment is described in Chapter 2.

6.4 U.S. Navy Methods for Determining Hull Girder Nominal Strength

The standard approach for determining the hull girder design bending moment is to perform a static balance on a trochoidal wave of height in meters equal to $0.607\ L^{1/2}$ ($1.1\ L^{1/2}$ in feet). The hull material determines the required section modulus, which is obtained by dividing the design bending moment by the allowable hull girder stress, which is given in Table 6.1.

Table 6.1 U.S. Navy Design Hull Girder Stress

Material	Yield Strength		Design Allowable Stress	
	MPa	Ksi	MPa	tsi
Medium Steel	230	33	116	7.5
Higher Strength Steel	350	51	131	8.5
HY-80/HSLA-80	550	80	147	9.5

The standard hull girder design bending moment computed by the above means is considerably less than the maximum hull girder moment. Sikora et al. (1982) estimated that the standard moment is on the average about 72 percent of the maximum lifetime moment, although the percentage for different ships was as little as 40 percent and as great as 90 percent. The factors of safety inherent in the U.S. Navy design practices preclude failure from bending moments that are higher than the bending moments calculated by static balance on a wave of standard height. The methodology used by Sikora et al. in 1982 to determine the maximum lifetime bending moments and fatigue loading spectrum has been refined since then, and is incorporated in a computer program SPECTRA8 (Sikora, 1998). This program was used to compute the maximum lifetime bending moments of the ten ships evaluated in this project.

In the SPECTRA8 computations, operations were assumed for 3,285 days, which represents 45 percent operability over 20 years. However, the maximum lifetime moments predicted are relatively insensitive to time of operation. NATO North Atlantic Sea State probabilities were used with the Ochi 6-Parameter sea spectrum to determine the waves encountered. The probabilities of heading and speed in various sea conditions were taken as the default values from SPECTRA, which are the same as were given in Tables 3.6, 3.7, and 3.8 in Chapter 3. The 20-year operational period is consistent with the ABS assumptions, although the percentage of operating time is less. ABS also uses North Atlantic sea state probabilities, and that is consistent. Table 6.2 compares the moments predicted by SPECTRA8 to the ABS design bending moments. It would have been interesting to also compare other design moments, such as the results from static balance on various standard wave heights, such as the U.S. Navy $1.1\sqrt{L}$ or U.K. 8-meter wave. However, those are design moments, not predicted lifetime maxima, as are shown in Table 6.2. The purpose of Table 6.2 is to show that the two methods compared give significantly different results for the maximum lifetime bending moments.

Table 6.2 Comparison of Maximum Bending Moments Computed by SPECTRA8 and ABS Rules

Ship	ABS Bending Moment		SPECTRA8 Bending Moment	
	Sag (ft-tons)	Hog (ft-tons)	Sag (ft-tons)	Hog (ft-tons)
A	72,894	73,863	106,640	118,745
B	279,122	242,734	553,485	451,777
C	68,517	70,133	105,892	128,484
D	71,071	70,508	99,886	108,801
E	37,662	48,837	56,438	75,692
F	125,716	164,610	197,914	250,973
G	120,387	169,721	192,665	256,222
H	111,894	176,152	184,928	263,959
I	533,415	413,268	1,098,000[1]	872,400[1]
J	151,221	116,175	257,701	209,499

[1] SPECTRA4 values used in design were 1,012,000 ft-tons sag and 771,100 ft-tons hog.

Given that the ABS moments are based on 80 percent operability and 20 years (5,840 days) in the North Atlantic and the Navy moments are based on 35 percent operability and 40 years (5,110 days) in the North Atlantic, the commercial operability is slightly more severe than the Navy operability. However, the U.S. Navy moments are 1.5 to 2 times the ABS moments. Clearly, there is a large difference between commercial and U.S. Navy approaches to maximum lifetime hull girder bending moment predictions.

The use of SPECTRA8 for computing maximum lifetime bending moments has only occurred in the design of one ship to date, the LPD 17 Class, for which an earlier version, SPECTRA 4 was used (Sieve et al., 1997). If this procedure becomes the standard for future naval ship designs, those ships will have significantly greater strength than equivalent commercial ships if the design stresses shown in Table 6.1 are used.

The U.S. Navy design procedure provides compressive strength to the hull girder by ensuring that individual structural members have adequate strength to resist compressive hull girder bending stress. The design procedure for longitudinal stiffeners includes the interaction equation:

$$\frac{f_c}{F_c} + \frac{f_b}{F_b} \leq 1.0$$

where:

f_c = is the calculated hull girder bending stress incremented by 15.4 MPa (1.0 tsi)

F_c = the plastic buckling strength of the stiffener in axial compression

f_b = the bending stress in the stiffener caused by local transverse loads, including water pressure and deck loads

F_b = The design allowable bending stress, equal to the yield strength reduced by a factor of safety
= 186 MPa (27 ksi) for OSS
275 MPa (40 ksi) for HSS

The hull girder section modulus is determined by adding the contribution of all longitudinally continuous structural members in the hull. No contribution to the calculated section modulus is generally made by the superstructure, except for several classes of ships where the superstructure extends from the bow over more than three-fourths the length of the ship and extends to the side of the ship for that length. In these cases, only the first deck of the superstructure is included in the determination of the section modulus, and that deck and the side shell below are designed to the same structural criteria as hull structure. Where there are openings in the deck, structure forward and aft of the openings is not included in the section modulus if it is within a shadow area determined by a four-to-one slope from the opening, as illustrated in Figure 6.1. As was mentioned above, ABS uses a 30-degree shadow area, which represents a slope of 3.84-to one, nearly the same as the slope used by the U.S. Navy. Reinforcement for openings is not considered unless it is longitudinally continuous.

With recent U.S. Navy designs, the nominal strength of the hull girder has been increased above conventional requirements to provide additional resistance to whipping moments caused by underwater explosions. Additionally, the design of these ships included a fatigue analysis of critical structural details. Consequently, these ships should have even better fatigue resistance than previous naval ships.

6.5 Canadian Navy Methods for Determining Hull Girder Nominal Strength

The design methods of the Canadian Navy are chiefly based on the U.K. Ministry of Defense Design Manual for Surface Ships (SSCP23, 1989). Because the design procedure uses estimates of the extreme bending moments, assessment for the ultimate strength of the hull girder in bending is an inherent part of the design process. Compressive failure modes of grillages are assessed using the procedure developed by Faulkner and presented in Evans (1975). Three modes of failure are investigated: buckling of plating between stiffeners, buckling of longitudinal stiffeners, and overall buckling of the grillage between stiff supports such as transverse bulkheads, decks, and the side shell.

In computing the buckling of stiffeners, the amount of effective plate is determined using load shortening curves developed by Smith et al. (1988). These load-shortening curves were developed using nonlinear finite element analysis, confirming the results by experimental testing. These curves are presented as a series of curves in SSCP 23 as a function of the plate slenderness coefficient β, defined by:

$$\beta = b/t\ (\sigma_y / E)^{1/2}$$

where:

b = stiffener spacing
t = plate thickness
σ_y = yield strength

E = elastic modulus

The load shortening calculations can be made using the U.K. computer program FABSTRAN (Dow and Smith, 1986), and the ultimate strength calculations can be computed using the computer program NS94 (Smith and Dow, 1986). However, these programs are neither commercially available nor easy to use without advice from ARE Dunfirmline and considerable user experience (SSCP23).

The computation of design hull girder bending moments on a standard wave height of eight meters was discussed in Chapter 2. The design allowable stress if the plating thickness-to-breadth ratio is less than 60 is 10.1 tsi (172 MPa) to the strength deck and 8.4 tsi (144 MPa) to the bottom. The result of this design standard is ships with section moduli approximately equal to the section moduli required by ABS for equivalent commercial ships.

As discussed in Chapter 2, the Canadian standard for fatigue analysis (which is based on the UK standard) is to use an exponential distribution for the fatigue load spectrum. The BS 5400 S-N curves are used with linear cumulative damage analysis to determine fatigue lives. Because the exponential distribution is a Weibull distribution with a shape parameter of 1.0, and the BS 5400 S-N curves are similar to the UK DEN curves, the Canadian Navy practice for fatigue analysis is similar to the ABS practice. For the ships analyzed, the ABS Weibull parameter tended to be less than 1.0, so the exponential distribution would result in higher bending moments in the range of 10^3 to 10^7 cycles. One would therefore anticipate lower fatigue lives computed by the Canadian method compared to the ABS method.

6.6 Comparison of Naval Ship Section Moduli with Commercial Requirements

Ten different naval ships have been evaluated. They are identified as Ship A through Ship J. Their principal characteristics, midship section modulus, and section modulus required by ABS rules are given in Table 6.3. The ABS required section moduli, which are discussed below, would be required by all classification societies that are members of the International Association of Classification Societies (IACS). The rules have a required moment that is the sum of a rule-determined wave moment and the maximum still water bending moment computed for a number of different loading conditions. The required section modulus is determined by dividing the maximum bending moment by the design allowable stress. The allowable stress for mild steel is 175 MPa (11.33 tsi). There are several ABS grades of Higher Strength Steel (HSS), but the grade used for U.S. Navy ships is grade HS-36, which has a yield strength of 350 MPa (51 tsi). The allowable stress for HS-36 is 243 MPa (15.74 tsi). In addition, the rules have a minimum required section modulus. Both requirements are listed in Table 6.3.

In assessing scantlings, ABS defines the length of the ship as being the distance from the intersection of the waterline with the stem to the center of the rudderpost. The length so defined may be no shorter than 96 percent of the length on the water line, but need not be any greater than 97 percent of the length on the waterline. In Table 6.3, the length is taken as 97 percent of the length between perpendiculars, which for naval combatant ships is approximately equal to the length on the waterline.

Table 6.3 Actual Section Modulus Compared to ABS Requirement for Naval Ships

Ship	Length[1] (meters) (feet)	Beam (meters) (feet)	Draft (meters) (feet)	Displace-ment (m. tons) (l tons	Block Coeff-icient[2]	As-Built SM (cm^2-m) (in^2ft)		ABS Required[3] SM (cm^2 m) (in^2ft)	
						Deck	Keel	Rule	Min.
A[5]	128.02 420.00	14.42 47.31	4.59 15.08	4,528 4,457	0.537	21,570 10,969	21,126 10,743	10,157 5,165	17,523 8,911
B[5]	167.03 548.00	25.67 84.17	6.55 21.5	16,818 16,553	0.602	110,010 55,942	126,232 64,191	38,881 17,738	57,653 29,318
C[4]	124.50 408.56	14.8 48.56	4.992 16.38	4,770 4,695	0.521	21,360 10,862	22,630 11,508	13,715 6,974	23,448 11,924
D[4]	121.30 397.96	15.24 50.00	4.94 16.20	5,108 5,027	0.563	21,370 10,867	22,540 11,462	12,946 6,583	22,733 11,560
E[4]	108.51 356.00	12.741 41.8	4.183 13.723	2,964 2,917	0.515	11,210 5,700	11,600 5,900	9,518 4,840	14,740 7,495
F[5]	161.24 529.00	16.76 55.00	5.50 18.06	7,943 7,818	0.537	48,022 24,420	52,270 26,580	22,401 11,391	34,661 17,625
G[5]	161.24 529.00	16.76 55.00	6.80 22.31	9,800 9,646	0.536	49,902 25,376	54,588 27759	23,057 11,725	34,661 17,625
H[6]	161.24 529.00	16.76 55.00	6.65 21.82	9,484 9,335	0.531	44,846 22,805	50,474 25,667	22,022 11,199	31,772 16,157
I[5]	200.00 656.16	31.9 104.66	7.0 22.97	25,294 24,896	0.569	220,300 112,030	297,2901 51,180	68,262 34,713	108,549 55,199
J[5]	155.45 510.00	16.31 53.50	5.03 16.50	7,111 6,998	0.561	40,018 20,350	44,404 22,580	19,484 9,908	30,983 15,755

1 Length is nominal length between perpendiculars (LBP), approximately equal to length on waterline.
2 Block coefficient given is based on ABS rule length, which is no more than 0.97 LBP. A minimum value of 0.60 is used to determine required section modulus.
3 Rule section modulus is for a ship with the hull of the same yield strength as the naval ship.
4 Hull of mild steel
5 Hull of higher strength steel
6 Hull of HSLA -80

In two related surveys of 86 ships, 9 of which were naval ships, 607,584 details were observed during the overall survey period with a total of 6,856 failures (Jordan and Cochran, 1978) and (Jordan and Knight, 1980). This survey indicated a significantly lower percentage of failures in naval ships, compared to commercial ships. For example, in one of the twelve categories of details surveyed, beam brackets, there were 2,253 failures in 64,950 details observed, but only 3 of these were in naval ships. In the more than 20 years since these surveys were conducted, there is evidence that the quality of commercial shipbuilding has increased. Nonetheless, more recent studies, such as (Bea et al., 1997) indicate that a significant amount of cracking is continuing to occur on commercial ships. Future surveys will show if inclusion of fatigue analysis during design is having a significant effect in reducing fatigue fractures in commercial ships.

Although the naval ships have section moduli greater than IACS requirements, it does not necessarily follow that they should have greater fatigue lives than commercial ships of the same overall dimensions as the above surveys indicate. Naval ships tend to have more structural discontinuities than some types of commercial ships, particularly tankers, which have only small openings in the deck in the cargo area, and otherwise have continuous structure that tends to make overall structural response agree well with beam theory. Other commercial ships, such as bulk carriers and containerships, have large deck openings that lead to higher global stress concentrations such as occur on naval ships.

Naval ships tend to have better structural details than do most commercial ships. This is partially because of implicit requirements to withstand weapons effects. It is also a reflection that the cost of the fabrication of structure is a significantly lower percentage of the overall cost for the ship, and so with high-valued naval ships, additional care in construction to reduce local stress concentrations is cost effective.

6.7 Summary

The different methods for determining hull girder nominal strength result in different levels of strength for commercial and naval vessels.

For U.S. Navy ships, the actual section moduli are 25 percent to 90 percent greater than would be required for a commercial ship of the same dimensions. Consequently, U.S. Navy ships should exhibit superior fatigue performance compared to commercial ships.

For Canadian Navy ships, the section moduli very closely match the values required by ABS rules. Thus these ships should exhibit fatigue performance equivalent to that for which commercial ships are designed.

7. Lifetime Secondary Loads Prediction Technology Base for Commercial Ships

7.1 Purpose

The purpose of this chapter is to identify and list the technology base that supports commercial lifetime secondary load predictions. It covers external hydrodynamic pressure and internal tank loads.

7.2 Background

The computation of secondary loads, such as hydrostatic and hydrodynamic loads on shell plating, has not received the same degree of emphasis in the literature as has primary hull girder bending. However, estimates of this loading are essential for structural design. In many cases, standard hydrostatic heads are retained in classification society rules. Likewise, for cargo holds, design is based on standard design loads that have not been treated in a stochastic manner.

McAffe and Nappi (1990) pointed out the importance of secondary loads on the design of ship structure. The cost to the U.S. Navy to repair damage from wave loads on superstructure, deck-mounted equipment, hull, and appendages was more than $10M in the decade from 1980 to 1990. Because of the manner in which costs were characterized, not all of this damage was to ship structure, but the results are nevertheless significant, especially as the costs of secondary effects, such as the loss of mission capability, were not included. The effect of secondary loads on ship design was shown, on a weight comparison basis, to be one-half to one-third as important as primary hull girder loads in typical combatant ships, although for larger ships, secondary loads have a greater effect on ship weight. The secondary loads used by the U.S. Navy for design are based on historical empirical methods, and could be improved if methods such as ship motion programs were used to predict them.

This report describes only those secondary loads that are important for fatigue analysis: external hydrodynamic pressure, hydrodynamic impact loads, and tank sloshing loads. There are many other secondary loads that are important for structural design that are not addressed. These loads include tire loads from vehicles or helicopters, hydrostatic loads on bulkheads from flooding, typical deck live and dead loads, bow bulb or sonar dome slamming loads, and dynamic loads such as air blast, gun blast, or missile blast. In cases where these loads predominate, local scantlings will be designed to accommodate them, and the cyclic fatigue loads will become of less importance in such areas of the structure.

7.3 External Hydrodynamic Pressure

Accurate predictions of pressure distribution on the hull have received attention for the computation of fatigue loads on longitudinal stiffeners and transverse framing. Two different investigators used linear strip theory to predict loads in the midship region in oblique seas

(Watanabe, 1994) (Ito et al., 1994). This method is accurate in waves of short wave length, which is the predominant loading for fatigue analysis.

The estimation of secondary loads is an integral part of the ABS Dynamic Load Analysis procedure, and has been included in the SafeHull loads computations. The pressure load on the side shell is not a linear function of the wave height, as indicated by Chen and Shin (1997). They suggest that the pressure is a linear function of wave height up to a wave height equal to twice the distance from the point in question on the hull to the waterline. For waves of greater height, the pressure increment is one-half the increment in wave height. The pressure reduction factors shown in Figure 7.1 were derived using this assumption in conjunction with a Rayleigh probability density function for wave height.

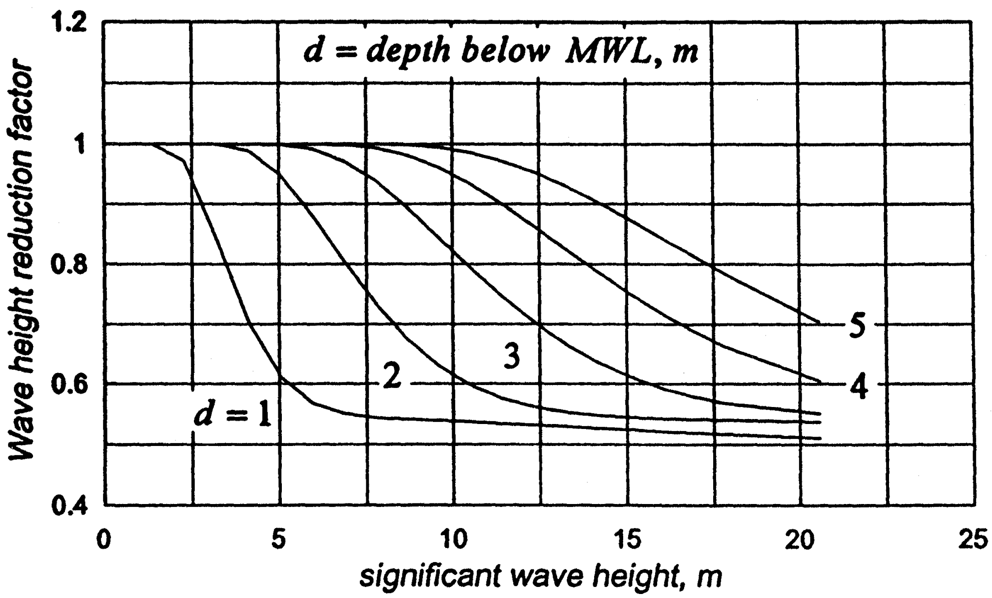


Figure 7.1 Pressure Reduction Factor Applicable to Significant Wave Height

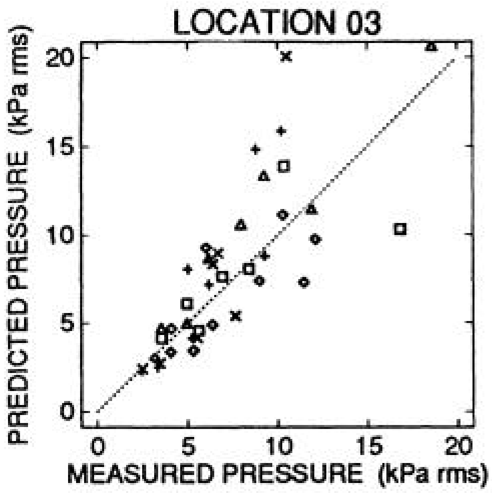
(Chen and Shin, 1997)

This reduction in pressure is used for fatigue analysis as a correction to the factor C_y in the Rules for Building Steel Vessels, Part 5, Section2AA.3.3.5a as $C_y = 0.656\ z^4$, where z is the distance to the waterline (ABS, 1999). Part 5, Section 2 of the ABS rules pertains to double hulled tankers, but the same correction is applied in Part 5, Section 3AA.3.3.5a (bulk carriers) and in Section Part 5 Section 6.AA.3.3.5a (containerships). It is worthy of note that those sections also contain a correction to the calculated fatigue stress at the end of a longitudinal stiffener with an asymmetric section, such as a bulb flat or an angle section. This correction is based on torsional bending in the stiffener due to lateral pressure loading.

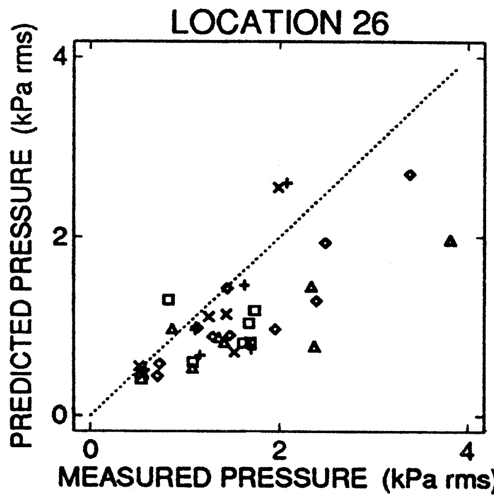
The technology base for predicting the secondary loads on the side and bottom shell has little experimental data with which predictions can be compared. The loads used in the ABS rules and in SafeHull are based on analysis with the linear ABS/SHIPMOTION program (ABS, 1999). Further documentation on the procedure given by Chen and Shin (1997) relates to analytic studies including a linear analysis by Ogilvie and Tuck (1969) and a nonlinear analysis by Salvesen and Lin (1994).

In their report for 1994, the Loads Committee of the ISSC criticized procedures of calculation of the pressure loads on the side and bottom shell using strip theory. The report stated that the strip methods do not readily predict these loads because these methods do not provide a proper treatment of the interaction between the steady and unsteady fluid flow fields. That report also showed a significant difference between the design pressures used by several classification societies, which were typically far smaller than predicted using linear strip theory. However, a large part of the difference was attributed to the probability levels combined with the allowable design stresses. The committee pointed out that design loads should not be considered in isolation, but that loads, structural analysis methods, and permissible stresses have to be considered in conjunction with each other. This discussion of pressure loads was based on computational analysis, and no experimental data were cited for comparison of computations with analytic predictions. Furthermore, the emphasis of the discussion was on prediction of maximum loads, where nonlinearities are important, and not on fatigue loads, which are generally in the domain of linear response.

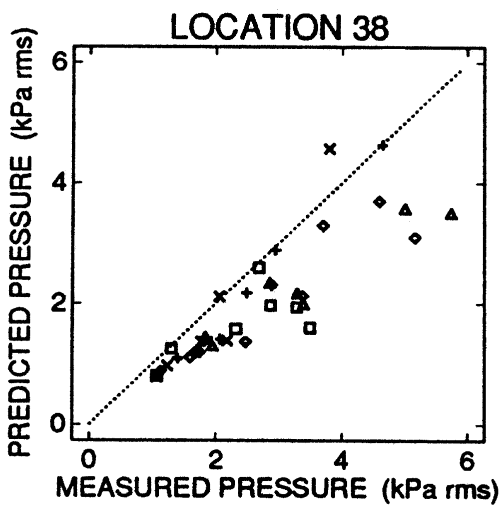
Analytic and experimental pressures were compared by DREA for the research vessel CFAV Quest (2,400 m. tonne displacement, 71.6 m length, 12.8 m beam, 4.9 m draft) (Stredulinsky et al., 1997). The vessel was instrumented with 38 pressure transducers below the waterline along the length of the hull. The ship was operated at 5 and 11 knots in head, bow, beam, quartering, and following seas with significant wave heights ranging from 0.9 m to 4.2 m. The pressures on the hull at the same locations as the pressure transducers were computed using the linear 3-D ship motion program PRECAL, which was developed by the NSMB Cooperative Research Ships Organization (NSMB, 1995). The results of the comparison at the bow, midships, and stern are shown in Figure 7.2. Although there was fair agreement at the bow (Location 03, Frame 5.25), the experimental results amidships (Location 26, Frame 50.75) were twice as great as the predicted pressures for bow seas. The predicted pressures at the stern (Location 38, Frame 91.75) were somewhat better than amidships.



a) Frame Station 5.25



b) Frame Station 50.75



c) Frame Station 91.75

□ Head △ Bow ◇ Beam ´ Quartering + Following

Figure 7.2 Comparison of Predicted and Experimental Hull Pressures on CFAV Quest (Stredulinski et al., 1997)

7.4 Hydrodynamic Impact Loads

A recent Ship Structure Committee report reviewed methods for analysis of hydrodynamic impact loading (Daidola and Mishkevich, 1995). A large number of analysis techniques were discussed in three different categories: slamming (14 methods), wave slap (3 methods), and frontal loading (5 methods). For many of these analysis methods, good agreement with experimental data was cited. The report described the types of ships to which method is applicable, the assumptions made in the analysis, and whether pressure or force is determined using the method.

For the computation of slamming loads, Daidola and Mishkevich recommend either the Stavovy-Chuang method (Stavovy and Chuang, 1976) or the Ochi-Motter method (Ochi and Motter, 1973). Both methods are semi-empirical in nature, and thus are correlated with experimental data, although the Ochi-Motter method has not been compared with full scale or model experiments.

For the computation of frontal loading, Daidola and Mishkevich recommend the Kaplan-Sargent method (Kaplan and Sargent, 1972), which estimates bow flare impact by computing changes in momentum and buoyancy using 2-D seakeeping theory. The method is applicable to computation of hull girder whipping, and has shown good correlation with experimental data.

Any method of analysis of loading must be considered in the context of its application, including the type of structure to which it is applied, structural analysis methods used, and structural design factors of safety. In this context, Daidola and Mishkevich recommend the use of the U.S. Navy specified design loads for wave slap, cautioning that they must be used in conjunction with U.S. Navy structural design methods.

7.5 Tank Sloshing Loads

A major effort has been made to determine other secondary loads, such as liquid sloshing loads in tanks, and to take them into account in the design process. For procedures such as SafeHull, consideration of sloshing loads make the scantlings of items such as longitudinal bulkheads in tankers vary as a function of their transverse location.

The loading on large cargo tanks due to ship motions and the resulting motion of the liquid is called the sloshing load. This subject has been discussed heavily in the literature and has been dealt with by classification societies for the design of cargo tanks in tankers, bulk carriers, or wherever large tanks exist on ships. The effect of sloshing on combatant ships is far less, as shown by Richardson (1991). He investigated ships that had interconnected compensated fuel tanks, which are always filled and never slack, and found that the small amount of entrapped air at the top of those tanks is significant. The entrapped air permits oil flow between the interconnected tanks during ship motions and accelerations, which causes a different type of dynamic effect. Richardson developed a computer program for computing the dynamic loads due to flow of the fluid through the pipes that connect several tanks in a bank. Richardson's method has not been verified by experimentation.

Chen and Shin (1997) considered the dynamic effect of ship motions, including accelerations in computing cargo loads. However, they did not include the impact load from sloshing effects in determining fatigue loads. The total instantaneous internal tank pressure, Pt, is computed by:

$$P_t = P_0 + ?h_1\sqrt{(g_x + A_x)^2 + (g_y + A_y)^2 + (gz_z + A_z)^2}$$

where:

P_0 is the vapor pressure (relief valve setting)
ρ is the density of the liquid
h_1 is the head to the surface of the liquid

For fatigue loads, the dynamic portion of the load, P_d is determined by the equation:

$$P_d = P_t - (P_0 + ?gh_0)$$

where h_0 is the internal pressure when the ship is in an upright position.

In the ABS Rules, Part 5, Section 2, specific means are given to compute sloshing loads in tanks. The loads are a function of the size of the tank, the density of the liquid in the tank, the natural frequency of the motion of the liquid in the tank, the period of pitch and of roll of the ship, and the percentage of the tank that is full. The shape of the tank also influences the period of the tank and the sloshing load. If necessary, sloshing loads are to be determined by model experiments.

There is considerable experimental and analytic background for prediction of sloshing loads, as these are viewed to be significant loads in large tankers and bulk carriers. The Loads Committee of the ISSC compared the predictions made by 11 different computer programs of the loads in a tank. The computer programs all used time domain simulation in either 2-D or 3-D analysis. The programs all varied in their ability to treat effects such as viscous flow, boundary layers, laminar flow, and free surface conditions. The results were in good agreement if there was no impact, as shown in Figure 7.3. In the cases involving impulsive loads, as shown in Figure 7.4, the agreement between the different predictions was not good at all. Unfortunately, there was no experimental data for comparison with the numerical results, so no judgment could be made as to which was correct.

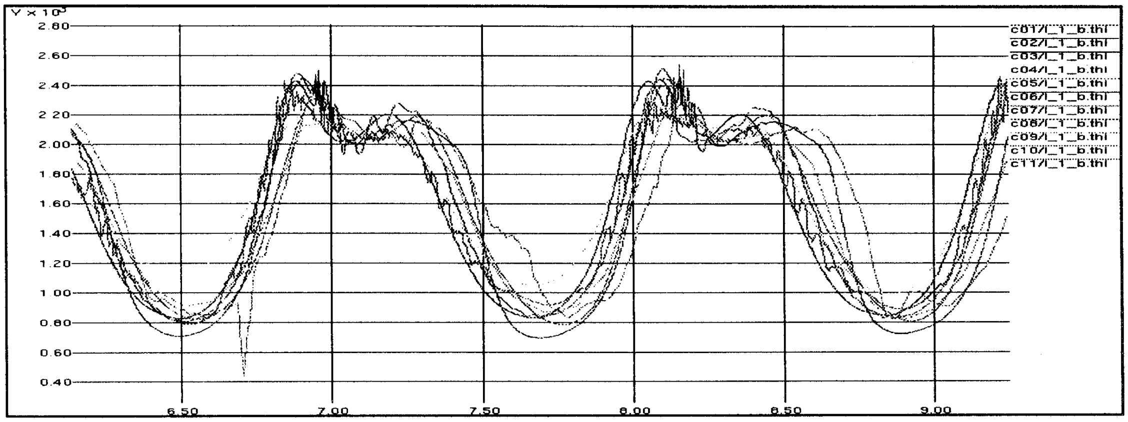


Figure 7.3 Comparison of Swash Tank Pressures without Impulse

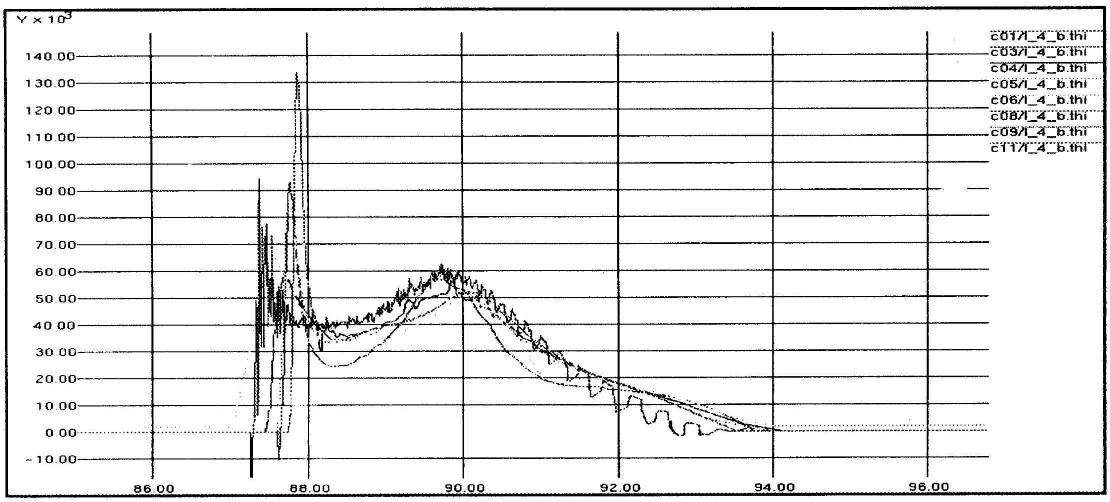


Figure 7.4 Comparison of Slosh Tank Pressures with Impulse

The ISSC also noted that for fatigue loading, sloshing pressure responses are nonlinear, and, therefore, the probability density function of their occurrence is not Gausian. A solution is provided by Casella et al. (1996) of linearizing the response around a selected ship motions-pressure response couple, which results in a so-called pseudo-RAO. Use of this method requires careful selection of calculation conditions and structural elements to keep the computational and data analysis effort within reasonable limits.

7.6 Summary

The technical base for computation of secondary loads appears to be stronger in commercial practice than in military practice. This is particularly true of external hydrodynamic pressure on the side and bottom shell. This emphasis has included fatigue loads on side shell stiffeners, which have been a problem on some commercial ships, particularly tankers. However, the methods used in commercial practice appear to lack experimental verification.

Where computations of loads on the side shell have been compared with experimental data, the results were not encouraging, pointing out the need for additional work in this area.

There is better correlation between analysis and experimental data at low amplitudes, which are more important than maximum loads for fatigue analysis of ship structure. Fatigue loading spectra may be more accurate id developed from linear response at low amplitudes than if a distribution such as a Weibull distribution is applied to the estimated maximum loads.

Bow slam forces have been treated extensively in both commercial and military practice, although the emphasis has been on predicting the maximum loads, and not the spectrum of response for use in fatigue analysis. It may be possible that the distribution of loads in this region is such that design for the extreme events results in structure capable of providing many years of satisfactory service without fatigue damage. This appears to be the case, but should be further explored.

8. In-service Hull Girder Inspection Requirements of Commercial and Naval Ship Operators

8.1 Purpose

This chapter addresses ship maintenance and inspection policies that apply to both commercial ship operators and military services. The instructions that document the policies do not all directly specify the frequency and detail of in-service hull girder inspections, but do establish the requirements to make the inspections and assign the responsibilities for accomplishing them. The requirements for commercial ships are established by U.S. Coast Guard regulations. Military ships operated by the Military Sealift Command, most of which are manned by civilian crews, generally follow practices and policies of commercial ships. The requirements for U.S. and Canadian Navy ships are considerably different than the commercial ship requirements, reflecting the difference in original design requirements as well as the much larger and organized industrial support facilities and organizations that serve these navies.

8.2 Commercial Ship Requirements

In-service inspections of the hulls of commercial ships are regulated by Coast Guard or other national regulatory bodies. Insight into current U.S. Coast Guard inspection procedures is contained in the SSC report Guide for Ship Structural Inspections (Basar and Jovino, 1990). The report prescribes methods and requirements of inspections for all stages of a ship's life from the onset of the design process through construction to the final operational years in service. This report is used as a guide by U.S. Coast Guard inspectors. U.S. Coast Guard inspection procedures, especially as relevant to fatigue analysis, are described in a paper by Williams and Sharpe presented at the March 1995 Symposium and Workshop for the Prevention of Fracture in Ship Structure (Williams and Sharpe, 1995). In this paper, the authors described the difficulties encountered in conducting effective inspections of commercial ship structures, particularly in single hull tankers. Difficulties cited include the large size of tankers, which makes inspection of the upper portions of tanks difficult without staging. Lighting conditions are generally poor; lack of cleanliness makes defects difficult to see; tanks are often extremely hot, and the extent of the structure to be inspected leads to fatigue.

U.S. Coast Guard Navigation and Vessel Inspection Circular NVIC 2-99 describes the Streamlined Inspection Program (SIP), which is an alternative to traditional U.S. Coast Guard inspections and was developed in response to the Maritime Regulatory Reform Initiative. The initiative challenged the Coast Guard to re-evaluate its regulatory programs and to develop alternatives that would ensure the same level of safety. The significant difference between SIP and the traditional annual inspection program is in the process of how compliance is ensured. SIP is primarily an "overlay" of the Code of Federal Regulations (CFR) requirements that regulate vessel safety. It identifies an alternative process for ensuring compliance with the CFR, where company personnel conduct frequent, periodic examinations of the various vessel systems, document their findings, and take the necessary corrective actions specified in the U.S. Coast Guard approved plans when discrepancies are discovered. The Coast Guard will still conduct required inspections of the vessel(s); however, the manner of conducting the inspection will be considerably different.

NVIC 15-91 of 16 Oct 1991 describes the U.S. Coast Guard's Critical Areas Inspection Plans (CAIP's). These plans are required for certain types of ships, such as tankers or ships carrying hazardous cargoes. A CAIP is a management tool that serves to track the historical performance of a vessel, identify problem areas, and provide greater focus to periodic structural examinations. The use of a CAIP is an application of the philosophy in International Maritime Organization (IMO) Resolution A.647 (16), "IMO Guidelines on Management for the Safe Operation of Ships and for Pollution Prevention." Since the CAIP is a management tool, its preparation is the primary responsibility of the vessel owner or operator. Once developed, it becomes part of an integrated management plan for achieving an adequate level of structural monitoring, maintenance, and repair. Owners and operators of vessels are required to maintain CAIPs as a management tool to document and track structural failures, and to monitor the performance of various repair methodologies. The purpose of CAIPs is to provide owners, operators, surveyors, and marine inspectors with detailed information on the vessel's fracture history, corrosion control systems, and repair experience so that structural examinations can be focused upon existing or potential problem areas. The CAIP is intended to record the various repair methodologies employed, in order to ascertain which repairs or modifications have been effective over time.

The aim of the CAIP program is to promote a proactive approach to structural repair that emphasizes identification and remediation of the underlying causes of the structural failure, rather than merely treating the symptoms. The scope and frequency of CAIP examinations is predicated upon the gravity of the structural failures being experienced, and the vigor and success with which the underlying causes of the failures are being addressed. The scope and examination intervals initially established in a CAIP may be modified if successful remedial efforts that address the cause of a structural failure, such as a detail modification, justify such a change in the CAIP.

An important link between U.S. Coast Guard inspections and commercial inspections is provided in NVIC 15-91. Some examinations are conducted by an International Association of Classification Societies (IACS) member classification society pursuant to the enhanced survey requirements for oil tankers, as required by the 1992 Amendments to Annex I of Regulations for the Prevention of Pollution by Oil 73/78, Regulation 13G. Such examinations may be substituted for CAIP exams if they are shown to be substantially equivalent in scope, intent, and effect to the examinations conducted pursuant to CAIP requirements. Examinations conducted by an IACS member classification society pursuant to the enhanced survey requirements for bulk carriers established by IACS in response to the International Maritime Organization, Resolution 713(17) of 6 November 1991, may also be substituted for CAIP exams. They must be shown to be substantially equivalent in scope, intent, and effect to the examinations conducted pursuant to CAIP requirements.

Commercial inspection requirements are established in the rules of the classification societies. For ABS, surveys after construction are conducted during an ABS classed vessel's service life. ABS surveyors conduct periodic surveys to determine that the structure is being maintained in accordance with the ABS Rules. ABS surveyors also attend repairs and modifications to make recommendations as appropriate and to determine that the work conforms to the ABS Rules.

There are also statutory guidelines that affect commercial inspections of ships. Through the International Maritime Organization, the governments of the world's maritime nations have established international maritime conventions containing regulations for protecting life, property and the environment. The governments of individual nations must enact these requirements. Over 100 governments have authorized ABS, signatory to these conventions, to act on their behalf in conducting surveys and issuing certificates. The four major conventions are:

International Convention on Loadline
International Convention for the Safety of Life at Sea (SOLAS)
International Tonnage Convention
International Convention on Marine Pollution Prevention (MARPOL)

Ships classed by ABS have specific requirements for inspections, called surveys. The requirements for surveys are contained in the ABS Rules (ABS, 2001).

- Annual Classification Surveys are required for hull, machinery, automation, and cargo refrigeration. Structure inspected includes openings, such as hatches, structural areas particularly susceptible to corrosion, and verification that no structural modifications have been made.
- Intermediate Surveys are to be carried out at either the second or third Annual Survey, or between these surveys. Additional areas included in these inspections include ballast tanks.
- Special Periodical Surveys are to be conducted at 5-year intervals. All areas of the hull are to be inspected, and thickness measurements made in particular areas.
- Drydocking Surveys are to be carried out two times in any 5-year period. An underwater inspection may be made by qualified divers at alternate Drydocking Survey dates (ABS, 1996b).

When an underwater survey is made in lieu of a drydocking survey, thickness gauging of suspect areas may be required along with non-destructive testing for fracture detection. Underwater inspection is subject to special consideration in ships older than 15 years, and may not be accepted in lieu of drydocking if there are outstanding recommendations for repairs to the hull structure or if damage affecting the fitness of the vessel is found during the underwater survey.

In addition to these requirements, there are special inspection requirements for tankers and bulk carriers. To provide a database of inspection results, ABS has developed the SafeShip system. This system provides SafeHull engineering analysis techniques, construction monitoring, hull maintenance, survey status, maintenance and repair, marine information, and vessel drawing storage.

8.3 Military Sealift Command Maintenance Philosophy

The Military Sealift Command (MSC) maintenance philosophy consists of six major elements:

a. The people: Skilled, career, licensed marine engineers to operate the ships and maintain trained, motivated, and forward thinking shore side management
b. The tools: Providing technology and tools to analyze existing conditions and enhance maintenance planning and execution.
c. The management options: Integration of continuous ships force maintenance supplemented by industrial assistance.
d. The responsibility and authority: Coordination and alignment of life cycle management responsibilities with fiscal oversight.
e. The bottom line: Maximizing ship availability for customer use at the lowest possible cost.
f. The future: Consolidation of inspections, pursuit of extended regulatory body certifications and self-inspections, and compliance with international shipping standards.

This philosophy follows commercial merchant service practices and has been updated to be proactive, quantitatively based, and adapted to MSC ships' missions. Commercial practice emphasizes maximizing cost effectiveness and ship availability. MSC ship design, construction, manning levels, maintenance, repair, and alterations are governed by commercial standards and practices. Military standards are employed only where interoperability applies, such as UNREP equipment, fleet communications and weapons handling systems and equipment. In the mid-1980s, MSC began implementing a maintenance management system based on preventive and predictive tools and technologies. This approach is proactive, flexible, and directed towards providing the Chief Engineer the information and tools necessary to make informed, prudent, and cost effective maintenance decisions. These decisions can only be made with accurate and documented information as to system and equipment conditions. The Shipboard Automated Maintenance Management (SAMM) system and its associated components; vibration monitoring, lube oil supply and analysis, chemical treatment, performance analysis, and diesel engine performance monitoring constitute the family of MSC condition based predictive maintenance systems. These systems shift efforts from corrective to preventive maintenance, from casualty correction to proactive intervention, and result in fewer days out of service and reduced catastrophic failures.

The policy of MSC of having its ships ABS classed and USCG certificated influences ship design, operation and maintenance practices. Regulatory body approval of the MSC condition based maintenance approach translates into cost avoidance by reducing open and inspect requirements. If preventive maintenance has been performed and documented, and condition based data indicates no deterioration, then survey credit can be issued.

MSC employs a single line of responsibility from the Program Manager down to the individual ship's port engineer. The port engineer concept closely integrates technical and financial management of maintenance and provides a single point of contact for accountability and responsibility of the life cycle management of material condition and regulatory body (ABS/TJSCG) interface. This allows flexibility in planning a continuous integrated maintenance approach coordinated with ships' schedules. All available opportunities to perform normal and corrective maintenance are utilized while limiting scheduled repair availabilities and time out of service. When planning for periodic maintenance and voyage repairs, the most efficient means of performing maintenance and repair must be evaluated considering cost and schedule impact of using either ship's force labor or industrial assistance. The high skill level of the career merchant mariners employed by MSC provides a level of technical expertise equivalent to a Navy intermediate maintenance. This means that MSC ships must be spared at the "O" and "I" levels, and only "D" level maintenance is accomplished with industrial assistance.

The new Memorandum of Understanding (MOU) with President of the Board of Inspection and Survey (PRESINSURV) provides for the coordination of different inspection requirements and synchronization of ship inspections with maintenance cycles. MSC will continue to consolidate all required inspections in an effort to minimize impacts on ship schedules. MSC will pursue self-inspection initiatives available from ABS and USCG and continue ISM certification.

In summary, the goal of MSC is to employ efficient and cost effective maintenance approaches that strive to correctly identify work that must be accomplished, determine the most cost effective and schedule efficient way to perform that work and maximize availability to the customer.

8.4 Canadian Statement of Structural Integrity (SSI) Overview

The Statement of Structural Integrity (SSI) provides confirmation that the ship hull structure is materially fit. The SSI formally communicates a recommendation to the ship that the hull is structurally safe to withstand the rigors of all operations consistent with the as-designed capability. Refusal to issue an SSI by the Design Authority does not indicate that a ship is in imminent danger but that material fitness is known to be substandard, and, thus, ship deployment is not recommended prior to repair of outstanding significant defects.

The SSI is issued by the Design Authority for individual Canadian Forces Ships. This standard outlines policies associated with the SSI program in sufficient detail that Command Technical Authorities and Design Agents can develop specific procedures to enable compliance with this standard.

For initial issue at construction, the SSI provides assurance to operators and maintainers that the hull has been constructed in accordance with the approved design. Subsequent issues during the ship's in-service life confirm that the ship has been returned to its' baseline condition in accordance with all relevant maintenance standards, specifications, preventive maintenance routines. As the final formal quality assurance document concerning platform, the SSI confirms that the material fitness of the ship is, in all respects concerning structural integrity, satisfactory such that the vessel can undergo all normal operations consistent with her original design assumptions and subject to changes to capability as a result of any post construction modifications. Any outstanding deficiencies in material fitness of hull structures have been recorded and the impact on considerations such as safety or operations has been fully considered by the Design Authority.

Specific information on Canadian Ships is documented in a series of Design Disclosure Documents (DDD) that are developed for each class of ship. Specific information in these documents includes:

- Design requirements

- Ship description, including major dimensions
- Intended operating conditions
- Structural materials
- Primary hull strength
- Secondary loads
- Fatigue strength
- Special structure and structural details, Structural maintenance, including maintenance philosophy and preventive maintenance requirements
- Structural drawings to be managed
- Structural history, such as major modifications or upgrades to ships of the class

For each class of ships, a Naval Preventive Maintenance Schedule is prepared. These inspections are in several categories.

Ship's Staff Structural rounds are performed at 6-month intervals by formally trained members of the crew. These inspections address areas most prone to defects. Examinations are intended for the early identification of potentially serious structural defects where the consequences of failure are significant. Figures are provided identifying areas to be inspected. Typical areas of inspection include:

- Feet of the mast structure
- Foundations of radar and weapons
- Intersection of the superstructure with the hull
- Shear strake at the quarterdeck cut down
- Specific door openings in longitudinal bulkheads

The Hull Structures Progressive Survey provides for a 5-year inspection cycle. This survey ensures that all ship's structure is surveyed at least once during that time. The surveys are conducted by the Fleet Maintenance Facility, Engineering Division, Naval Architecture Officer. The survey document includes a list showing every compartment of the ship with an associated schedule for maintaining a record on spaces inspected and planned for future inspections. Associated with the document are specific procedures for designated areas. These areas are:

- Hull (Shell and Appendages) — These inspections must be performed when the ship is in drydock.
- Decks — Specific areas are identified for inspection at 24 month and 48 month intervals, such as specific deck openings and major butt welds in the strength deck
- Masts
- Hull Structure (Structural Tanks and Voids)
- Bilge areas

A review of structural and corrosion problems on Canadian destroyers was provided by Hussey, 1982. Specific areas of the different classes of ships were described along with successful and unsuccessful repair methods that were used. Areas of the hull that were particularly prone to corrosion were described, and suggestions made for design improvements that would prevent or minimise such problems. Inaccessibility of structure for inspection and maintenance was listed as particularly important. A detailed description was given of the work required to perform structural repairs. The work required for dealing with interferences, such as removal and replacement of insulation, electrical cables, furniture, equipment, deck tiles, and piping will cost more than the structural repairs themselves. The author recommended that the same persons conduct successive structural inspections so that the experiences from one inspection on a particular ship of a class and inspections on other ships of the same class can be used to identify problem areas.

8.5 Design and Maintenance of Canadian Coast Guard Ships

All Canadian Coast Guard ships of substantial size are built to a classification society class. In the past, this society has often been Lloyds', but this is not a general CCG requirement. Once delivered and in service the CCG ships are not kept in class. Surveys and repairs are done in accordance with the requirements of the Canada Shipping Act regulations.

Vessels for the Department of Fisheries and Oceans (DFO) of about 30 m (100 ft) are also built to classification society requirements, and traditionally, these were maintained in class. Since the merger of the two fleets about 3 years ago, several of the DFO vessels have been withdrawn from class and others may follow as surveys become due. At this time the following ships are still in class:

- Hudson
- Matthew,
- Alfred Needier,
- Cygnus,
- Leonard J. Cowley,
- Tolcost,
- Gordon Reid
- John Jacobson.

There are no specific fatigue requirements over and above class rules that are specified by CCG/DFO.

8.6 U.S. Navy Maintenance Policy

Inspection and repair of the structure of naval ships is not always easy to perform. Difficulties include:

a. Most interior structure is inaccessible due to clutter and insulation.
b. The large number and relatively small size of inner bottom tanks, which must be emptied, cleaned, gas freed prior to entry. Inspection of these tanks requires crawling through a series of small access openings to reach all areas of tanks and similar void spaces.

c. Cracks are costly to repair because structural backfit repairs and modifications include temporary removal, reinstallation, and retesting of nearby system runs, equipment, and machinery, which are extensive in naval ships.
d. Class problems are applicable to multiple ships (30+), which increases the need for careful analysis of repair alternatives.

8.6.1 Maintenance Authority

The principal authority in the United States Navy for the integrity of a ship is its Commanding Officer. The Commanding Officer is given guidance and direction for inspection and maintenance through a series of directives established from the Chief of Naval Operations (CNO). These are further detailed by directives from subordinate Commands, resulting ultimately in a system of inspection and maintenance actions which are specifically directed at the type of ship and, as necessary, to a specific hull. The requirements for inspections of ships are given through the U.S. Navy Planned Maintenance System (PMS) and documented in the Maintenance Data System (MDS), which are established by OPNAV Instruction 4700.7.J, Maintenance Policy for Naval Ships, Appendix A. Requirements for the performance of required inspections and for the maintenance and repair of ships are provided by the Naval Sea Systems Command through the Naval Ships' Technical Manual. Further requirements for inspection and repair are provided by Fleet Commanders, including Commander, Surface Forces Atlantic (SURFLANT) and Commander, Surface Forces Pacific (SURFPAC). However, notwithstanding all other directives, U.S. Navy Regulations require that the Commanding Officer cause inspections to be made to ensure the proper preservation, repair and maintenance of the ship.

A U.S. Navy Board of Inspection and Survey (INSURV) is separately established as the ultimate authority for determining whether a ship of the U.S. Navy is fit for service. INSURV is required by both U.S. law and by U.S. Navy Regulations to examine every ship at least once every three years and determine if it is fit for continued service. This responsibility has been extended into the examination of newly constructed ships as well as existing fleet assets. Whenever the Commanding Officer believes that the ship is in such condition as to require an inspection by INSURV, a request to do so is to be forwarded to the Chief of Naval Operations via the official chain of command.

8.6.2. Maintenance Material Management

The Chief of Naval Operations (CNO) establishes the maintenance policy for ships of the U.S. Navy. OPNAV Instruction 4700.7J/N433, dated December 4, 1999, defines the Ship Maintenance Program (SMP), which is designed to keep ships at the highest level of material condition practicable, and to provide reasonable assurance of their availability. Extracts from that instruction are contained in Appendix K. The program encompasses three echelons of maintenance: organizational, intermediate, and depot level. Maintenance is intended to be based on reliability centered maintenance principles where it can be determined that the expected results will be commensurate with associated costs. Condition based maintenance diagnostics, inspections, and tests are also to be used to determine performance and material condition of, and to schedule corrective maintenance actions for ships. Condition directed maintenance is to be based on objective evidence of actual or potential failure or valid condition trend data. Condition based maintenance principles are to be used to adjust time-directed preventive maintenance.

OPNAV Instruction 4700.7J requires that the fleet commanders be responsible for the material conditions of their assigned ships. The commanders are to identify and authorize required maintenance actions, and ensure that required maintenance actions are performed by ship's force and by intermediate and depot level maintenance organizations.

An example of maintenance requirements established by fleet commanders is that of the Surface Forces, Atlantic (SURFLANT). Inspections by SURFLANT are the same for all ship classes except for the wooden hulled MCMs, the composite hulled MHCs, and other ships with unusual requirements. They are driven by a desired 10-year docking strategy and the interdeployment training cycle. The interdeployment training cycle is an 18–24 month cycle that calls for a ship inspection prior to deployment and another inspection after deployment and prior to an availability. These inspections will include looking at foundations for main engines, condensers, or other locations that are prone to corrosion. Qualified inspectors from the Fleet Technical Support Center carry out the inspections. Progressive tank inspections to support the 10-year docking cycle are performed whenever a tank is open, such as for maintenance within a tank, or when one tank must be opened and cleaned because of maintenance in an adjacent tank. Tank inspections are also performed as part of repair availabilities funded by the CNO, which occur on a 3- to 5-year time frame. In addition, Level 1 underwater hull inspections are required by the NAVSEA Office of Diving and Salvage (NAVSEA 00C) prior to deployment. These include a complete underwater inspection of the hull. Level 2 underwater inspections are performed more frequently, but these are only for cleaning of propellers and other appendages.

Preventive maintenance, which includes periodic inspections, is detailed on Maintenance Requirements Cards (MRCs) for organizational level accomplishment, and on Master Job Catalog (MJC) items for intermediate and depot level accomplishment. These requirements are known as the Planned Maintenance System (PMS). The MRCs and MJC items describe the maintenance requirement, the frequency with which it is performed, the qualifications required of those performing the maintenance, the estimated labor hours, and related maintenance actions. A specific MRC related to structural integrity is Maintenance Identification Page (MIP) 1102/001-C3, Hull Structure. This MIP calls for pre-overhaul inspection and inspection whenever damage or deterioration is suspected. The inspection is to be supervised by the Commanding Officer, the Engineering Officer, or their designated representative, who is usually the Damage Control Officer. The inspection may be performed by ship's force, but outside assistance may be and often is used.

When a need is identified for more frequent inspections or maintenance of problem areas, special MRCs are developed. MIP 1501/Z01-17, for example, was developed for inspection of the hull structure at the forward end of the superstructure of a class of ships. This area has experienced cracking on many ships of the class, and structural modifications have been made to reduce the probability of future cracking. The special inspections are made to be certain that there is no cracking or other failures of structure in that area.

8.6.3 Naval Ship's Technical Manual

For new construction, standards for fabrication and inspection of structure, including welding and tolerances for alignment of members and flatness of plate are provided by Military Standard 1689 (MIL-STD 1689). Technical requirements for inspection, maintenance, and repair of ship structure is provided by the Naval Ship's Technical Manual (NSTM), which is the responsibility of the Naval Sea Systems Command (NAVSEA). Extracts of Chapter 100, Hull Structure, of NSTM are contained in Appendix L. This document provides guidance on inspection of structure, including rules-of-thumb for determining minimum scantlings. It also refers to checklists and tabulations of minimum scantlings that have been developed for some classes of ships. However, the document has not been revised since 1979 and therefore doesn't represent the current practice in inspection. In particular, it does not refer to the OPNAV Ship Maintenance Plan for the inspection of ship structure. However, other chapters of NSTM are more up-to-date, particularly:

- Chapter 074, Volume 2, Nondestructive Testing of Metals—Qualification and Certification Requirements for Naval Personnel (Non-Nuclear)
- Chapter 079, Damage Control, Volume 4, Compartment Testing and Inspection
- Chapter 081, Waterborne Underwater Hull Cleaning of Navy Ships
- Chapter 90, Materiel Inspections of Active and Inactive Ships and Service Craft
- Chapter 631, Preservation of Ships in Service

NSTM Chapter 074 provides the required qualifications of personnel who will perform nondestructive test and evaluation. The standards pertain largely to the inspection of welds associated with fabrication and repair of structure and other welded systems, such as piping. However, ultrasonic inspection is used for surveys of hull structure, and the qualifications of the individuals who will perform such inspections are contained in Chapter 074. The chapter also provides useful tables of reference to other documents that pertain to nondestructive testing.

NSTM Chapter 079, Volume 4 provides the technical requirements for the required testing of compartments for watertight integrity. The watertight compartments of ships in service receive periodic tests under air pressure to determine the presence of leaks. Most leaks come at the gaskets of hatches and doors, as well as stuffing tubes for electrical cable, but such air testing will also reveal advanced corrosion that has penetrated the structure. The chapter also contains a useful table for reference to the compartment inspection and test requirements of other chapters of NSTM as well as in the Planned Maintenance System.

NSTM Chapter 081 provides the requirements for cleaning of the underwater hull without drydocking. No specific intervals are given for the frequency of cleaning, because the rate of fouling of the bottom by marine growth varies with factors that include geographical location and ship operations. However, the cleaning is done frequently to prevent the loss of speed and increase in fuel consumption that is caused by marine fouling of the hull. The hull is inspected by divers before and after cleaning and any deterioration of the coating or corrosion is noted.

NSTM Chapter 090 provides general requirements for all tests and inspections. The chapter provides guidance for inspection of coating systems and for the detection of corrosion of structure. Guidance is provided for the inspection of critical areas that will require special attention, such as tanks and voids.

NSTM Chapter 631 provides requirements for the preservation of ships in service. It also contains information on the preparation of surfaces for coating, which includes inspection for corrosion of structure.

8.6.4. Underwater Inspections

Visual inspections of the interior of the ship are complemented by underwater hull inspections. The requirements for underwater hull inspections are contained in chapter 17 of the Underwater Ship Husbandry (UWSH) manual. Extracts from that manual are contained in Appendix M. These procedures detail inspectors' qualifications, process, criteria and record keeping but they do not address inspection intervals or analysis. There are three levels of underwater inspections. The level one inspection is a cursory inspection of the entire hull, whereby the diver is typically looking for damage to a specific system. For hull plating, they would be looking at the coating condition, biofouling, and damage such as dents, corrosion, and cracks, on the shell plating. The intent of a level two inspection is to perform more detailed documentation of damage detected during level one inspections. The level three inspections are system-specific, invasive procedures requiring some amount of disassembly of the system or component to complete the inspection.

In addition to the inspection by divers, underwater ultrasonic gauging (UT) of the hull is often performed when requested by the ship's commanding officer or type commander. Requirements for underwater UT gauging are not contained in the NSTM, UWSH, or PMS MRCs, but are conducted by several commercial organizations for the requesting authority. The intention is that this UT gauging of plate thickness replaces the drydocking that would be necessary to inspect the hull plating for deterioration. In addition to inspection of the external surface, the gauging provides an indication of deterioration within tanks. Although the surface of tanks, including tank tops, can be gauged to provide an indication of internal conditions, the condition of internal stiffening members can not be determined without entering the tanks. Tanks can not be accessed without pumping out the fuel and gas freeing, a time-consuming and costly process.

8.6.5. Thin Hull Check Lists

Chapter 100 of NSTM provides a general rule of thumb that structure must be replaced if corrosion in excess of 25 percent of the original thickness occurs. Guidance that is more specific has been developed by NAVSEA for a number of combatant ships in the form of checklists for hull inspection of deteriorated structure. These documents identify areas of the structure that are more prone to corrosion, the original thickness of plating and the webs and flanges of stiffeners, and the allowable minimum thickness. The checklists call for the thickness of the members to be measured and recorded on the checklists so that the information will be available for future examinations of the structure.

8.6.6. Corrosion Control Information Management System (CCIMS)

For aircraft carriers, specific guidance for inspections of ship structure and recording the results of the inspections is contained in the Corrosion Control Information Management System (CCIMS) Inspection Manual. Extracts from that manual are contained in Appendix N. The system provides a uniform set of inspection attributes and inspection criteria for coating systems, using standard descriptions and pictures of corrosion for reference. The standard used is the American Society of Testing and Materials standards ASTM D610 “Method for Evaluating Degree of Rusting on Painted Steel Surfaces,” and ASTM D714 “Method for Evaluating Degree of Blistering of Paints.” The management system is aimed primarily at the inspection and maintenance of coating systems, but there are also requirements for inspecting the structure for corrosion or of cracking, and reporting such damage to the structure.

8.6.7 Board of Inspection and Survey (INSURV)

The Board of Inspection and Survey (INSURV) is required by Title 10 U.S. Code 7304 and Article 0321, U.S. Navy Regulations to:

- Examine each naval ship at least once every 3 years, if practicable, to determine its materiel condition.
- Report any ship found unfit for continued service to higher authority.
- Perform other inspections and trials of naval ships and service craft as directed by the Chief of Naval Operations (CNO). Surveys are directed by CNO on an individual basis.

Extracts of Title 10, U.S. Code are provided in Appendix O.

In practice, INSURV performs these inspections as a combination of physical and administrative inspections. Selected items of ship systems are inspected, such as turbines and reduction gears, and the physical condition of the ship is accomplished by a walk-through inspection of all compartments. For many other areas, particularly ship structure, the ship’s maintenance records are reviewed to be certain that the required inspection and maintenance have been carried out. In particular, drydocking of the ship to assess the condition of the underwater hull, or cleaning and gas-freeing of tanks for inspection are not routinely done. Because U.S. Navy ships seldom have structural problems in service, the membership of the INSURV board does not include individuals with expertise in ship structures. If a ship is to be inspected and possible structural problems are known in advance, outside expertise is obtained by including an engineer from NAVSEA or other organization who has the required background and expertise.

8.6.8 Example – SURFLANT Policies

Inspections by SURFLANT are the same for all ship classes except for wooden-hulled MCMs, composite-hulled MHCs, and other ships with unusual requirements. They are driven by the desired 10-year docking strategy and the interdeployment training cycle. The interdeployment training cycle is an 18–24 month cycle that calls for a ship inspection prior to deployment and another inspection after deployment and prior to an availability. These inspections will include looking at foundations for main engines, condensers, or other locations that are prone to corrosion. Qualified inspectors from the Fleet Technical Support Center carry out the inspections.

Progressive tank inspections to support the 10-year docking cycle are performed whenever a tank is open, such as for maintenance within a tank, or when one tank must be opened and cleaned because of maintenance in an adjacent tank. Tank inspections are also performed as part of CNO availabilities, which occur on a 3-year to 5- year time frame.

In addition, Level 1 underwater hull inspections are required by NAVSEA 00C prior to deployment. These include a complete underwater inspection of the hull. Level 2 underwater inspections are performed more frequently, but these are only for cleaning of propellers and other appendages.

8.7 Summary

All ships, both commercial and military, have well documented inspection policies and procedures. The U.S. Navy maintenance policy is anchored by a required 3-year inspection by an independent board. In general, the current design practices combined with an aggressive policy towards preservation of structure result in a low incidence of structural deterioration from cracking or corrosion. Inspection requirements are to some extent condition based, so that when problem areas become known, the intensity of inspection is increased in those areas.

Commercial ships are assured of having regular inspections by both the classification societies and by state authorities such as the U.S. Coast Guard and the Canadian Coast Guard. The principal difficulty with commercial ships concern those that are registered in countries that do not require inspections, are classed by societies that are not members of IACS, and have irresponsible owners who are not concerned with the condition of the ships as long as they continue to earn revenue. Such ships are and their conditions are outside the scope of this study because it is assumed that the Navy that wishes to use commercial means for ship inspection, as part of a fatigue damage prevention program will consult with a responsible classification society. Table 8.1 compares the inspection policies of these different authorities.

Table 8.1 Comparison of Hull Girder Inspection Policies

Inspection Requirement	U.S. Coast Guard	ABS	U.S. Navy	Canadian Navy
Applicability	All ships calling at U.S. Ports. All U.S. flag ships.	All ships classified by ABS.	All combatant ships. Auxiliaries inspected by ABS.	All ships in Canadian Navy
Special Requirements	Critical Area Inspection Plans (CIAP)for tankers	Enhanced surveys for tankers and bulk carriers	Ships with known defects	Problem areas documented in requirements for inspection
Inspection Interval	Annual. Inspect foreign-flag if appears necessary	1, 2.5, and 5-year	3-year INSURV 2--year operational, 10-year fleet commander	5-year
Inspector Qualification	U.S. Coast Guard officers and qualified petty officers	Qualified ABS surveyors.	Ship's force, repair activity.	Ship's force, Fleet Maintenance Facility
Structure required to be regularly inspected (i.e. all, tanks, shell, decks, bilge, foundations, etc.	Discretion of inspector augmented by CIAP	Annual—openings, problem areas Intermediate—ballast tanks Periodical—entire hull	18—24-month • Machinery foundations • Corrosion-prone locations Pre-deployment • Underwater hull 10-year • Tanks	6-Month • Mast feet • Foundations of radar and weapons • hull-superstructure intersection • Shear strake at cut down • Specific door openings 5-year • Hull • Decks • Masts • Tanks and voids
Inspector is looking for (i.e. cracks, coating breakdown, corrosion, etc.)	Cracks, corrosion	Cracks, corrosion, coating	Corrosion, coating	Cracks, corrosion, coating
Inspection results database maintained	No	SafeShip system if requested by owner	No	Yes

9. Application of Commercial Methods for Fatigue Analysis of Existing Ships

9.1 Purpose

The purpose of this chapter is to present the application of ABS fatigue design practices and approaches to assess the hull structure of 10 current and past U.S. and Canadian naval vessels and compare the results between commercial and naval practice. The Project Technical Committee (PTC) agreed upon the hulls to be evaluated, and these ten ships are discussed in Chapter 6. These analyses were performed using the ABS SafeHull Phase A approach. Due to the time required to develop a finite element model for the SafeHull Phase B approach, only one of the ships was analyzed using the Phase B approach, as approved by the PTC.

9.2 Introduction

There are three versions of the SafeHull program available: containerships, bulk carriers, and tankers. In terms of hull form and speed, combatant naval ships bear the closest similarity to containerships. Therefore, the hull girder loading developed by ABS for containerships is the most applicable to the naval vessels. Furthermore, these similarities allow the midship section geometry of the naval vessels to be input into the program-loading feature. Therefore, the containership version of the SafeHull program was used to analyze all ten ships. It is noted that internal structural differences between naval vessels and containerships, i.e. complete upper and lower decks in the naval vessels and containerships having open structure required some innovative application of the SafeHull software. The version of the containership program that is distributed by ABS for commercial use is limited to ships that have a length of 130 meters or more. However, a special version of the program for shorter ships was made available by ABS for this task.

Limitations of the software for SafeHull Phase A in analyzing these ships were discovered during the analysis process. Those limitations will be discussed fully in Chapter 10, but the modifications to the input that were required to successfully run of the program will be briefly described in this chapter. Chapter 11 will provide a guide for conducting a Phase A SafeHull analysis of a naval vessel, including suggested modifications to the standard input found necessary by the investigator.

9.3 Phase A Analysis

9.3.1 Input Data

The Phase A analysis was limited to analysis of the longitudinal structure at the midship section. The Phase A fatigue analysis is for the intersection of longitudinal stiffeners with transverse frames, and for the fatigue of flat bar stiffeners on transverse frames that help support the longitudinal stiffeners. To perform this analysis, SafeHull does not require the scantlings of transverse members to be input. The program requires only a description of the type of cutout for the longitudinal, size of flat bar, and thickness of the web of the transverse frame, and size and thickness of lugs at the cutouts to support the longitudinals. Scantlings of transverse bulkheads are not needed for the analysis, and were not input.

Figure 9.1 shows the typical hull input for the ships analyzed. The midship section was extended fore and aft as parallel middle body in order to develop the "tanks" that are used to define local loads on the structure. The hull form for the forebody above the waterline is used to determine bow flare loading, and is also input as shown.

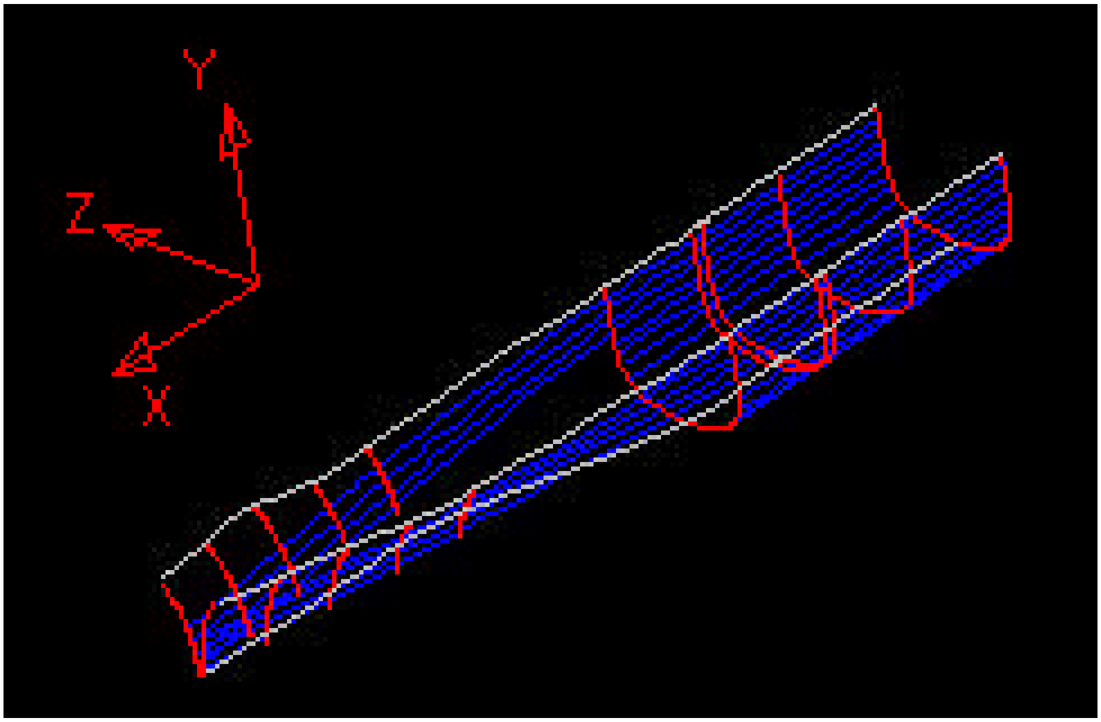


Figure 9.1 Phase A Hull Input for a Typical Ship

There are five different types of tanks that can be defined in Phase A:

- Cargo Hold
- Ballast Tank
- Void Space/ Underway Passage
- Duct Keel
- Fuel Oil Tank

Of these, the ballast tank and the fuel oil tank include air pipes that are part of the development of a hydrostatic head. The other types do not produce such loads.

The tanks for the ship are shown in Figure 9.2. The space between the upper deck and the deck below was defined as a void space. The space between the second and third decks was defined as a cargo hold, between the innerbottom and the third deck as a void space, and the doublebottom as a ballast tank. These definitions were determined largely on a trial and error basis, with other combinations resulting in failure of the program to properly execute. These definitions resulted in loads placed on the side shell to represent external wave action. Loads were placed on the innerbottom and bottom shell plating to represent pressure from fuel or ballast. These tank definitions resulted in no loads being placed on the decks. This is reasonable because in naval vessels most decks have little load fluctuation that would contribute to fatigue. In general, this type of loading would be unacceptable for a general cargo ship, where there can be a considerable range of loading due to the effect of ship motion on cargo.

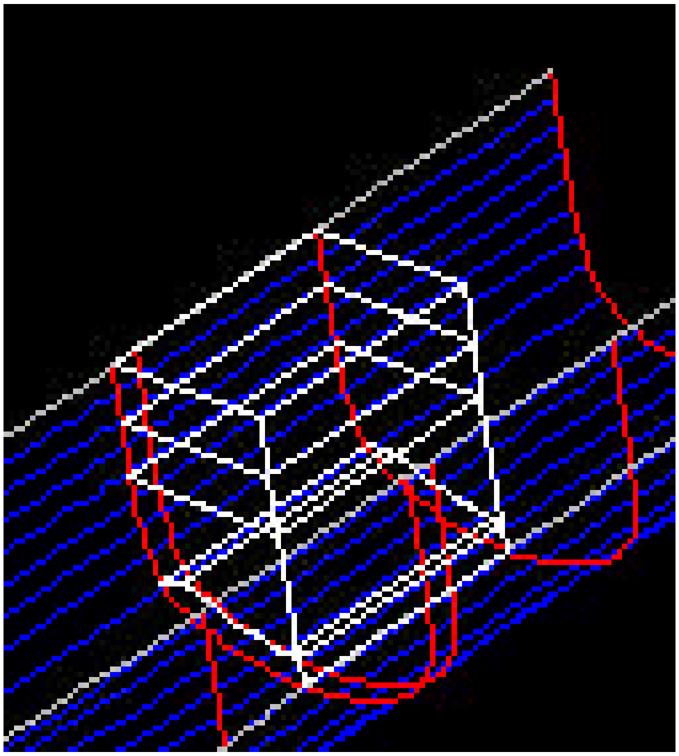


Figure 9.2 SafeHull Tanks for Development of Local Loading

A view of the midship section in the Phase A input is shown in Figure 9.3. Structure is defined as stiffener "plates." A typical plate would start and end at either the intersection with other plates, such as longitudinal girders in the innerbottom, or at changes in plating thickness. The scantlings of each longitudinal stiffener on each plate are described individually, but a plate can have only one thickness of plating. Plates are considered as straight lines, so that additional plates are entered as necessary to describe curvature. The decks have the fewest numbers of plates, with changes only at the change in plating thickness.

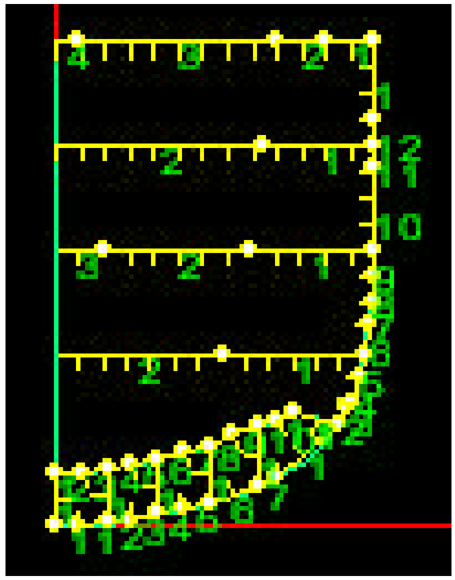


Figure 9.3 Section of SafeHull Model of a Typical Naval Vessel

In contrast with the typical naval vessel shown in Figure 9.3, Figure 9.4 shows a typical containership, the type of ship for which the SafeHull software was developed. Note the absence of decks and the presence of an inner skin in the containership. The ship in Figure 9.3 has an innerbottom, but many naval vessels do not have that feature, whereas containerships do. These differences in geometry present a challenge for the adaptation of the SafeHull software.

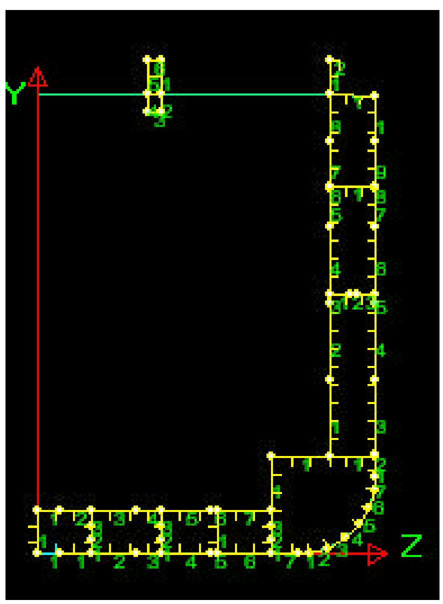


Figure 9.4 Section of SafeHull Model of a Typical Containership

The variables that are used to define end connections are shown in Figure 9.5. The depth of the flat bar stiffener and size of bracket can be input. Note that there are no other choices, such as a tee-stiffener as is frequently used on naval ships.

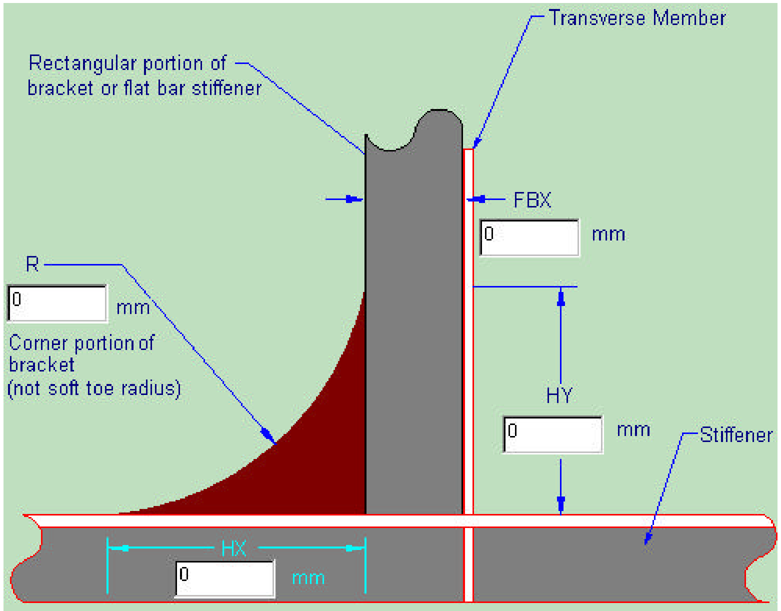


Figure 9.5 SafeHull End Connection Input

Figure 9.6 shows the types of cutouts and collar details that can be input for longitudinal stiffeners. Four of the six types are for tee stiffeners and the other two are for angles. Alternative shapes such as bulb flats or flat bar stiffeners are not included, and there is no variation where the top of the flange of the longitudinal is welded directly to the web of the transverse.

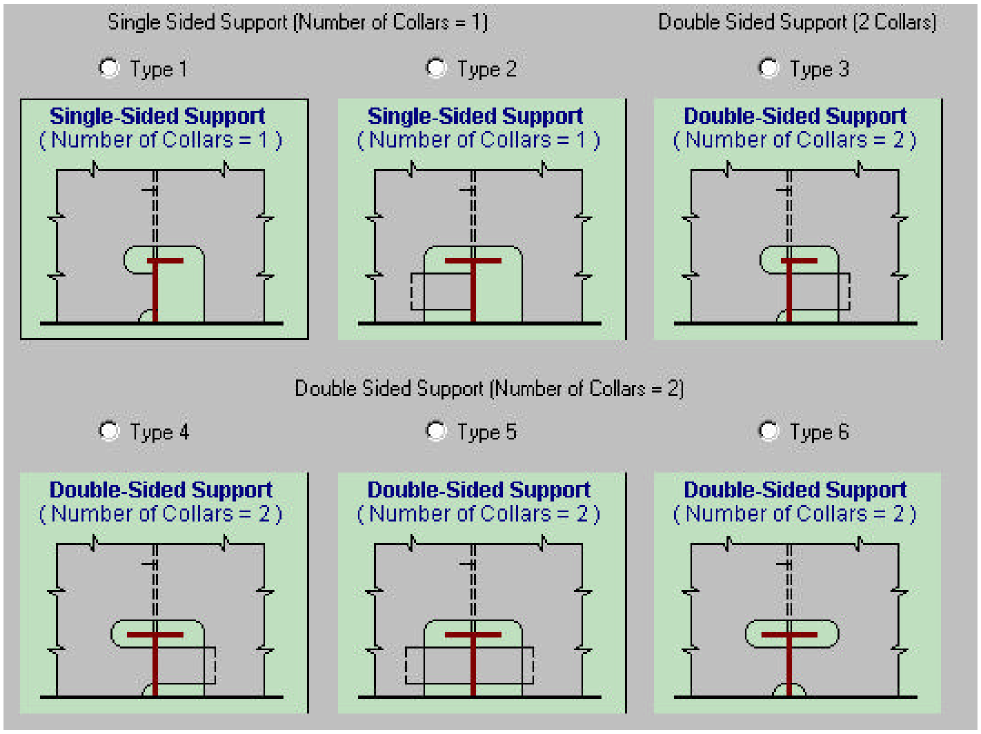


Figure 9.6 Details of Cutouts for Stiffeners

9.3.2 Results of Analysis

The results of the fatigue analysis of typical longitudinal stiffeners for Ship G are given in Table 9.1. The results of the fatigue analysis of typical flat bars for Ship G are given in Table 9.2. The complete results for all locations analyzed for all ten ships are given in Appendices A through J. The following definitions apply to the column entries on Table 9.1 and in the appendices:

TOE	Either the forward "F" or aft "A" end of the stiffener. Different details can be described for either end. (Unless otherwise identified, all ships had a flat bar at the forward end of each stiffener, but no flat bar at the after end.)
ID	Identification of the type of detail for flat bar stiffener used
Dist. from BL	Distance of stiffener from the baseline of the ship
SM	Section Modulus of the stiffener with effective plate
Span	Length of stiffener between transverse frames
Ct	Factor for combined bending and torsion
Cy	Factor for side longitudinals based on ratio of draft to distance from baseline of the stiffener.
LP#	
Load Case #	One of the ten different loading conditions that produces the maximum stress.

Local Load Range	The difference in equivalent hydrostatic head between the two load cases for the stiffener.
f_{RG}	The alternating stress range from global hull girder bending loads.
f_{RL}	The alternating stress range from local loads.
f_R	The combined stress range, computed by the equation $f_R = c_f\, c_m\, (f_{RG} + f_{RL})$
c_f	Coefficient equal to 0.95 to reduce stress from the fully wasted condition. SafeHull reduces scantlings by an average corrosion factor of (NDCV applied with the approximate impact to the hull girder strength) 0.90 times original scantlings to analyze the strength of the structure at the end of the lifetime of the ship. This factor adjusts the stress level to approximate the mid-life level.
c_m	Factor of 0.85 applied to connections of longitudinals to transverse webs or floors in the bottom.
Fatigue Class	The assigned fatigue classification for the intersection of the longitudinal with the transverse frame. (These were discussed in Chapter 5.)
Long Term Distribution Factor	The Weibull distribution factor defining the shape of lifetime fatigue loading spectrum.
Perm. Stress	The permissible stress range for the fatigue classification and the Weibull distribution factor.
Ratio f_R/PS	The ratio of the computed stress range to the permissible stress range. A value of 1.0 or less represents an acceptable fatigue life.

The following additional definitions apply for the fatigue analysis of flat bars in Table 9.2 and in Appendices A through J:

Force	The range in shear force at the end of the longitudinal.
Support Area A_s	Sectional area of the flat bar
A_c	Sectional area of the collar plates
SFC	Stress Concentration Factor for the detail
f_s	Nominal stress range in the flat bar stiffener
f_L	Stress range in the longitudinal as computed for the fatigue analysis of the longitudinal as shown in Table 9.6
f_{Ri}	Stress range for assessing fatigue life of the flat bar stiffener $f_{Ri} = [(SFC\ f_s)^2 + f_L^{\,2}]^{1/2}$
c_w	coefficient for the weighted effect of two paired loading conditions

Table 9.1 SafeHull Phase A Fatigue Analysis of Longitudinals for Ship G

STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP #	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
1	Bottom Long'l 1	A/	1	0	268	2.34	1	1	2	1&2	5.23	2249	470	2196	F2	0.889	2611	0.84	12 X 4 X 16# I/T
		F/	2	0	268	2.34	1	1	2	1&2	5.23	2249	470	2196	F2	0.889	2611	0.84	
12	Side Long'l 18	A/	1	6.61	156	2.34	1	.73	1	F1&F2	12.95	1472	1473	2798	F2	0.928	2443	1.15	8 X 4 X 10 # I/T
		F/	2	6.61	156	2.34	1	.73	1	F1&F2	12.95	1472	1473	2798	F2	0.928	2443	1.15	
19	01 Lvl Long'l 12	A/	1	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
32	I.B. Long'l 1	A/	1	1.4	156	2.34	1	1	2	1&2	0.48	1938	75	1912	F2	0.889	2611	0.73	10 X 4 X 12# I/T
		F/	2	1.4	156	2.34	1	1	2	1&2	0.48	1938	75	1912	F2	0.889	2611	0.73	
47	1st Plat Long'l 9	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	1499	0	1424	F2	0.889	2611	0.55	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	1499	0	1424	F2	0.889	2611	0.55	
58	2nd Plat Long'l 10	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	1600	0	1520	F2	0.889	2611	0.58	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	1600	0	1520	F2	0.889	2611	0.58	
59	I.B. Girder 2	A/	1	0.8	62	2.44	1	1	1	1&2	0	2067	0	1963	F2	0.889	2611	0.75	5 X 4 X 6.0# T
		F/	1	0.8	62	2.44	1	1	1	1&2	0	2067	0	1963	F2	0.889	2611	0.75	
64	Mn. Dk Long'l 12	A/	1	10.06	70	2.34	1	1	1	TZONE		1766	0	1678	F2	0.909	2514	0.67	5 X 4 X 6.0# T
		F/	2	10.06	70	2.34	1	1	1	TZONE		1766	0	1678	F2	0.909	2514	0.67	

Table 9.2 SafeHull Phase A Fatigue Analysis of Flat Bars for Ship G

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range Head (m)	Force (tf)	Support Areas A_s (cm^2)	A_c	SCF	Cf=0.95 Cw=0.75 Stress Range (kg/cm^2) f_s	f_L	f_{Ri}	FATIGUE CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
BTM10604	2	1	0.84	0.696	2.34	5.12	8.54	7.1	51.8	1.5	138	1953	1964	F2	0.889	2611	0.75
		2	0.84	0.696	2.34	5.12	8.54	7.1	51.8	1.25	138	1953	1961	F2	0.889	2611	0.75
[Weld Throat]			0.84	0.696	2.34	5.12	8.54	[Asw]=	4.5	1.25	138	0	273	W	0.889	1883	0.14
SHL10908	1	1	6.61	0.69	2.34	12.95	21.44	0	27.4	1.5	546	2798	2915	F2	0.928	2443	1.19
		2	6.61	0.69	2.34	12.95	21.44	0	27.4	1	546	2798	2851	F2	0.928	2443	1.17
[Weld Throat]			6.61	0.69	2.34	12.95	21.44	[Asw]=	0	1.25	546	0	*****	W	0.928	1760	NaN

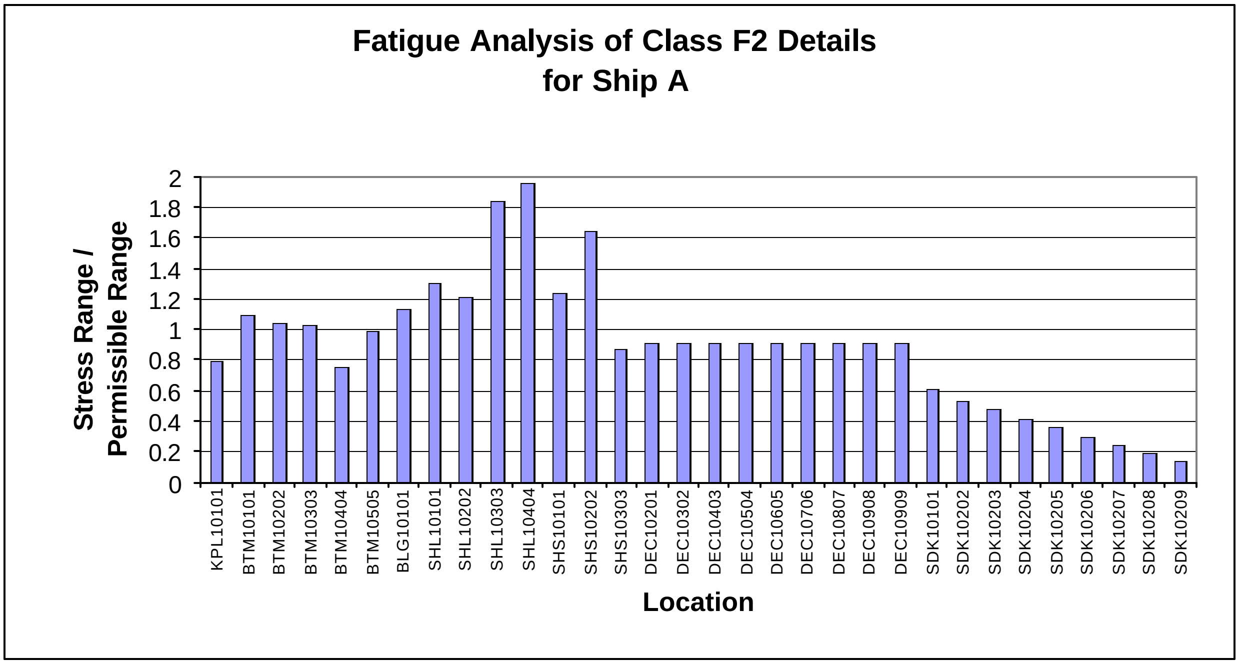
Figures 9.7 through 9.16 show the ratio of the computed stress range to the allowable stress range for all of the locations analyzed by SafeHull in Phase A for the subject ships. A value of 1.0 or less indicates satisfactory service life, and a value greater than 1.0 is a prediction of fatigue failure during service.

In Figures 9.7 through 9.16, the following abbreviations (which were generated by SafeHull) are used to designate areas of the hull:

KPL	Flat Plate Keel
BTM1	Bottom Shell
BLG	Bilge Strake
SHL	Side Shell
SHS	Sheer Strake
DEC1	Main Deck (Strength Deck)
SDK	Second Deck (Deck below Strength Deck)
WTF1	Watertight Flat 1 (deck below Second Deck)
WTF2	Watertight Flat 2 (deck below WTF1)
NTF	Non-Tight Flat (Platform)
INS1	Longitudinal Bulkhead No. 1
INS2	Longitudinal Bulkhead No. 2
INB	Inner Bottom
NBG	Non-Tight Inner Bottom Girder
BGR	Watertight Bottom Girder

Once familiarity with the program was gained, the input was altered so that designations that were more descriptive to the particular ship could be input. For example, Ship C has labels such as “A Strake” (Bottom Shell), “No 1 D” (Deck Number 1), and “No 2 L” (Longitudinal Girder Number 2). For other ships, such as Ship G, even more descriptive designations such as “Bottom Long’l 1” or “IB Margin Plate” were used.

Figure 9.7 SafeHull Analysis Results for Ship A



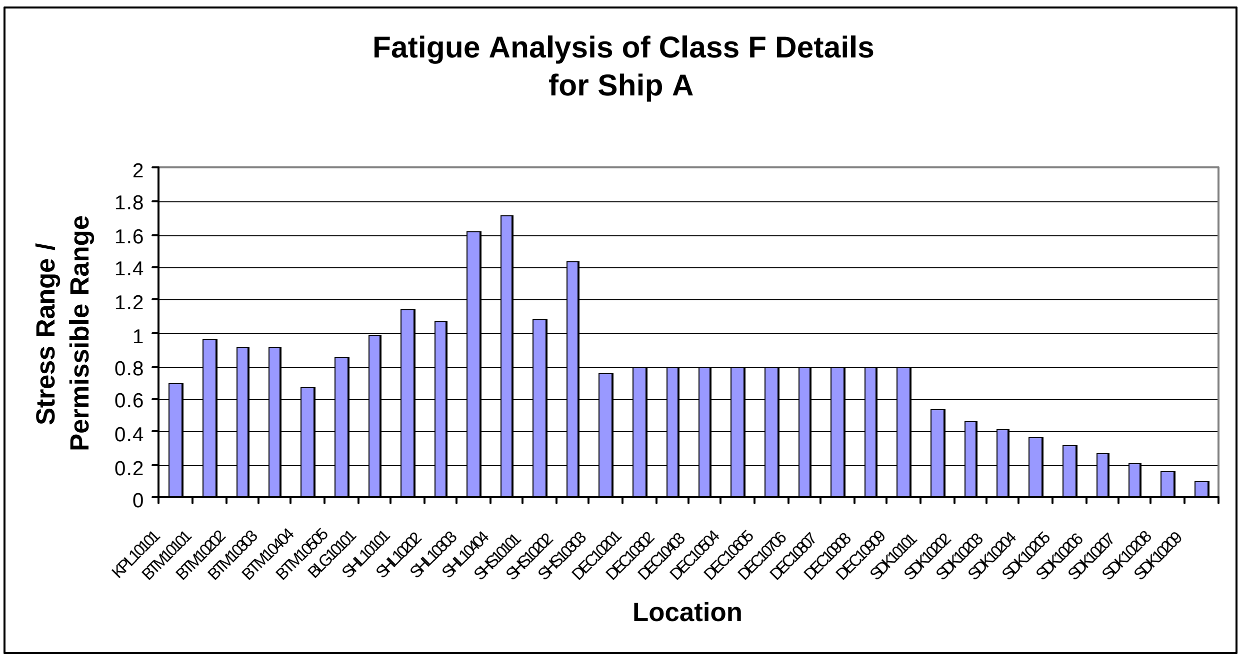
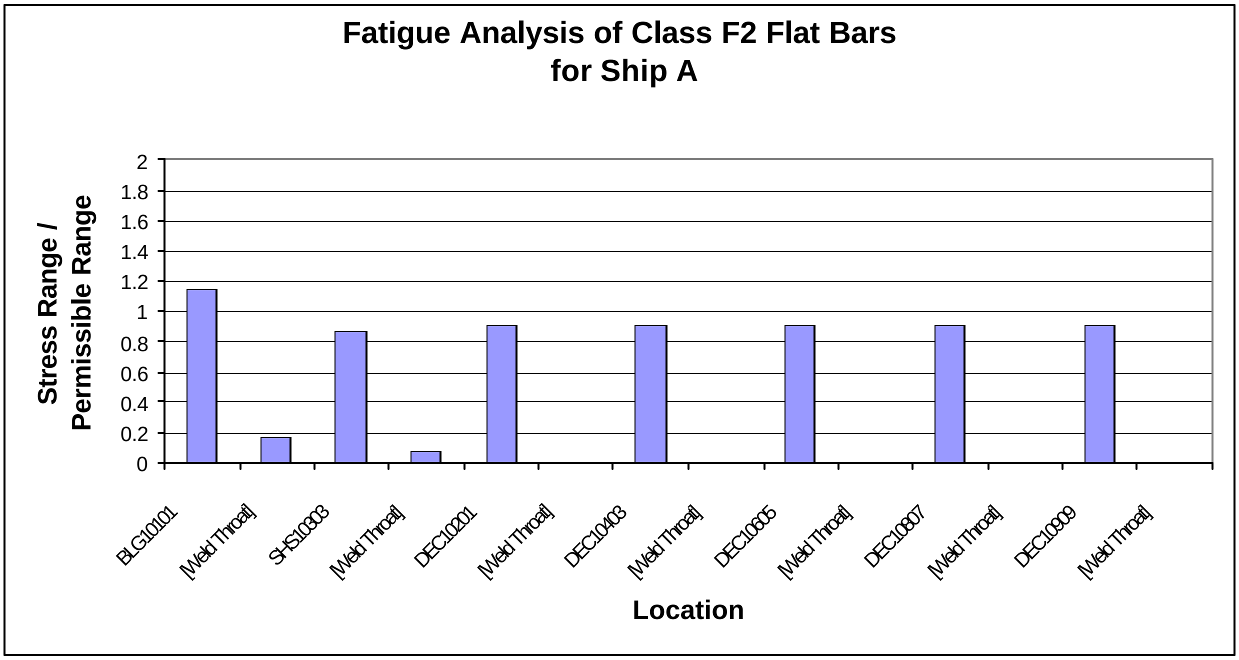


Figure 9.7 SafeHull Analysis Results for Ship A (Continued)



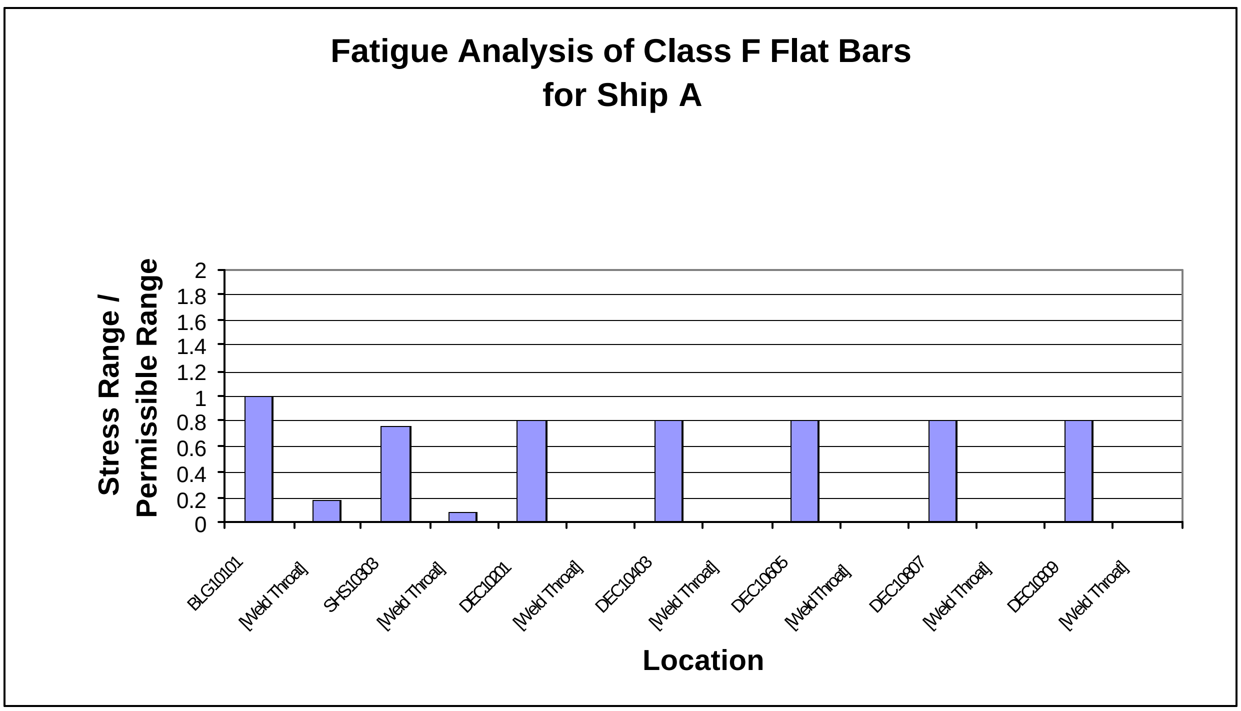
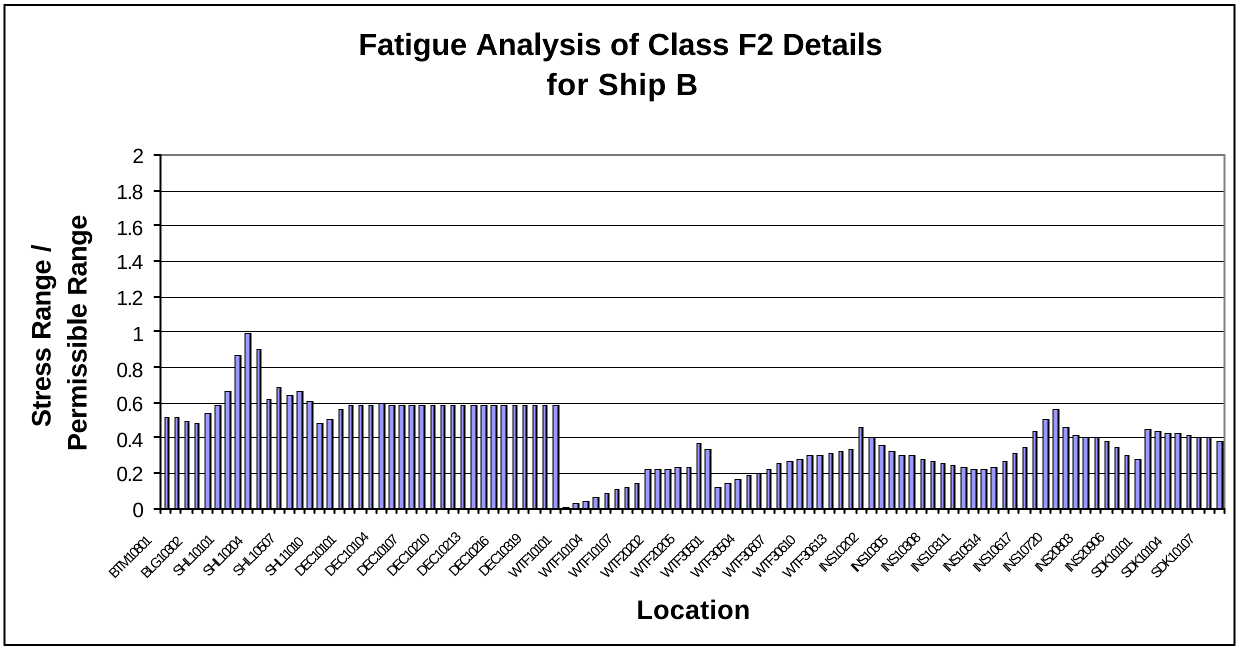


Figure 9.8 SafeHull Analysis Results for Ship B



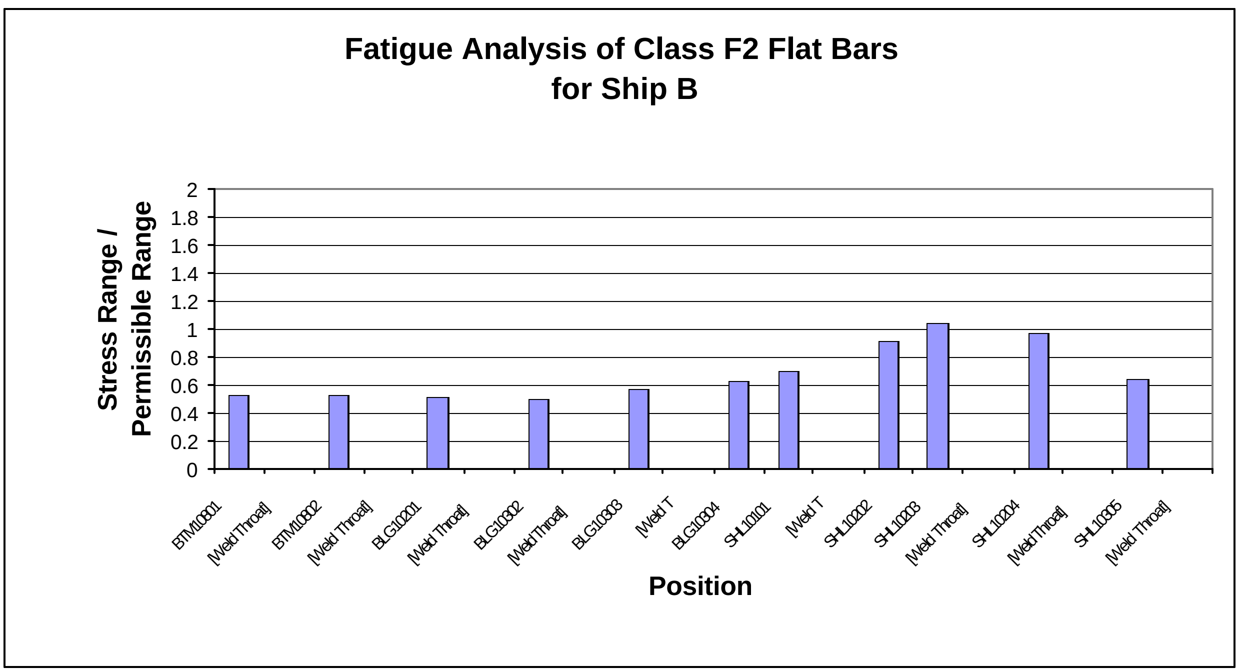
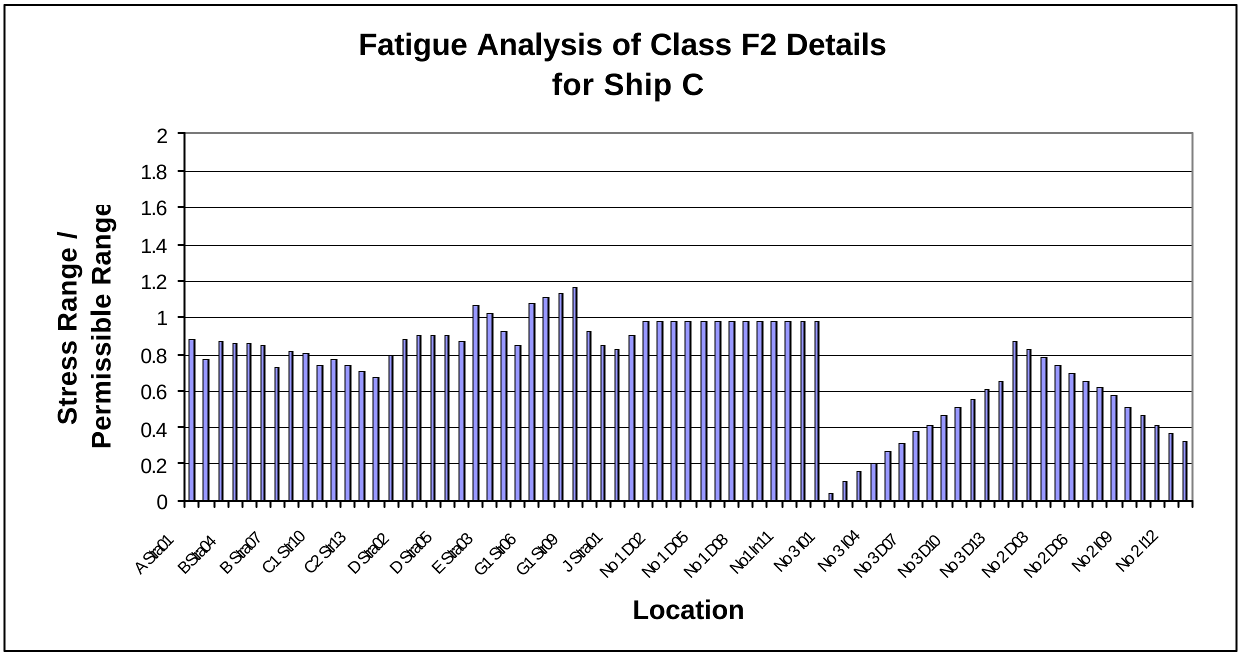


Figure 9.9 SafeHull Analysis Results for Ship C



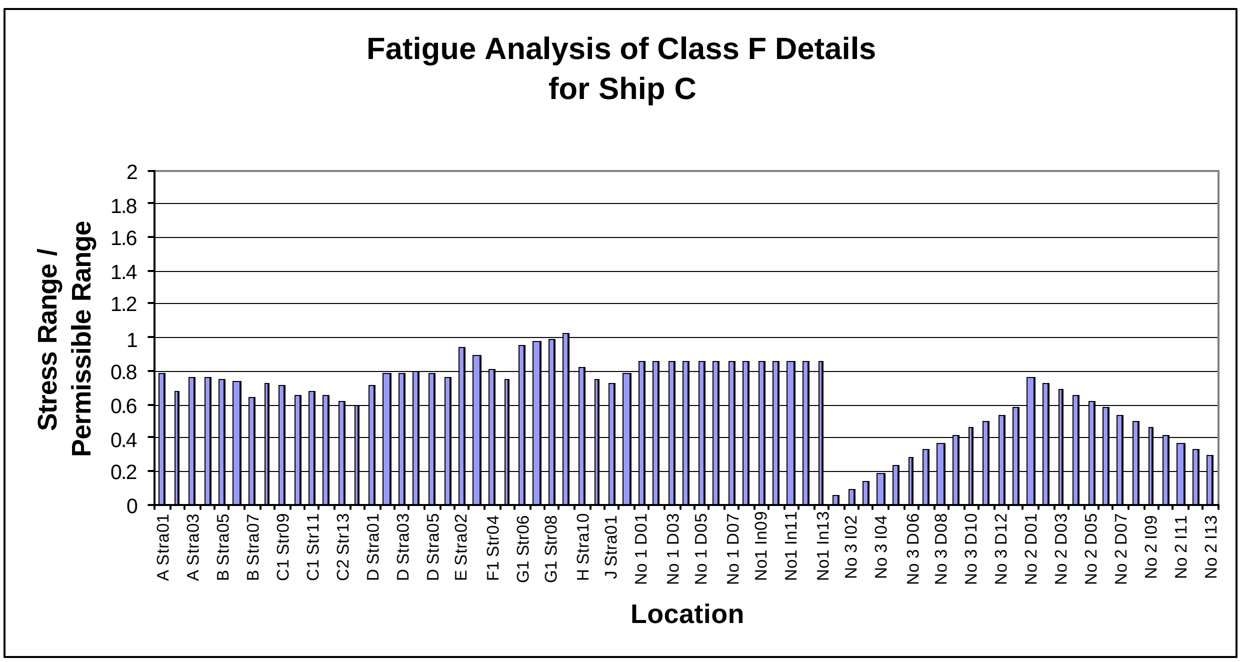
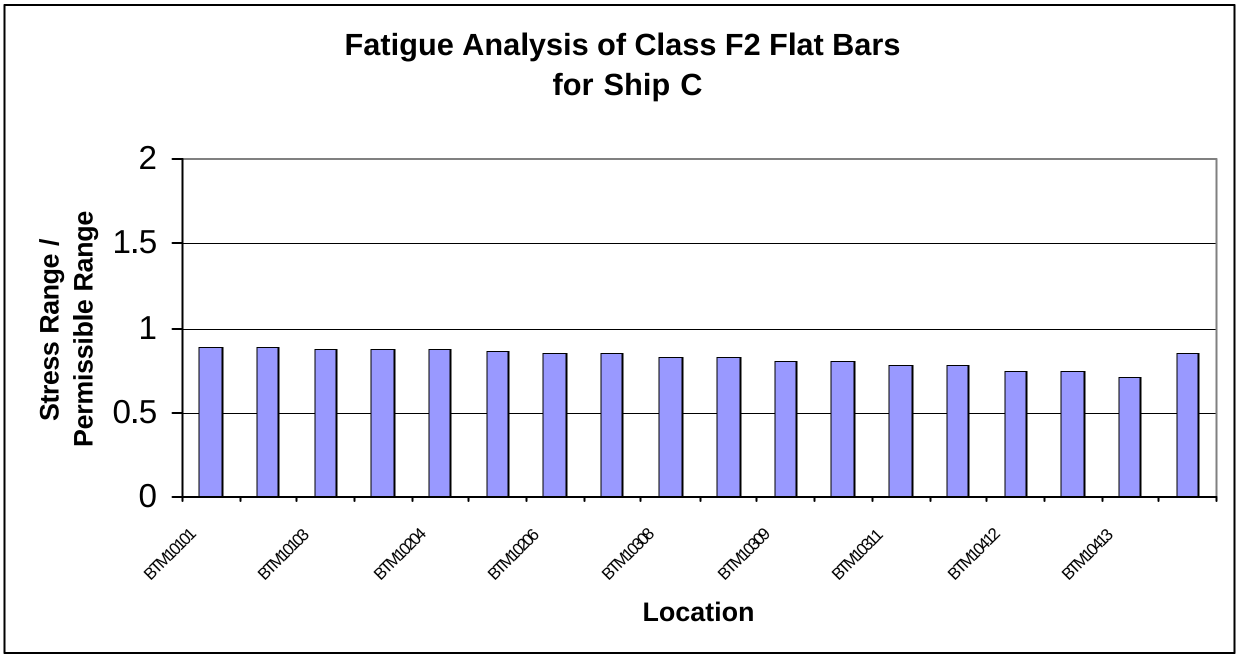


Figure 9.9 SafeHull Analysis Results for Ship C (Continued)



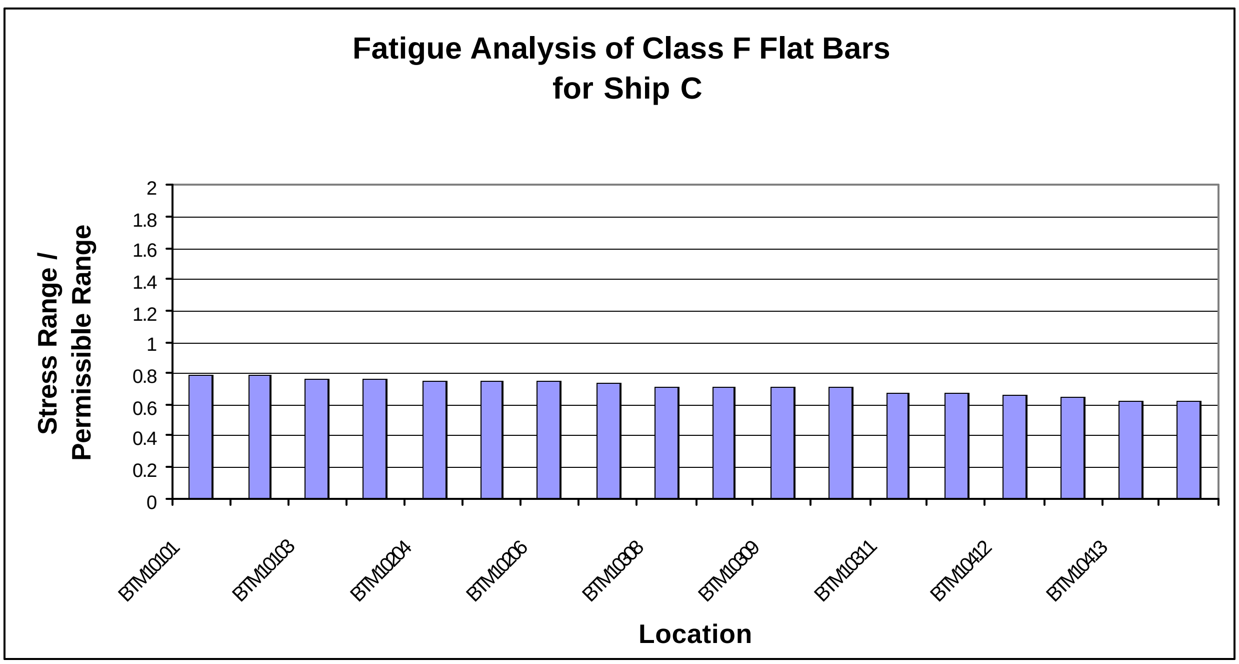
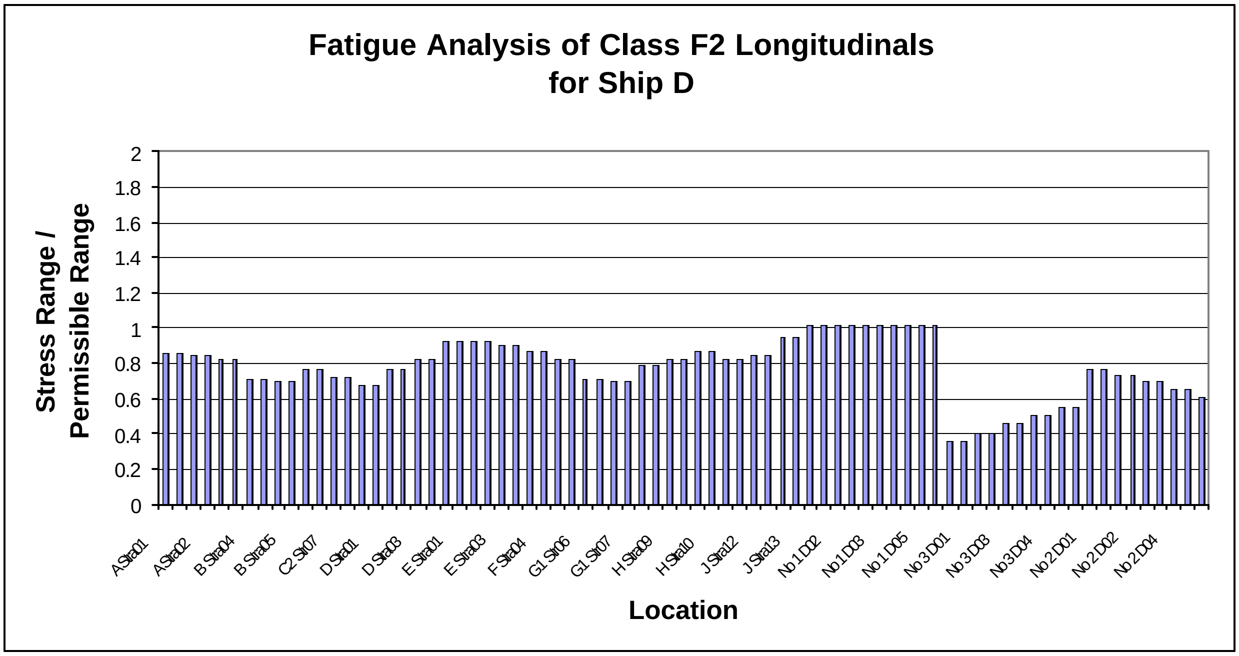


Figure 9.10 SafeHull Analysis Results for Ship D



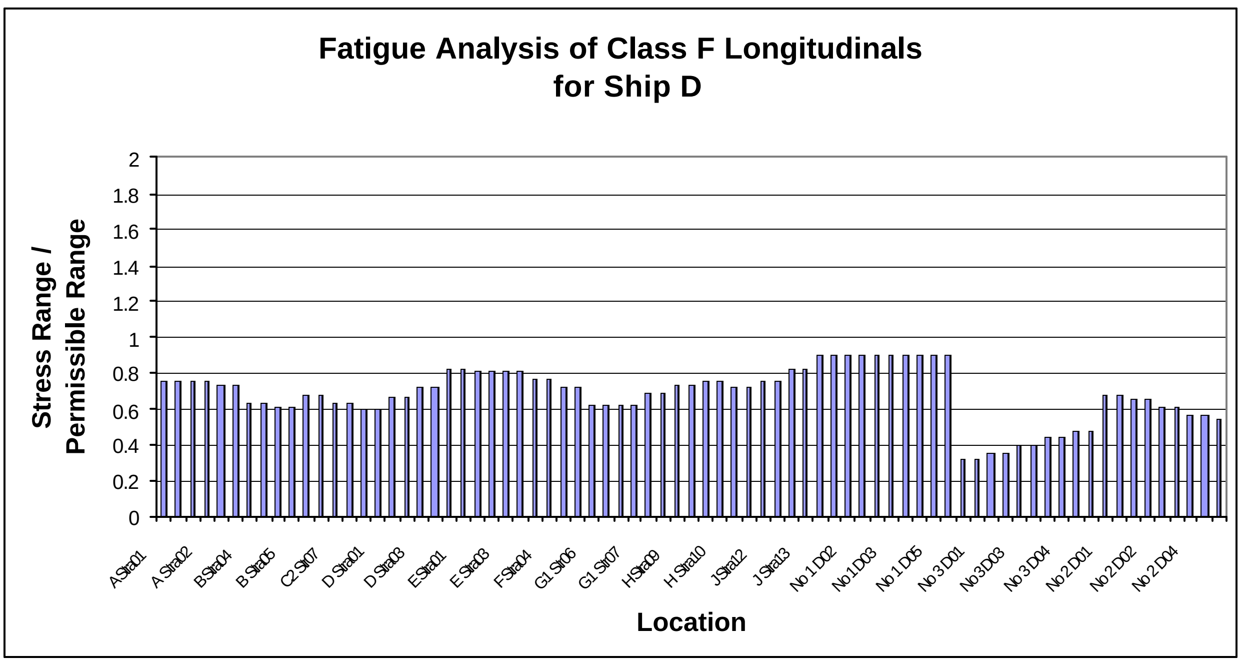
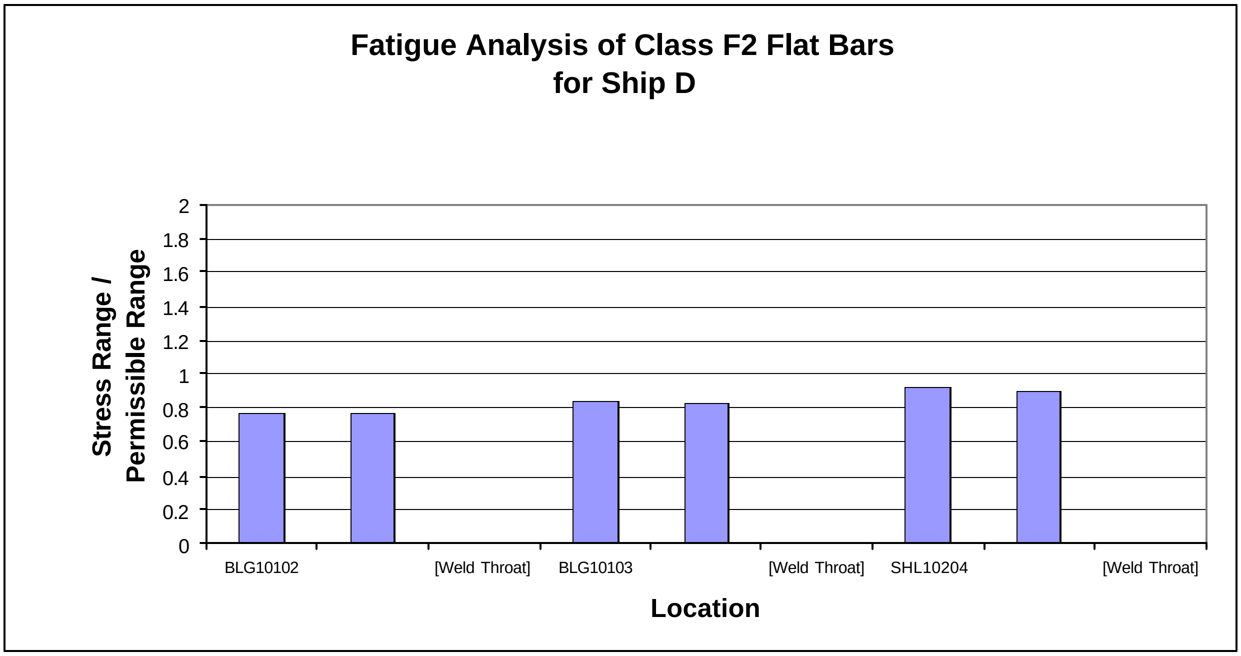


Figure 9.10 SafeHull Analysis Results for Ship D (Continued)



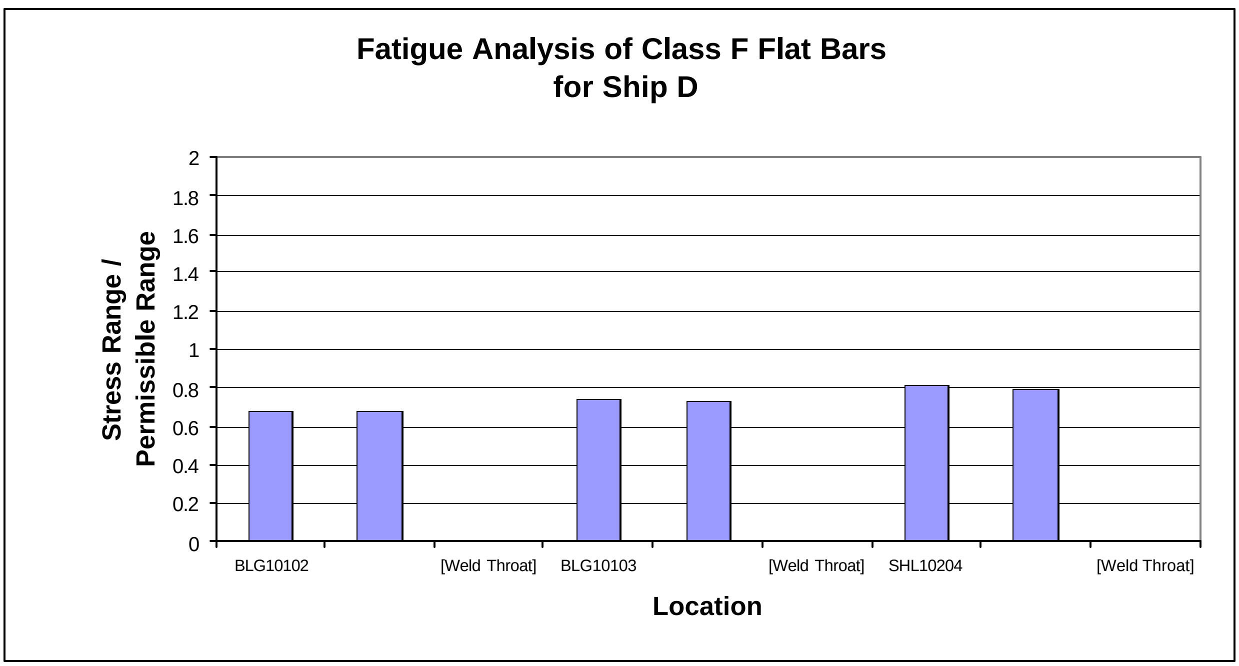
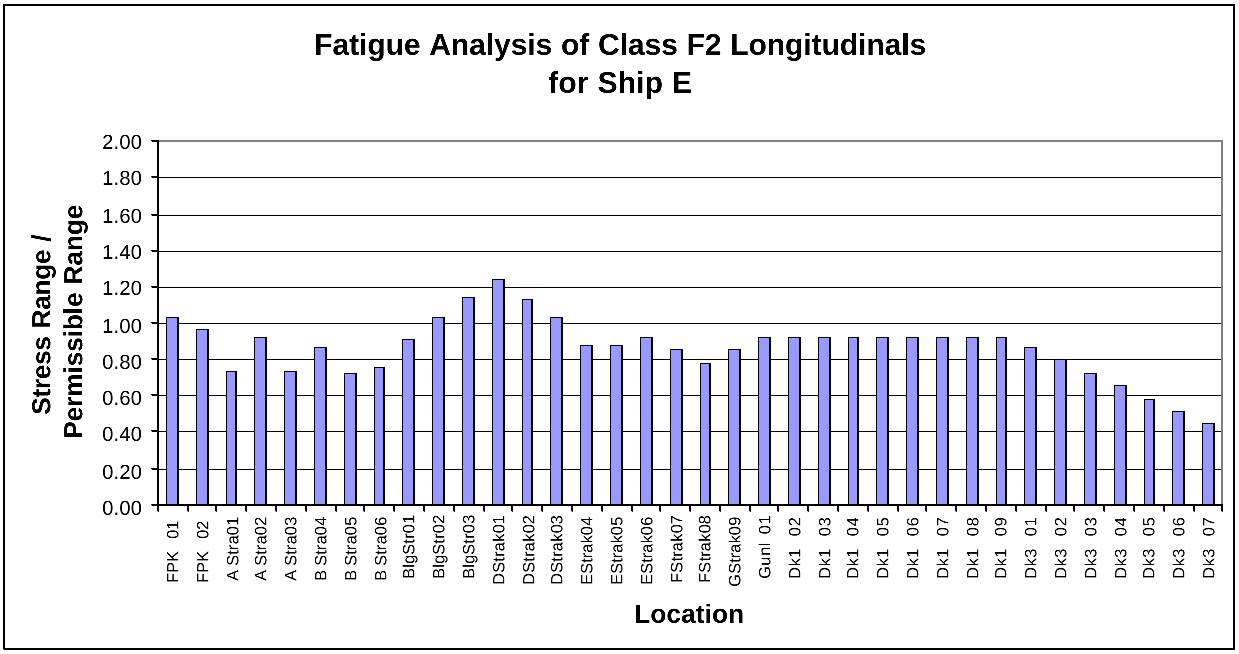


Figure 9.11 SafeHull Analysis Results for Ship E



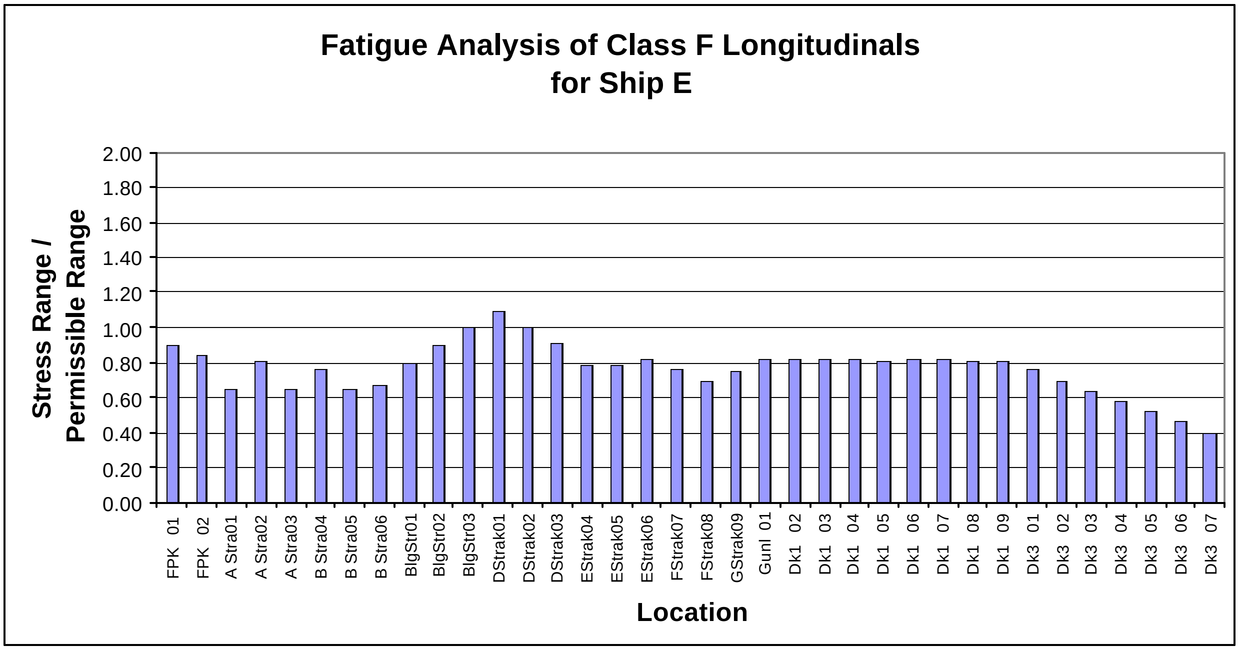
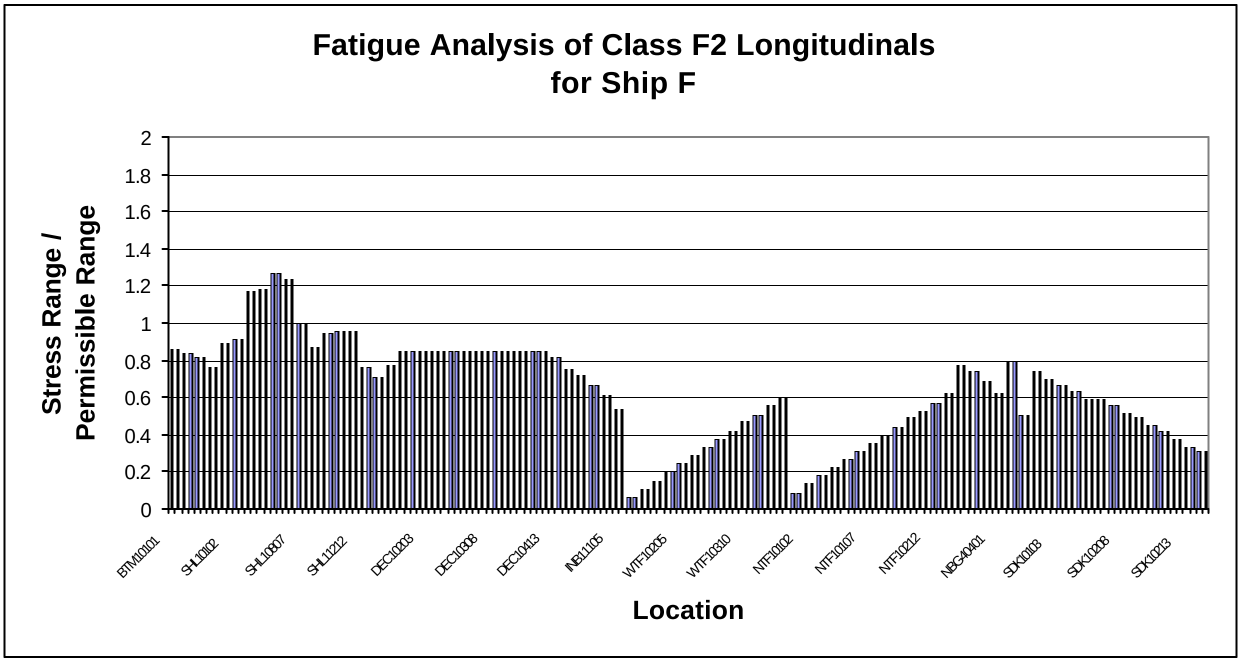


Figure 9.12 SafeHull Analysis Results for Ship F



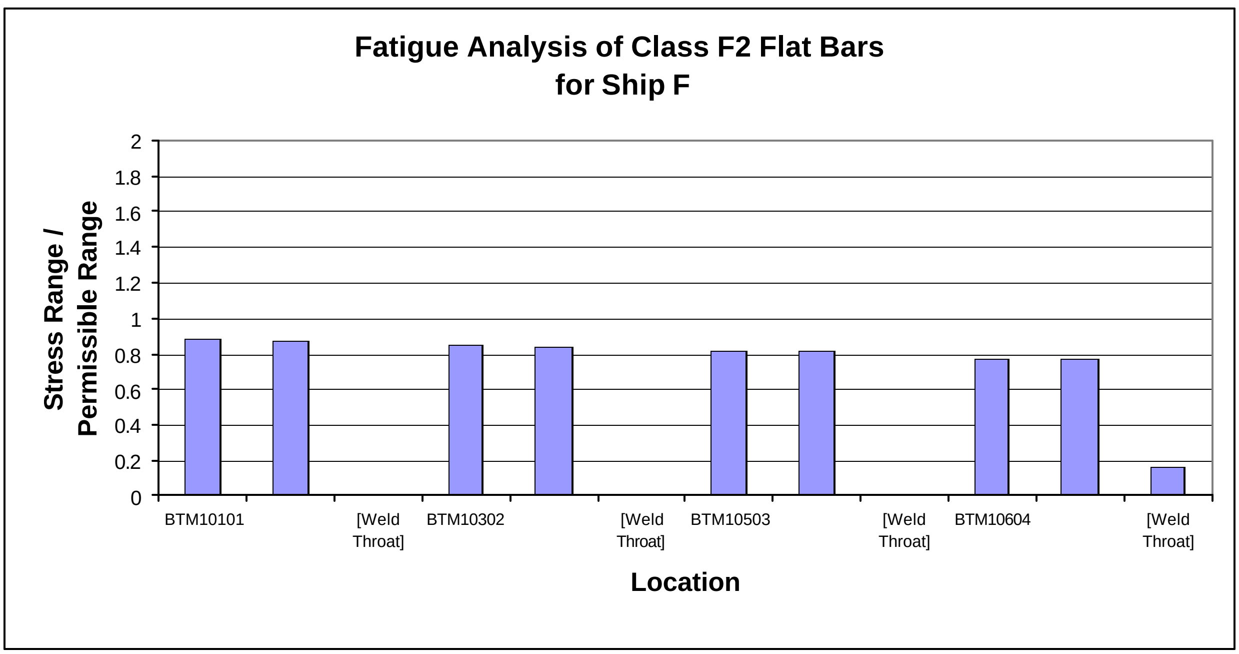
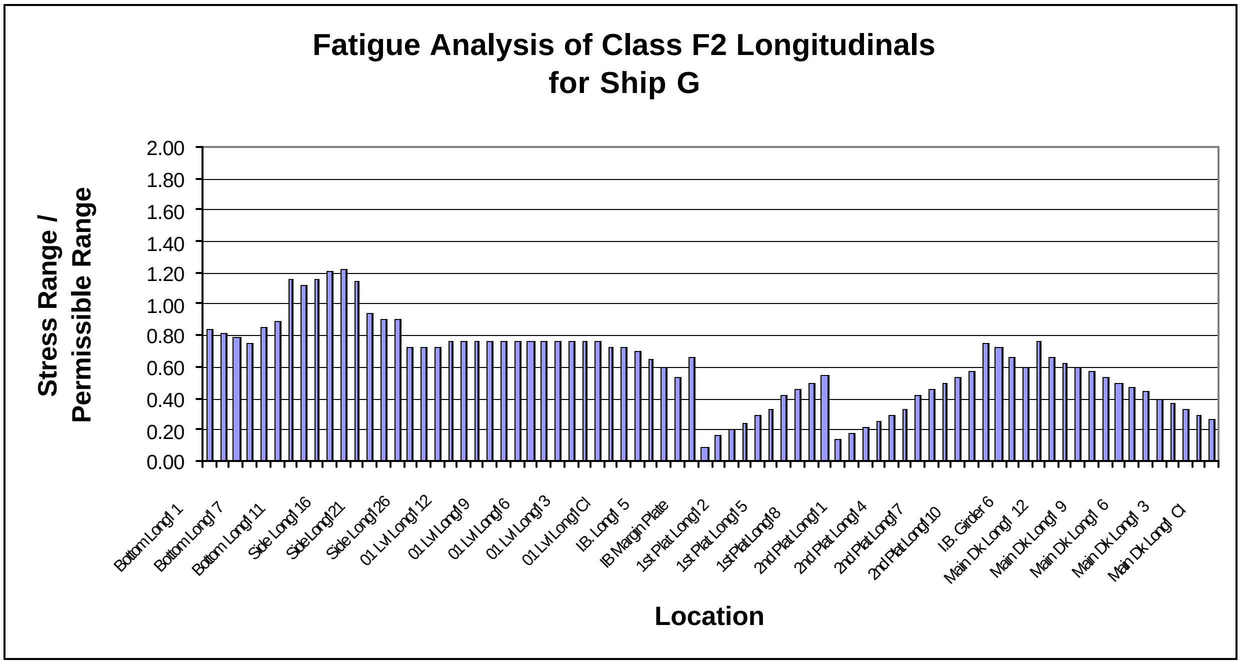


Figure 9.13 SafeHull Analysis Results for Ship G



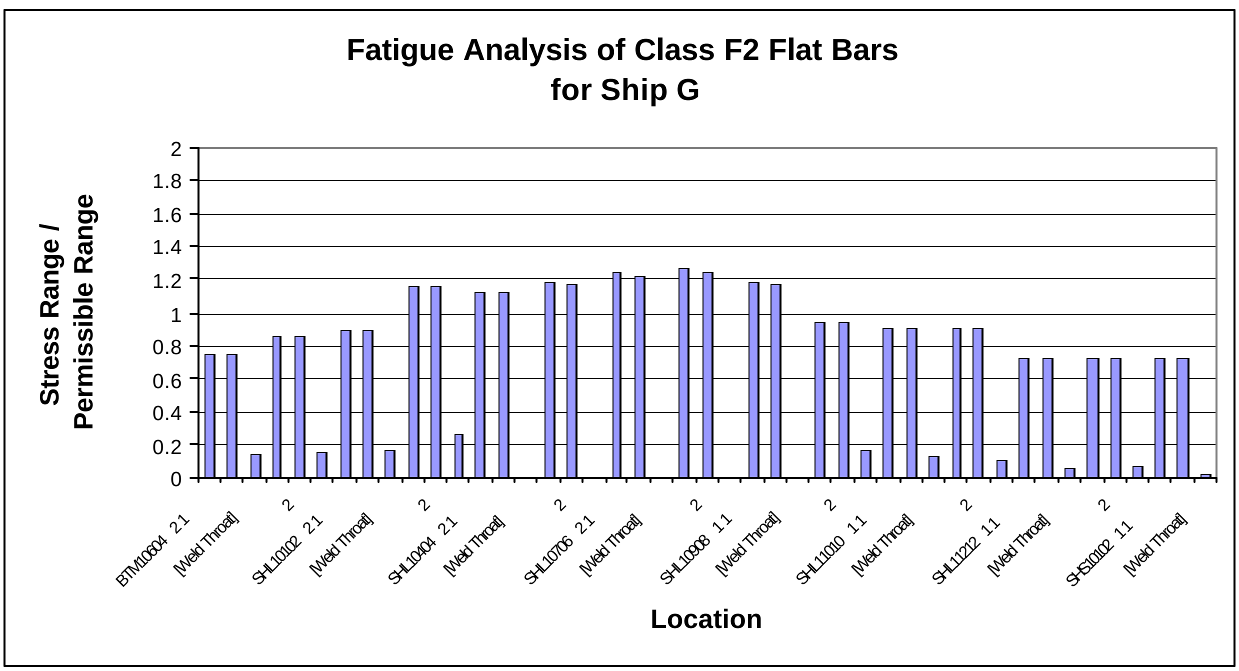
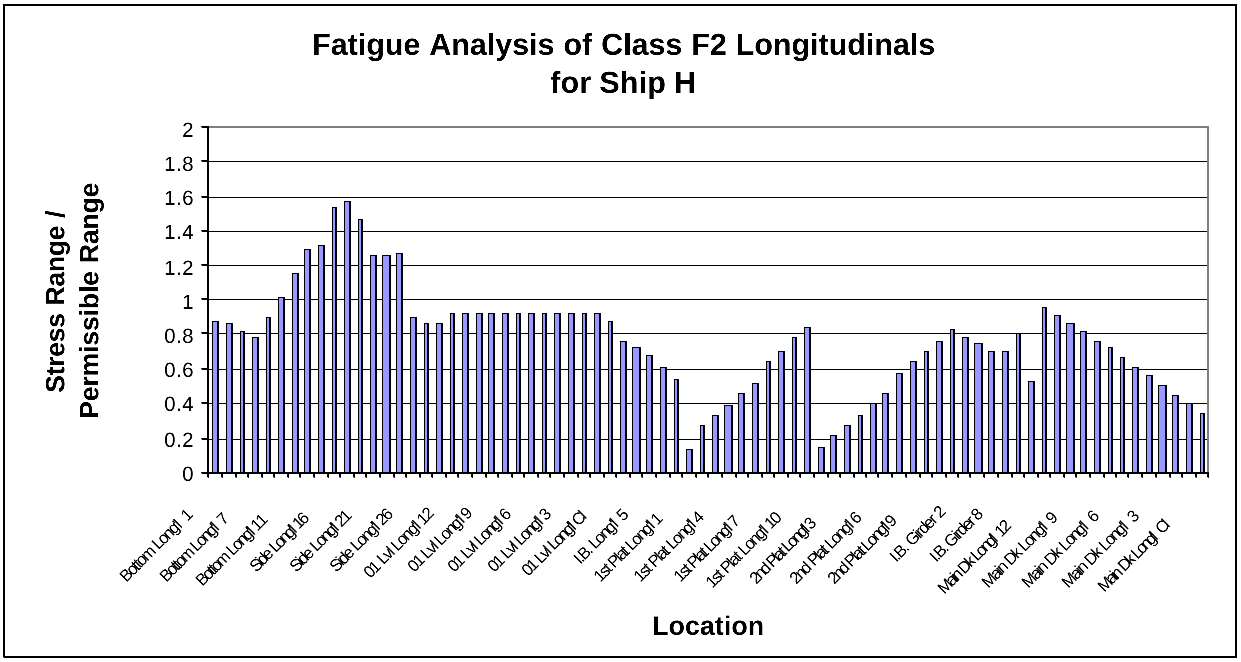


Figure 9.14 SafeHull Analysis Results for Ship H



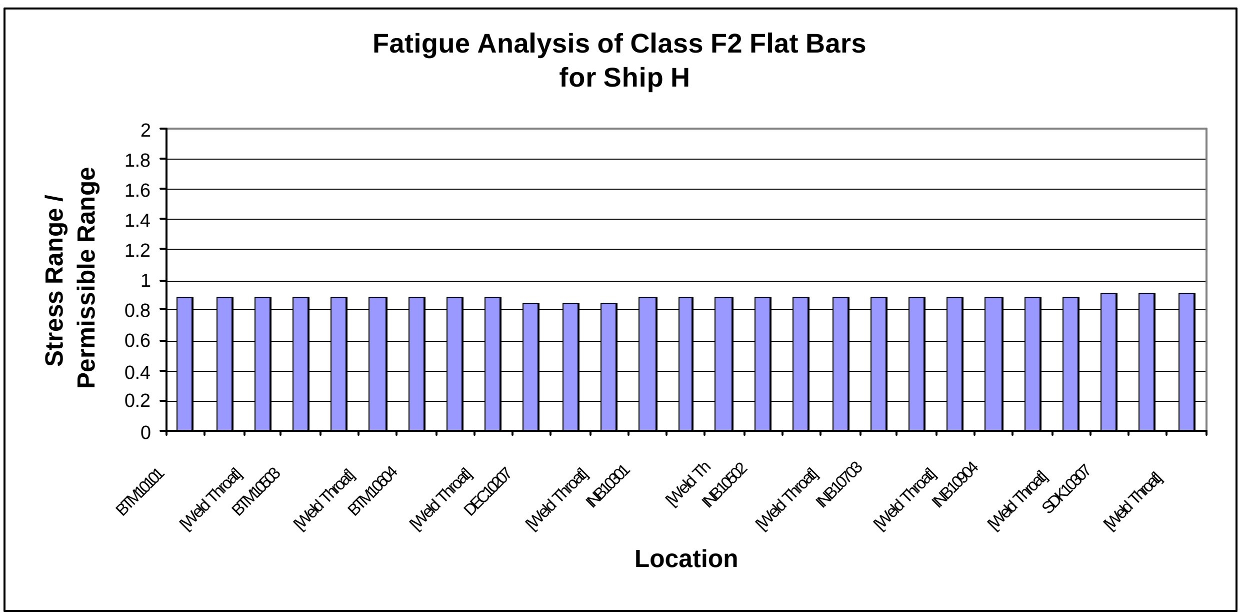
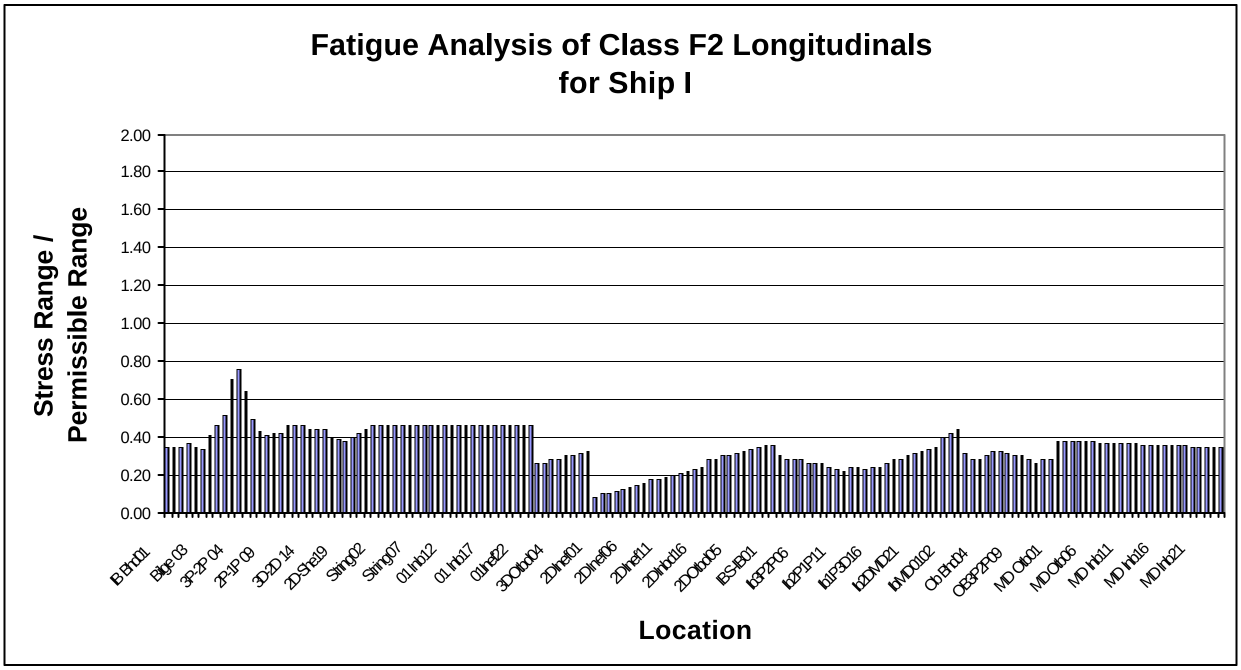


Figure 9.15 SafeHull Analysis Results for Ship I



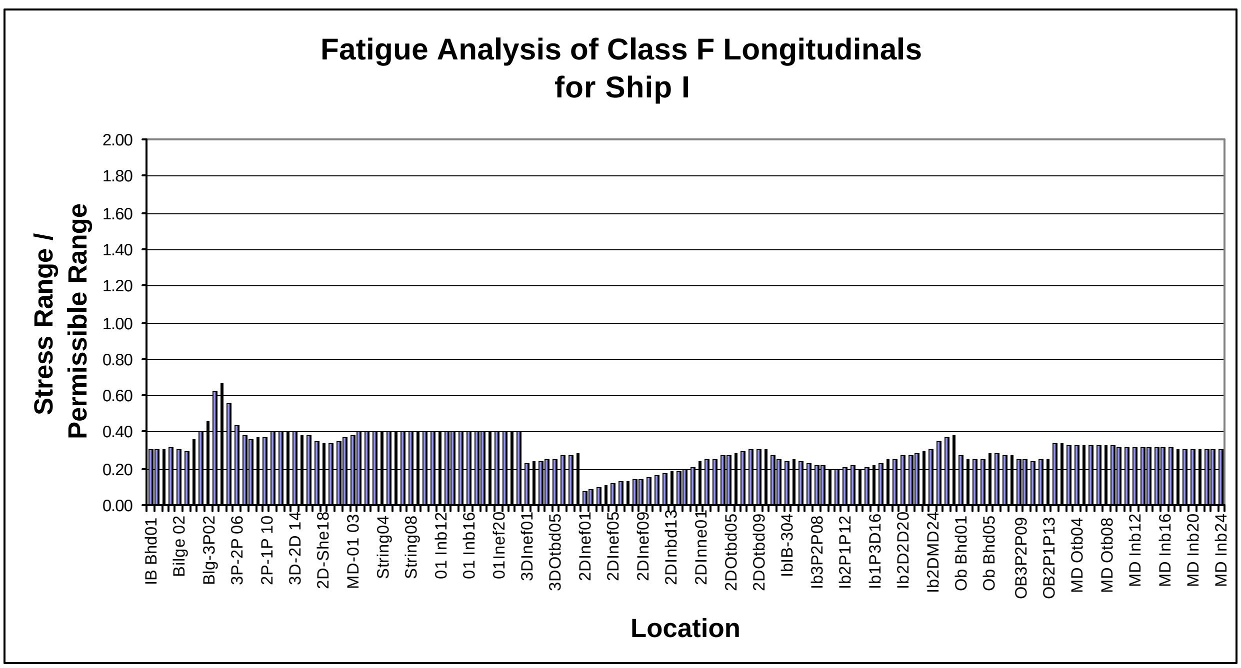
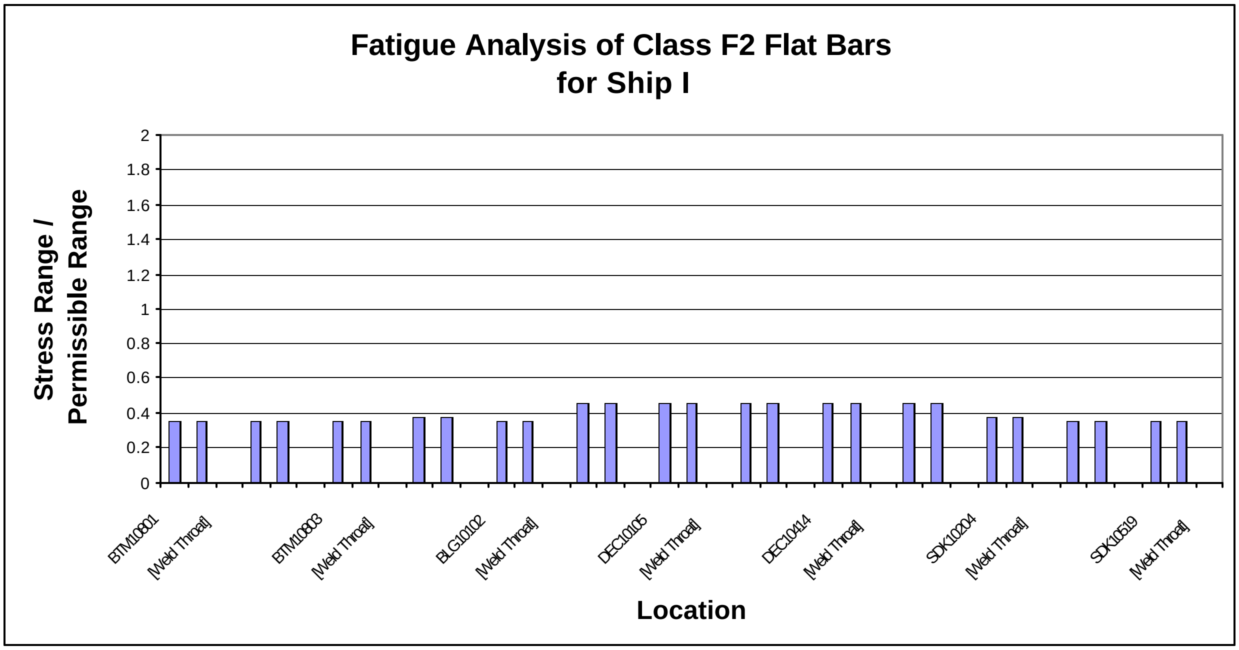


Figure 9.15 SafeHull Analysis Results for Ship I (Continued)



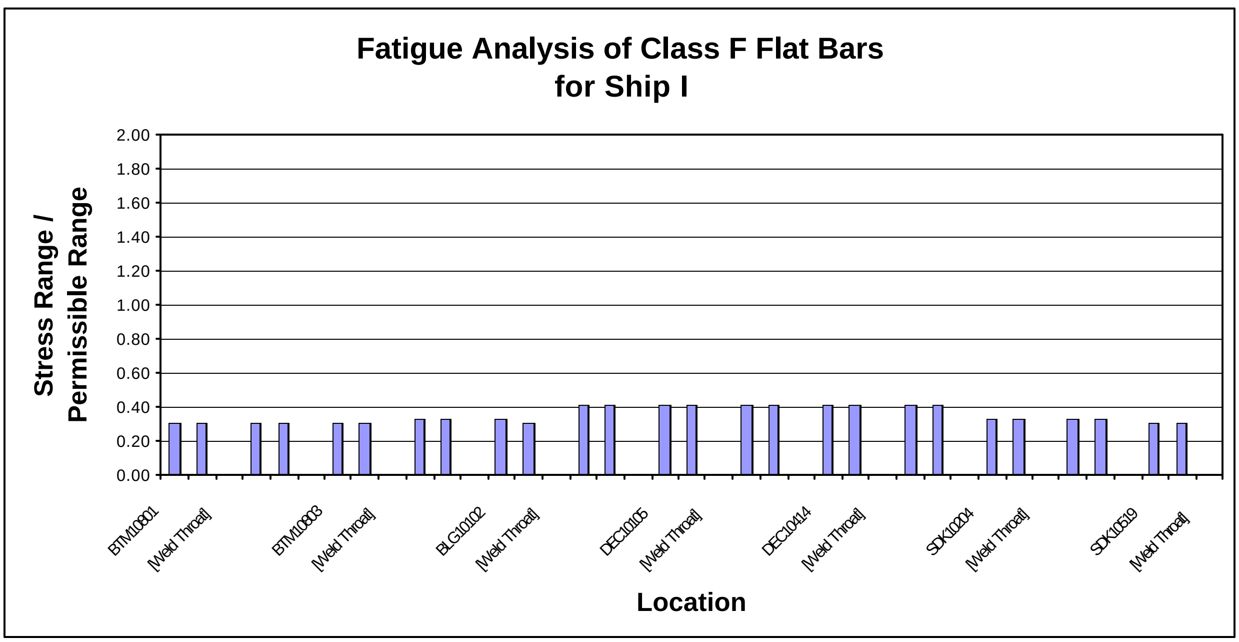
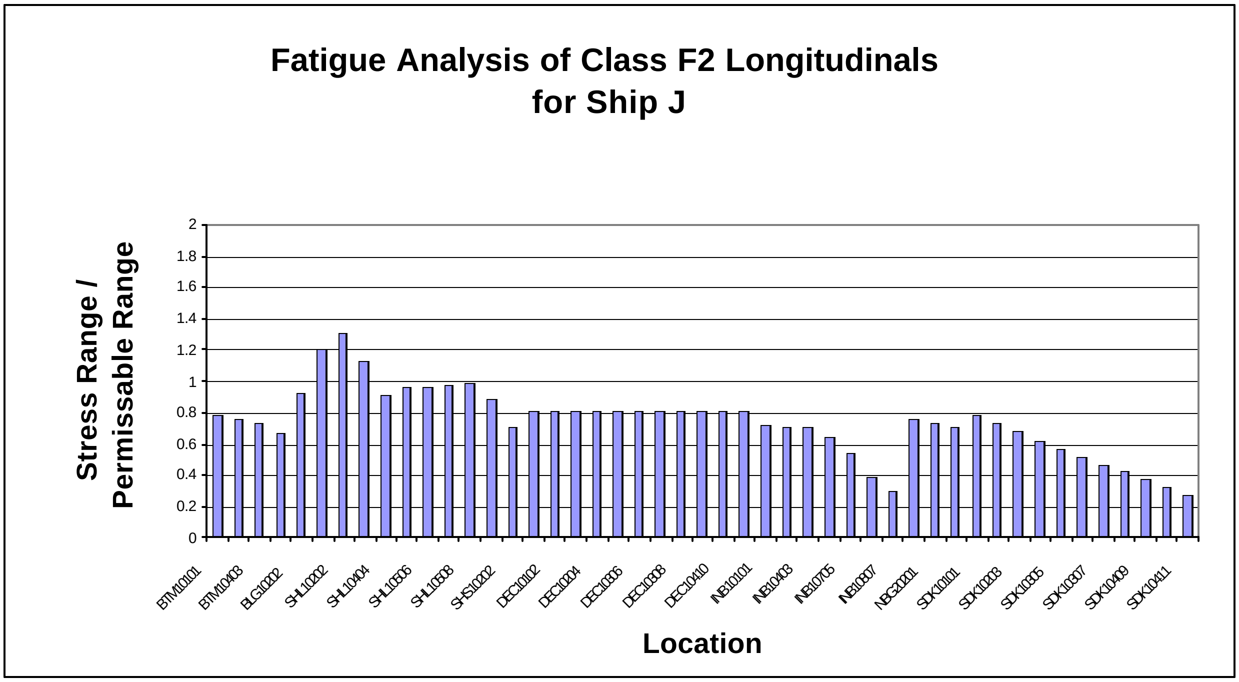
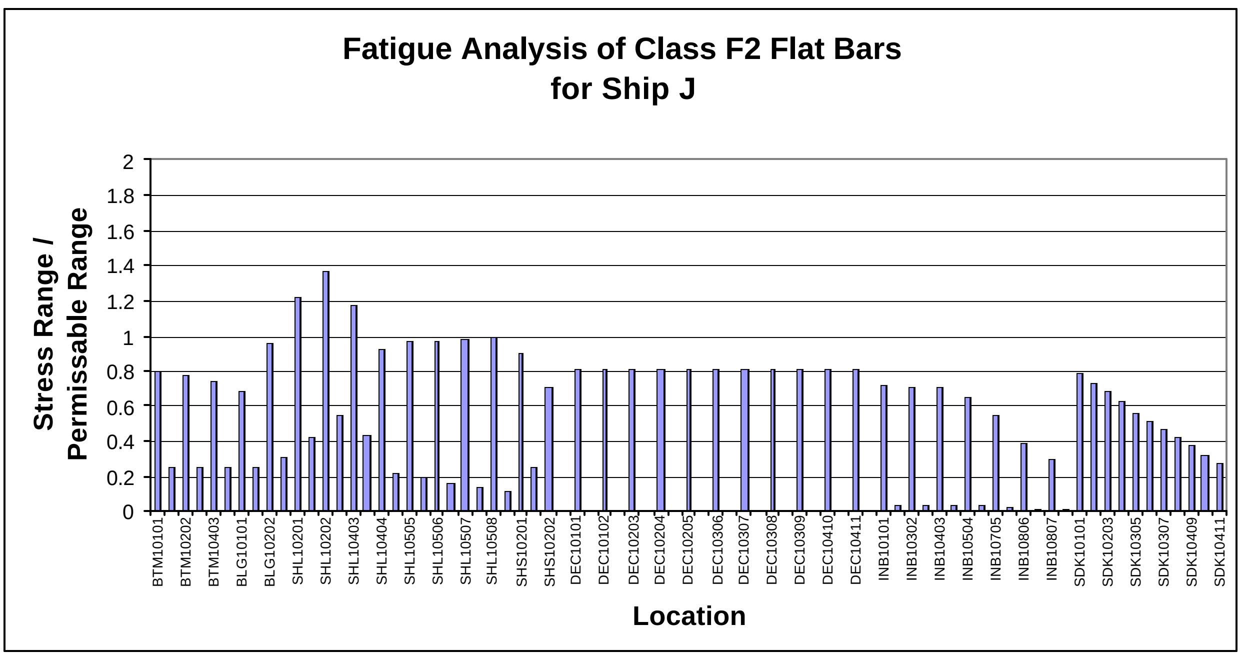


Figure 9.16 SafeHull Analysis Results for Ship J





The above results appear to be overly conservative for most of the ships analyzed in the area of the side shell near the waterline. Most of the ships analyzed have had 20 or more years of service. Those ships that have seen such service have not experienced fatigue failures in the locations indicated by the SafeHull Phase A analysis. However, there are several reasons why the SafeHull analysis is conservative.

The secondary loads are based on estimated lifetime maximum loads. It was shown in Chapter 7 that the analytic basis for predicting these loads is deficient, particularly for high-amplitude loadings. In spite of the reduction factors applied by ABS for these loads, they may still be higher than actual load magnitudes. Experimental validation of prediction techniques is needed for both maximum loads and for the routinely occurring loads that contribute to fatigue damage.

In the SafeHull analysis, the default classification for the structural details is Class F2. This classification was determined by ABS through comparison of typical details to the details tested to form the fatigue database. This classification was further confirmed through calibration by analysis of many ships.

The standards for fabrication and structural detailing of naval vessels may be higher than for typical commercial vessels. As a test of this hypothesis, some of the ships were reanalyzed considering the details to be Class F, which has a greater fatigue life than Class F2. The above results show the predictions of failure to be reduced with this assumption, although not entirely eliminated for all classes of ships analyzed.

On the other hand, many U.S. Navy ships are historically prone to corrosion in areas along the interior of the side shell in way of the exterior waterline. This corrosion may indicate coating failure due to high strains in the structure, providing some validation of the results of the SafeHull analysis. It is also possible that the ABS Phase A secondary loads are overly conservative in the region of the side shell near the waterline.

The analyses themselves may also be somewhat conservative because the effect of longitudinally continuous deckhouses on longitudinal strength was not included. The effect of the deckhouses is to reduce hull girder stress, reducing a portion of the fatigue loading. However, this will have little effect on the structure near the waterline, because this is near the hull girder neutral axis, and therefore has little primary stress from hull girder vertical bending. Lateral bending in this area may be significant, but the effect of the deckhouse on lateral strength is much less than its effect on vertical strength.

The greatest reason for lack of failures that were predicted by the SafeHull analysis is in the actual operating conditions that the ships encounter compared to the operating conditions assumed by SafeHull. As discussed in Chapter 3, the development of the ABS allowable stress ranges for fatigue assumed that containerships operate in the North Atlantic for 80 percent of the time over a 20-year period. Ship speed is assumed to be 75 percent of full speed at all times, and all headings relative to the waves encountered are assumed to be equally probable. However, U.S. Navy combatant ships are at sea for about 35 percent of the time, operate over a wide range of speeds, and tend to take preferred headings in relation to heavier seas. Because of the difference in percentage of operability, 20 years of service life for a containership is equivalent to 48 years of service life for a typical naval vessel. Furthermore, U.S. Navy combatant ships typical operate in a more benign environment than the North Atlantic. The analysis of this change in operational environment was shown in Chapter 3 to extend the fatigue life of structural details by a factor of two. The combination of percentage of time at sea and change in operating conditions make the 20 years of service life inherent in the SafeHull analysis equivalent to about 96 years of operations for a typical naval vessel.

These differences in assumptions of operations reduces the apparent conservatism in the SafeHull analysis, because none of the naval vessels analyzed saw more than 35 years of service, some are just beginning their service life, and one is still in the construction phase. In Chapter 11, means of modifying the results of the SafeHull analysis to adjust for changes in operability and service conditions will be discussed.

Because none of the ships analyzed have seen failures in service at the locations analyzed by SafeHull, full calibration of the method may not be possible. Calibration is the critical element in the SafeHull development for the three ship types. Efforts to compare a design where operations are different, with limited failure data, and no other method of fatigue analysis for the design, permit only limited ability to demonstrate the utility of SafeHull.

For most areas of the hull structure, SafeHull predicts adequate fatigue life, a result that correlates with experience of the ships in service. This correlation does not necessarily mean that the SafeHull approach is conservative. For example, if SafeHull is underpredicting hull girder bending moments, it may predict adequate fatigue life of deck longitudinals. However, it is possible the actual hull girder bending moments the ship is seeing are higher the SafeHull moments, but not high enough to cause fatigue failures.

9.4 Phase B Analysis

The Phase B analysis consists of an expansion on the Phase A analysis by using a finite element analysis of the ship to determine stresses. The requirement is for a "3-bay" model that encompasses three cargo holds in the middle of a typical containership. For a naval vessel, the corresponding section would be the space between the transverse bulkheads forward and aft of midships, and the additional spaces defined by the transverse bulkheads immediately forward and aft of these bulkheads.

For development of the finite element model, SafeHull Phase B takes the definition of longitudinally continuous structure defined in Phase A and extends it along the length of the finite element model. This development of the finite element model is done in the program Modeler, which is part of SafeHull. The location of transverse frames and other transverse sections that define the length of individual plate and stiffener elements are defined by the user. Two options exist, coarse mesh and fine mesh analysis. Coarse mesh analysis generally makes plate elements as wide as the strakes that were defined in Phase A. Fine mesh analysis breaks the model at each longitudinal stiffener as defined in Phase A.

In this analysis of Ship G, the coarse mesh option was chosen so that the length of elements would be one transverse frame spacing, and the width of elements would be approximately within a factor of two of the length. This led to a somewhat unusual finite element mesh because the Phase A strake definition was not made considering its effect on the Phase B finite element model. Where there was a change of shell plating thickness close to deck or other intersecting member, a separate strake was defined. Therefore, some of the elements have a very high aspect ratio.

The ABS Modeler program does not develop transverse frames or transverse bulkheads for containerships. There is a program that does this called Model Builder, which is available for tankers and for bulk carriers, but the containership version is still under development. Therefore, the transverse frames and scantlings of transverse bulkheads must be individually entered in the ABS Modeler program. With the coarse mesh definition of decks, the arrangement of finite element grid points at each deck is sparse, and insufficient to input all of the vertical stiffeners on the bulkheads. To provide the necessary in-plane stiffness, membrane plate elements were used in a coarse mesh at each bulkhead, with a few auxiliary points manually added to define the elements. The somewhat irregular resulting finite element mesh was considered sufficient for this analysis because the stress in the bulkhead does not enter into the fatigue analysis of stiffeners. The resulting finite element model is shown in Figures 9.17 and 9.18.

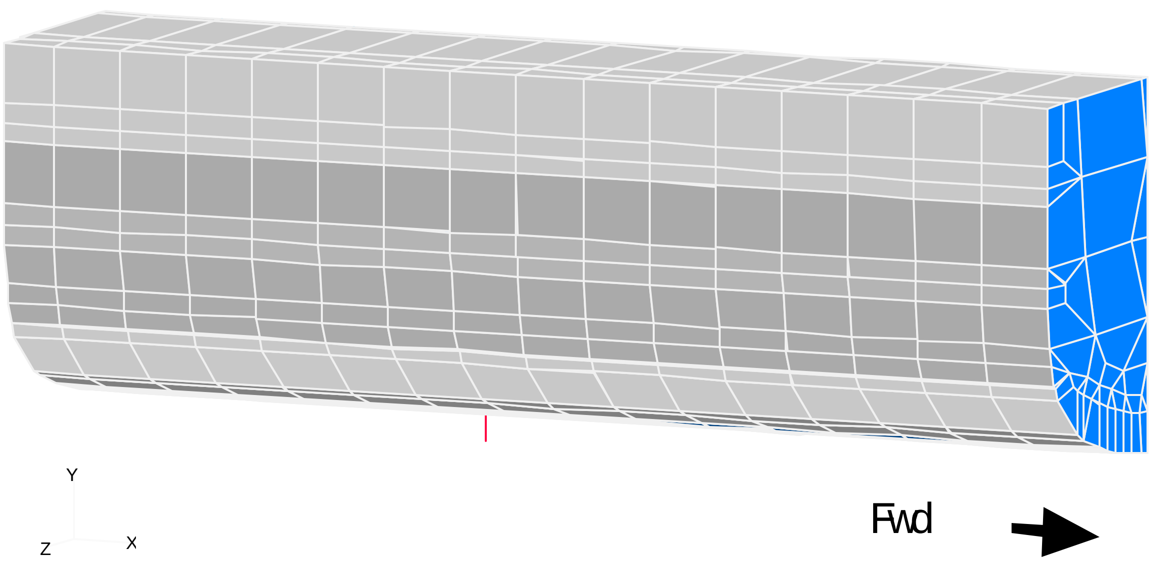


Figure 9.17 SafeHull Phase B Finite Element Model of Ship G

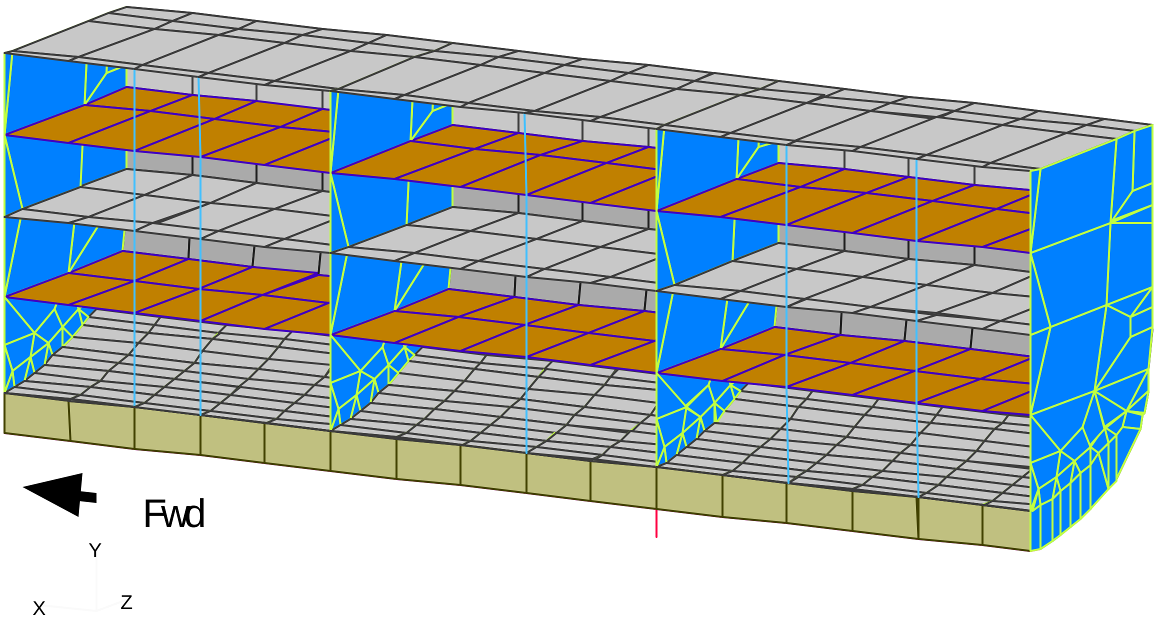


Figure 9.18 Interior of SafeHull Phase B Finite Element Model of Ship G

The containership version of the SafeHull Phase B program was not able to develop the loads for the finite element model. The difficulty arose from lack of longitudinal bulkheads or inner skin on the naval ship modeled. The containership version uses that internal structure for the application of torsional loads on the hull girder, and their absence resulted in failure of the program to develop loading. Because of the structure of the program, failure in this one area resulted the program aborting, and leaving no loads defined on the model.

After conferring with the staff of the ABS SafeHull section, it was determined that the only way that loading could be developed for the model in SafeHull would be to use the tanker version of the program. This was done, and a full NASTRAN model, including loads and boundary constraints was developed. Table 9.3 compares the loading between the tanker and containership versions of SafeHull. The comparison is made based on the data for the analysis of Ship G.

Table 9.3 Comparison of Tanker and Containership SafeHull Loadings Based on SafeHull Version 6.0 (Rules 2000)

SafeHull Phase B Loading	Tanker	Containership	Notes
Ship Motion	5-1-3/5.7.1(a) Pitch (1997)	5-5-3/5.5.1(a) (1998)	identical
	5-1-3/5.7.1(b) Roll (1995)	5-5-3/5.5.1(b) (1998)	Small difference
k_0	$0.86 + 0.048V - 0.47C_b$	$1.09 + 0.029V - 0.47C_b$	-13%
k_s	1	$k_o^{1/2}$	+24%

SafeHull Phase B Loading	Tanker	Containership	Notes
Combined Load Cases	5-1-3/Table 1 L.C. 1 to L.C. 8	5-5-3/Table 1 L.C. 1 to L.C. 8	Tanker Version 1) No Container Cargo Load 2) No Torsion Effects 3) No Sloshing Loads
Hull Girder Loads	Boundary forces are applied at both end of the 3-tank-length model to produce the specified hull girder bending moment of each load case as in Table 1 at the middle of the structural model	Same as in Tanker. However, the wave induced (dynamic) bending moment is about 24% higher than by using Tanker version.	K_C factors are the same for Tanker and Containership
External Pressure	5-1-3/5.3.1 k = 1	5-5-3/5.3.1 $k = k_s$ dynamic load is also about 24% higher than by using Tanker version	K_C and k_{f0} factors are the same for Tanker and Containership
Internal Tank Pressure	5-1-3/5.7.2	5-5-3/5.5.3 inertia load is about 13% lower than by using Tanker version	Kc, wv, wl, wt, pitch and roll factors are the same for Tanker and Containership

The NASTRAN model was run successfully, and the results evaluated using the post-processor FEMAP. A typical view of hull stresses is shown in Figures 9.19 and 9.20.

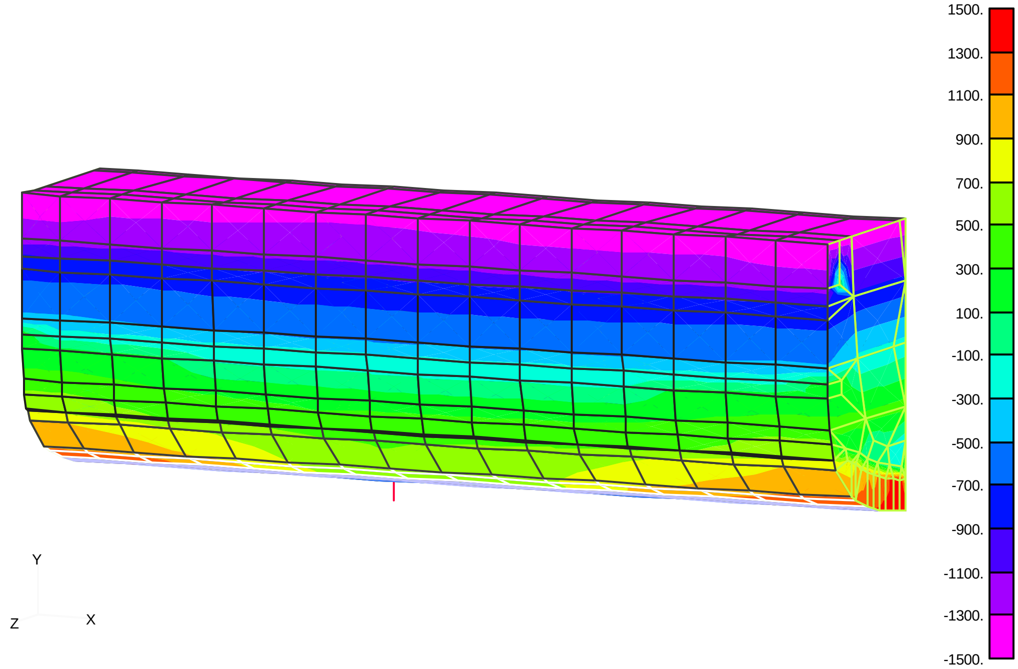


Figure 9.19 Typical Stress Plots from NASTRAN Analysis (kg/cm^2)

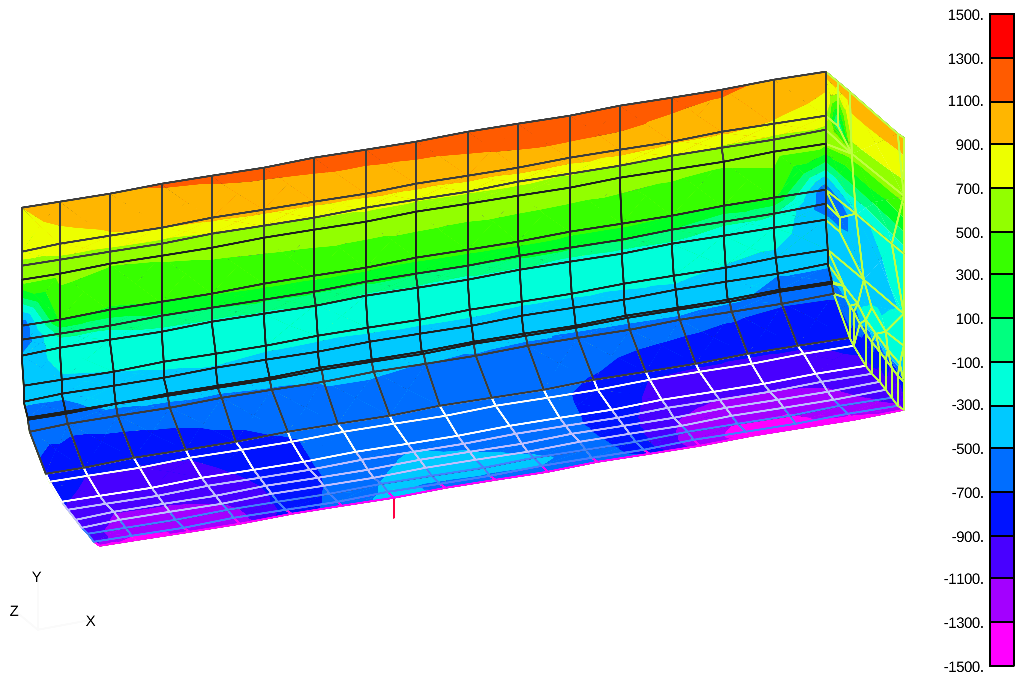


Figure 9.20 Typical Stress Plots of Bottom from NASTRAN Analysis (kg/cm^2)

SafeHull Phase B does not have a program module for conduct of fatigue analysis as in Phase A. The intention of using the finite element model for fatigue analysis is to determine stress distributions that would be different from the hull girder beam bending analysis that is used in Phase A. Additionally, any irregularities in the structure that could cause stress concentrations and possible fatigue problems can be modeled, and the resulting local stress range used to make a fatigue analysis of these areas.

For fatigue analysis, the proper dynamic stress range should be determined according to the ABS Rules (Part 5-5-A1/7.5 Resulting Stress Ranges) as follows:

1. Dynamic stress range = global dynamic stress range + local dynamic stress range
2. Global dynamic stress range is calculated by pairs of combined loading cases, such as L.C. 1 & 2, L.C. 3 & 4 for Zone A (deck and bottom structures) and L.C. 5 & 6, L.C. 7 & 8, L.C. 9 & 10, and L.C. F1 & F2 for Zone B (side structures)
3. Global dynamic stress = total stress (static + dynamic) - static stress
4. Local dynamic stress = local bending stress due to dynamic pressure only

The objective of the 3-dimensional global finite element analysis is to

1. Perform strength evaluation (yielding and bucking) and
2. Obtain boundary displacements for the subsequent 2-dimensional fine-mesh finite element analysis for main supporting members' strength evaluation (yielding and buckling). This is the current procedure of the SafeHull Phase B system.

However, the results of the global dynamic stress range should be very close in Phase A and Phase B 3-dimensional finite element analysis for the fatigue analysis of longitudinals. In the current demonstration, details of the structure were not modeled, and the results were used only to modify the Phase A fatigue analysis. Because a fine mesh model was not generated for stiffeners and their associated structural details, the local stresses computed in phase A were used with the global hull girder bending stresses computed in Phase B. The stress at each longitudinal for which fatigue analysis had been made in Phase A was determined for each of the ten load conditions applied to the model. These stresses were taken in pairs, such as Case 1 with Case 2, Case 3 with Case 4, etc. to determine global stress ranges. The resulting stress ranges were substituted for the Phase A global stresses, and the resulting analysis for typical locations shown in Tables 9.4 and 9.5. The results for all locations are provided in Appendix G. Figure 9.21 shows the ratio of maximum stress range to fatigue-permissible stress range for all locations analyzed.

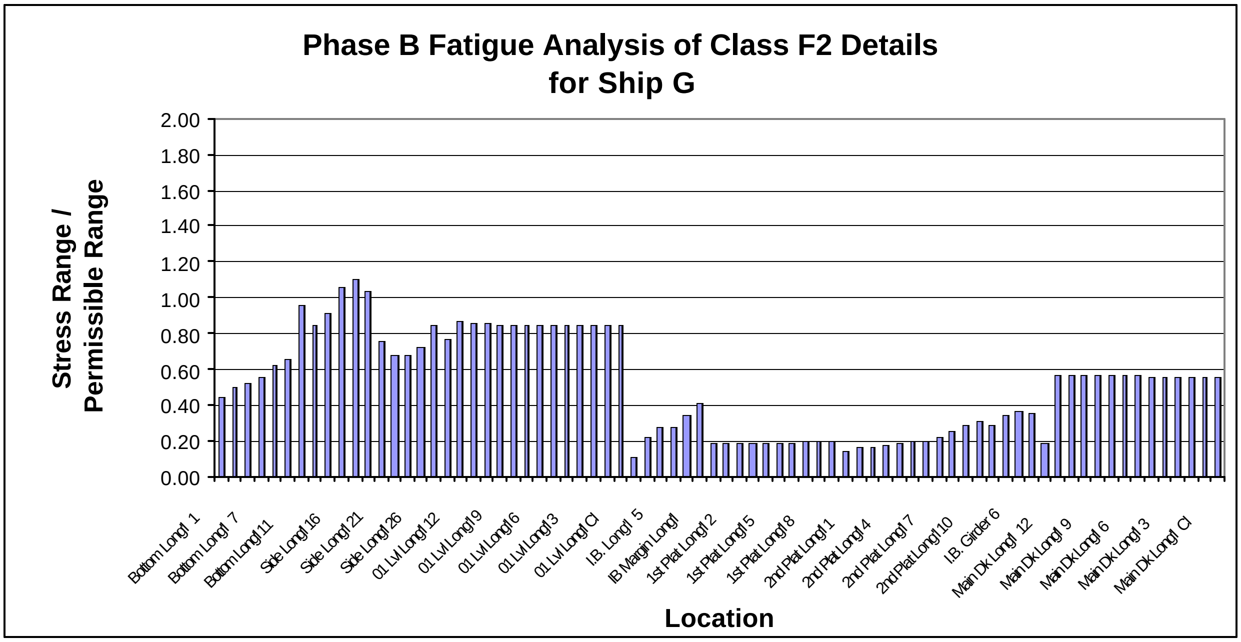
Table 9.4 Comparison of SafeHull Phase A and Phase B Analyses for Ship G

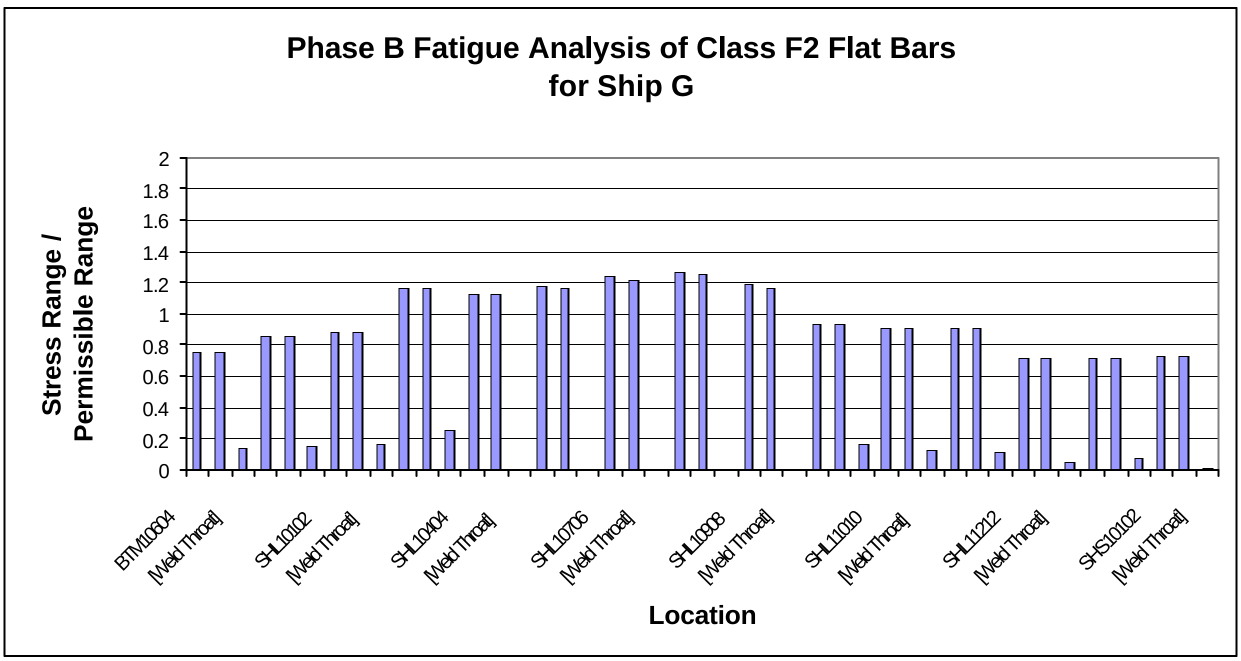
									PHASE A ANALYSIS									PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm^2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
1	Bottom Long'l 1	A/	1	0	268	2.3	1&2	0.85	5.23	2249	470	2196	F2	0.889	2611	0.84	960	1155	0.44
		F/	2	0	268	2.3	1&2	0.85	5.23	2249	470	2196	F2	0.889	2611	0.84		1155	0.44
12	Side Long'l 18	A/	1	6.61	156	2.3	F1&F2	1.00	13	1472	1473	2798	F2	0.928	2443	1.15	1185	2525	1.03
		F/	2	6.61	156	2.3	F1&F2	1.00	13	1472	1473	2798	F2	0.928	2443	1.15		2525	1.03
19	01 Lvl Long'l 12	A/	1	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2580	2451	0.87
		F/	2	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2451	0.87
32	I.B. Long'l 1	A/	1	1.4	156	2.3	1&2	1.00	0.48	1938	75	1912	F2	0.889	2611	0.73	209	270	0.10
		F/	2	1.4	156	2.3	1&2	1.00	0.48	1938	75	1912	F2	0.889	2611	0.73		270	0.10
47	1st Plat Long'l 9	A/	1	7.32	52	2.3	F1&F2	1.00	0	1499	0	1424	F2	0.889	2611	0.55	532	505	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	1499	0	1424	F2	0.889	2611	0.55		505	0.19
58	2nd Plat Lg'l 10	A/	1	4.57	141	2.3	F1&F2	1.00	0	1600	0	1520	F2	0.889	2611	0.58	863.2	820	0.31
		F/	2	4.57	141	2.3	F1&F2	1.00	0	1600	0	1520	F2	0.889	2611	0.58		820	0.31
59	I.B. Girder 2	A/	1	0.8	62	2.4	1&2	1.00	0	2067	0	1963	F2	0.889	2611	0.75	786	746	0.29
		F/	1	0.8	62	2.4	1&2	1.00	0	2067	0	1963	F2	0.889	2611	0.75		746	0.29
64	Mn Dk Long'l 12	A/	1	10.06	70	2.3	TZONE	1.00		1766	0	1678	F2	0.909	2514	0.67	1503	1429	0.57
		F/	2	10.06	70	2.3	TZONE	1.00		1766	0	1678	F2	0.909	2514	0.67		1429	0.57

Table 9.5 SafeHull Phase B Analysis of Fatigue of Flat Bars for Ship G

Cutout	FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2)	Phase A Analysis					Phase B Analysis			
				SCF	Stress Range (kg/cm2)			fR/PS	Stress Range (kg/cm2)			fR/PS
LABEL ID LOC			PS		fs	fL	fRi		fs	fL	fRi	
BTM10604 2 1	F2	0.889	2611	1.5	138	1953	1964	0.75	138	1453	1468	0.56
2	F2	0.889	2611	1.25	138	1953	1961	0.75	138	1453	1463	0.56
[Weld Throat]	W	0.889	1883	1.25	138	0	273	0.14	138	0	173	0.09
SHL10908 1 1	F2	0.928	2443	1.5	546	2798	2915	1.19	546	2525	2655	1.09
2	F2	0.928	2443	1	546	2798	2851	1.17	546	2525	2584	1.06
[Weld Throat]	W	0.928	1760	1.25	546	0	*****	NaN	546	0	*****	NaN

Figure 9.21 Phase B Fatigue Analysis of Class F2 Details for Ship G





Tables 9.4 and 9.5 include the results of the Phase A analysis for comparison with the Phase B analysis. As can be seen, the global hull girder bending stress for the Phase B analysis is less than from the Phase A analysis, resulting in fewer structural details failing the fatigue criteria. This difference is due to two reasons; reduced loads from the tanker version and from greater section modulus in the Phase B model than in the Phase A model. It was noted in Table 9.3 that the coefficient k_s is 24 percent less for a tanker than for a containership. This coefficient

is applied to the vertical wave bending moments and shears, so it directly affects the stress computed in the finite element model.

The SafeHull program presents the hull girder section modulus in the file ShipName.OSC in Phase A, and in the file ShipName.LST in Phase B. Table 9.6 compares the section moduli for both cases. The Phase B model had significantly greater section moduli. This may a result of the model Phase B finite element model not being modified to include deck openings.

Table 9.6 Comparison of Phase A and Phase B Section Moduli for Ship G

	Phase A	Phase B	Difference
Section Modulus to Deck (cm^2-m)	53,890	63,480	+18%
Section Modulus to Keel (cm^2-m)	54,100	66,100	+22%

The effects of the difference in loads between the tanker and containership versions of SafeHull have a marked difference in the results. Table 9.3 shows that the coefficient k_s is 24 percent greater for the containership than for the tanker. This coefficient is applied to the vertical hull girder bending moments and shears, which are therefore 24 percent greater for the same ship if it is considered to be a containership, rather than a tanker. The effect of the difference in global and local stresses is shown in Table 9.7. Therefore, had there been a successful Phase B analysis of Ship G as a containership, the results would have been more severe than those shown in Tables 9.4 and 9.5, Figure 9.21, and Appendix G.

Table 9.7 Difference between Tanker and Containership Fatigue Analysis of Typical Stiffener of Ship G

Stiffener #11	$C_f = 0.95$		$f_R = C_f \times (f_{RG} + f_{RL})$		
	$\mathbf{f_{RG}}$	$\mathbf{f_{RL}}$	$\mathbf{f_R}$	**PS**	$\mathbf{f_R/PS}$
Containership	1517.0	1655.0	3013.4	2443	1.23
Tanker	1152.9	1257.8	2410.7	2443	0.99

There are still predicted fatigue failures for the Class F2 details analyzed. Although this class of ships has had numerous fatigue failures in service, those failures have not been at the locations analyzed. To determine the likelihood of failures in locations other than those analyzed, a detailed finite element analysis is required. Such is the intent of a Phase B analysis, and SafeHull Phase B provides the loads for such a detailed analysis as well as acceptance criteria that are consistent with the loads and analysis procedure. However, because such loads apparently cannot be applied to a ship with the geometry of the ship analyzed, such a procedure does not appear to be feasible for analysis of naval vessels. Furthermore, because the SafeHull program does not currently include the means of automatically retrieving key stresses for the fatigue analysis, a significant amount of manual review of finite element analysis results is required. Therefore, the use of SafeHull for a Phase B fatigue analysis of a naval vessel is of questionable value. However, if a full understanding of the loads applied in SafeHull is made available, these can be applied to a finite element model produced by other means, and the resulting stresses compared with the ABS allowable fatigue stress ranges to determine if the structure is adequate for fatigue. This failure to provide full information on all of the applied loads is a shortcoming of the program, which will be addressed in Section 10.

9.5 Summary

The SafeHull Phase A program in the containership version can be rather easily applied to the fatigue analysis of longitudinal stiffeners of typical naval vessels. However, ships less than 130 meters long require a special version of the program that is not distributed by ABS. The analysis of ten different ships showed that the only areas subject to fatigue failure are stiffeners on the side shell. However, none of the ships analyzed have reported any fatigue cracking in this area, although some have been susceptible to corrosion damage.

Naval vessels typically operate for a smaller percentage of time and in a less severe environment than was assumed by ABS for development of allowable fatigue stress ranges for containerships. The difference between the assumed and actual operating conditions can help explain why the SafeHull fatigue analysis appears to be overly conservative when comparing predicted failures to experience. Most of the ships analyzed have had 20 or more years of service without the occurrence of fatigue failures at the locations indicated by the SafeHull analysis. During that time, they typically operated for about 35 percent of the time, and mostly in benign sea states. Therefore, it can not be said that the SafeHull analysis is overly conservative, as these ships have seen less fatigue loading than is assumed to occur over the 20-year life of a typical containership.

The significant difference between predicted and actual failures can also be due to differences in commercial and naval fabrication standards. Furthermore, the structural details of the naval vessels differ in some aspects from the details included in the SafeHull library of details. Adjustment of the fatigue class from Class F2 to Class F in the analysis significantly reduced the number of predicted fatigue failures. A detailed analysis of fatigue life of typical details for naval vessels is required before firm conclusions can be made.

The Phase A analysis is limited to analysis of sections of the ship that are longitudinally continuous. This study looked only at midships, but similar analyses could be made at different sections of the ships analyzed. However, the Phase A program does not analyze larger discontinuities, such as breaks in superstructures, irregularly spaced large deck openings, and other irregularities in the structure of naval vessels that have been the cause of fatigue failures of the ships in service. Analysis of these discontinuities requires a detailed finite element analysis, such as is conducted in Phase B.

The Phase B analysis procedure provides allowable stress ranges that are consistent with a standardized set of loads that is applied to a finite element model of the ship. This constitutes a calibrated methodology for detailed fatigue assessment of containerships and other ship types for which the SafeHull was intended. If that method could be applied to a detailed finite element model of a naval vessel, insight could be gained on the validity of that methodology for the analysis of such ships. Unfortunately, the current version of the SafeHull containership program will not apply Phase B loads to a ship that does not have an inner skin, a necessary feature that precludes most naval vessels. Therefore, the current Phase B containership version of the SafeHull program is not useful for the fatigue analysis of naval vessels. The tanker version can be used, but the difference in loading for full-form, slow-speed tankers compared to fine-hulled, high-speed naval vessels reduces the viability of that approach.

10. Shortcomings/Limitations of the SafeHull Approach for Fatigue Analysis of Naval Vessels

10.1 Purpose

The purpose of this chapter is to present the shortcomings and limitations of ABS fatigue design practices and approaches when applied to naval vessels. The basis for this assessment is the analysis of the hull structure of 10 current and past U.S. and Canadian naval vessels, which was described in Chapter 9.

10.2 Introduction

There are a variety of commercial methods available for conduct of fatigue analysis of ship structures. In this project, only one of these programs, the SafeHull program developed by ABS, was used to determine the fatigue life of typical naval vessels. There are many factors to be considered in the development of a standardized methodology for fatigue analysis. The SafeHull program represents a methodology that is sufficiently different from current practice in naval ships to be a useful demonstration. Furthermore, because of its commercial availability with an existing staff to address users' problems, the program is a good candidate for expanded use if the shortcomings and limitations uncovered can be resolved.

At the beginning of this project, SafeHull was available in three programs (identified as "Navigators"): one for Tankers, one for Bulk Carriers and one for Container Ships. The latter version was selected for use on this Task. The Containership version of SafeHull was used for several reasons.

1. Most modern containerships are high speed vessels with relatively fine hull forms. Operating speeds are generally in the 20–25 knot speed range, compared to about 30 knots for a typical combatant ship. These similarities in hull form will result in similar responses of the ships to the seas encountered. The SafeHull loading spectrum was calibrated for containerships, but should be roughly equivalent for combatant ships operating in the same sea conditions.
2. Containerships generally have bulbous bows for increased speed. The shape of these bulbs is different from the bow sonar domes that many modern combatant ships have, but would be expected to have a similar effect on bow slamming.
3. Many containerships have large bow flare to help keep boarding seas from damaging deck cargo and to increase the beam forward for greater cargo volume. Similarly, many combatant ships have large bow flare to reduce the effect of boarding seas. The containership version of SafeHull has an algorithm for computing the effect of bow flare on slamming and hull girder whipping, and that is important for fatigue analysis.
4. All three ship types, tankers, bulk carriers, and containerships are longitudinally framed, and the SafeHull procedures reflect this structural arrangement. There are some significant differences however. The tanker version of SafeHull only addresses

double hulls, and although combatant ships generally have double bottoms, as do containerships, they do not generally have double hull structure on the side, as do tankers. Bulk carriers have upper and lower wing tanks with sloping sides, and this geometry would be difficult to adapt to the structural configuration of a combatant ship. With the varieties in structural arrangement of a containership capable of being input to SafeHull, a reasonable representation of a combatant ship could be made. It was recognized that the configuration of combatants is significantly different than that of any of the three types of commercial ships that the SafeHull programs address. Nevertheless, evaluation of this type of issue is the reason for this project.

Most of the shortcomings and limitations uncovered relate to the loading of the structure and on the types of structural details that can be analyzed. The version of the containership program that is distributed by ABS for commercial use is limited to ships that have a length of 130 meters or more. However, a special version of the program for shorter ships of was made available by ABS.

There are basic differences in methods of fatigue analysis and factors that must be considered in the development of standardized methods for fatigue analysis, either commercial or military. These differences have been discussed in the previous chapters, and are outlined below.

I. Technical differences in fatigue analysis
   - A. Approach,
     1. S-N fatigue crack initiation analysis
     2. da/dN fatigue crack growth analysis
   - B. Loading Analysis
     1. Spectral Fatigue Analysis
     2. Weibull Distribution
     3. Standardized Loads
        - a. Hull Girder Bending moments
        - b. Side Loads
        - c. Generalized RAO's
   - C. Fatigue Detail Database
     1. Specialized database
     2. Standardized curves
   - D. Hot-Spot stress approach
   - E. Inclusion of Hull Girder Whipping
   - F. Acceptable Probability of Failure
   - G. Standardized Operating Conditions

II. Commercial vs. Military
   - A. Calibration of Weibull Loading Spectra for Ship Types and Operating Conditions
   - B. Development of Standard Bending Moments for ship Types
   - C. Development of RAO's and Whipping Moments for Ship Types
   - D. Differences in Assumed Operating Conditions

III. Standardization of Method

A. Selection of Methodology

B. Adaptation to Specific Conditions

There are considerable differences between the historical approaches to the structural design of military and commercial ships for environmental loads. These differences have diminished in recent years as the commercial procedures have evolved to include structural design based on analytically developed loads and detailed stress analysis. Both the ABS DLA approach and the current U.S. Navy approach use definition of loads made by analysis of typical ships, and generalize the results for future designs. The approaches, in general, provide for direct computation of ship response and for differences in assumed operational profiles. The differences between procedures may diminish in the future as the classification societies develop rules for military ships and the military authorities adopt these rules. The degree of difference will not be able to be ascertained until ships are designed using the new rules, and the scantlings so developed are compared to equivalent ships designed under the old approach. An important difference as far as fatigue life of structure will be which approach will result in heavier scantlings, and thus have an inherently greater fatigue life. In either case, because fatigue assessment has now become standard practice for both commercial and military ship design, either approach should result in satisfactory fatigue lives.

There is nothing inherent in either a commercial or military ship that should affect the overall methodology. However, the current commercial and military fatigue philosophy is different. The ABS approach is to prevent fatigue cracking in general to and assess details in highly stressed areas important to safety. The U.S. Navy approach is to prevent fatigue cracking (safe life). These differences in approach come from historical development and preferences in the organizations developing the methods. There are unique features associated with specific ship types and operating environments that can affect a standardized method. The objective of this study is to determine if a standardized method developed from a set of assumptions on hull form, operating environment, and type of structural details can be used in conditions in which those assumptions have changed.

If a methodology developed for commercial ships is applied to military ships, a determination is needed to as to how much difference will there be in results. A broader question can be asked as to the degree of accuracy of any methodology. The paucity of real data points of well-documented service experience combined with the inherent variability in analyses makes calibration poor. Application of fatigue analysis to design and assessment of existing ships seems to be pointing in the right direction for identification of bad actors in the structure that should be fixed, but there is still a lot of inconsistency in results between areas that have cracked and the fatigue predictions. However, comparison of analysis with service failures on operating ships is somewhat shaky, with both unpredicted failures and predictions that are not borne out by experience.

The question then is what would be the changes required to the commercial approach to develop an approach acceptable for analysis of military ships. Guidance will be provided in Chapter 11 to modify the ABS simplified method of analysis to account for time at sea. Note that the assumptions currently made by ABS on operability, such as tanker operation for 90 percent of the year, are not directly supported by accurate records of actual hours underway, but the assumptions are based on experience with ship operations.

A method will also be provided in Chapter 11 to account for differences in the S-N database and assumptions of linearity vice bilinear S-N curves. This method will permit use of specific S-N data for a unique detail, although if such information is not available, the method should use the S-N curves used to do the benchmarking of the standardized method, and not other S-N curves, no matter how widely recognized they may be.

Because of the inherent nature of assumptions of operating areas and operating conditions in the development of fatigue spectra, a method has not been developed to account for differences in these areas. This limitation is not as important as others are because both the U.S. Navy and ABS are currently using North Atlantic operations as the standard for design, even though actual service conditions will vary.

If the ABS SafeHull approach for fatigue analysis is to be made useable for analysis of a broader range of ship types, then more options in the parameters must be made available optional so the user can select the option they prefer. The use of SafeHull as a tool for fatigue analysis of naval vessels is limited because each of the SafeHull program modules has been customized for a specific ship type. Naval ships are not one of these specific types. A broader approach to design and analysis of ship structure is provided by the ABS Dynamic Loading Approach (DLA) and the ABS procedure for Spectral Fatigue analysis. The DLA approach for containerships is documented in the ABS Analysis Procedure Manual for the Dynamic Loading Approach for Container Carriers (ABS, 1993). A more general description of the DLA procedure is provided in the ABS report Dynamic Loading Approach for Monohull Vessels (ABS 1999). Documentation for the Spectral Fatigue analysis is under development.

Application of a standardized computer program that was developed for a particular type of vessel to an entirely different type for which use was not contemplated is bound to be fraught with difficulties. It should not be surprising then that there were many problems encountered in trying to adapt the Phase A and Phase B modules of SafeHull to the fatigue analysis of naval ships. The following shortcomings described for SafeHull are illustrative of the types of difficulties that can be encountered.

10.3 Phase A Shortcomings

The SafeHull program is under continuous development, including the correction of program errors and clarification of the required data entry by users. Because the program was not being used in its intended way for this project, many difficulties were encountered which would not have occurred in the analysis of a containership. Other problems were encountered because the analysts had neither used the program previously nor attended the training classes offered by ABS. Information on all of these problems was provided to the ABS SafeHull staff, which will try to make the input requirements more general to minimize such problems in the future.

There are several areas of analysis that have an effect on fatigue of the ship structure of a typical naval ship that are not addressed in SafeHull Phase A. Fatigue at deck openings, especially large openings in way of machinery spaces and weapons systems can be a problem in naval ships. The SafeHull analysis routines for fatigue of hatch corners are not generalized enough to be able to treat these areas. Discontinuities in the structure, such as the ends of deckhouses and superstructure are common areas of fatigue cracking in naval ships. There is no Phase A option for the treatment of these areas, even in a generic fashion. Stress from the grillage behavior of the innerbottom structure is not as important an issue for naval ships as for ships with large unsupported innerbottoms such as containerships. However, the analysis of the innerbottom grillage that is performed in Phase A is not used for the fatigue analysis of those members, and that can be a significant shortcoming. Likewise, transverse members can experience fatigue damage, but the Phase A fatigue analysis does not address this aspect of these members.

In addition to the dimensional information such as length, depth, breadth, etc., the required data includes the Block Coefficient (C_b) of the ship. A note highlights the fact that the C_b must be 0.60 or greater. The value for Ship J is 0.48. Although the documentation does not so state, a default value of 0.60 is used for any values of C_b that are less than 0.60.

The material zone data entry screen's list boxes include only the ABS grades of commercial steels, with no ability to add to the library of material types. For the analysis of naval ships, the nearest commercial equivalents to the naval steels used Ship J were selected. This shortcoming in the input data has no effect on fatigue analysis because it is assumed that the fatigue behavior of welded structural details is independent of the alloy used. The input for SafeHull is entirely in the metric system. Standard U.S. structural shapes are not included in the SafeHull stiffener library, even in their metric equivalents. Input to the program must be done manually, with no direct way of addressing such data items as tables of offsets. The format used by the SafeHull program does not lend itself to editors such as Word or Excel to perform this function nor provide generalized offset tables to be electronically captured and directly used by the program. Manual entry of the individual Y and Z offsets of various waterplanes for each section is required. These shortcomings can be overcome, but they make the use of the program more difficult.

By contrast with these shortcomings associated with use of SafeHull for fatigue analysis of naval ships, the ability to develop SafeHull input for commercial ships continues to improve. A direct interface has recently been developed between SafeHull and two systems used in ship design to develop a 3D-product model of a ship, the Tribon system and the FORAN system (ABS, 2000b). Translator programs generate interface files that are imported into SafeHull for analysis, the results of which are then supplied back into the Tribon or FORAN system to compare ABS Rule requirements directly with the design.

10.4 Phase A Limitations

There are limitations in assessment of fatigue in Phase A. Phase A only addresses stiffener end connections and hatch corner detail for large deck openings that approach those seen on container ships

- Fatigue Analysis is performed only for longitudinals at their intersection with transverse frames and for flat bar stiffeners at those transverse frames.
- A limited number of cutout details are available for the transverse frames.

- Other types of stiffeners, such as tee stiffeners are not available for the transverse frames.
- A fatigue analysis of the transverse frame at its intersection with the longitudinal is not made if there is no flat bar at all.
- The fatigue analysis of hatch corners for containerships is based on the stresses that occur at the corners of large hatch openings and are caused by hull torsion. However, for naval vessels, torsional stresses are not an issue. However, there are numerous deck openings that are prone to fatigue failure from hull girder bending stresses. The program does not address these openings.
- A longitudinal stiffener can not be made ineffective in longitudinal strength unless the associated plating is also made ineffective.
- The loading on decks is limited for several reasons. Adjacent tanks may not be cargo tanks, and so void tanks must be used, which generate no loads. The methodology of generating loads on cargo decks is not clear, but should be modified so that live deck loads or dead loads can be defined by the user. Further limitations exist because only 10 tanks can be defined within one structural cross-section. This is a limitation for more complex naval vessels that have many compartments.
- The number of stiffeners to be used is limited. Within one cross-section of the hull, the limit is 150, and on any plate panel there can be a maximum of 15.

In addition, there are underlying differences in the methodology used in SafeHull compared to the methodology currently used in fatigue analysis of naval vessels. For example, Chapter 6 identifies that U.S. Navy predictions of the maximum lifetime bending moments are 1 ½ to 2 times the ABS moments. This difference in maximum lifetime moments may not affect the moments in the regime of $10^5 – 10^7$ cycles where the maximum fatigue damage occurs, but it is difficult to determine this from the information available on loads.

10.5 Phase B Shortcomings and Limitations

The major shortcoming to the user of the SafeHull Phase B Containership program is the difficulty of creating a finite element model from the Phase A data. For tankers and bulk carriers, program modules called Model Builder for Tanker and Model Builder for Bulk Carrier have been developed. A similar Model Builder for Container Carriers is currently being developed by ABS. Therefore, the difficulties that were encountered in creating a Phase B model will not be discussed, as the procedure will be changed in future versions of the program.

The major limitation in the application of the SafeHull Phase B program to naval vessels is the requirement that ships analyzed have inner skins. This limitation precludes the analysis of most naval vessels. With this limitation, the containership version of the program could not be exercised for the fatigue analysis of a naval vessel.

There are currently no features built into the Phase B software for the conduct of fatigue analysis. The program does assess maximum stress and buckling strength through special routines that extract relevant information from the output of the finite element analysis and apply the resulting loads to the structure. Without such features for fatigue analysis, most of the work of Phase B fatigue analysis is a manual effort by the user, not an automated process of the program.

The reason for this limitation is that the intention in Phase B is to apply the fatigue criteria inherent in the ABS approach to specific structural details. These details must be developed as separate fine-mesh finite element models, either 2-D or 3-D. The range of stress to apply is determined by taking the appropriate pair of conditions such as roll to port and roll to starboard. Automating such a process would not seem to be feasible, because the assumption is that the details to be analyzed are different from standardized details previously used. It would seem extremely difficult for a computer programmer to develop such a method that would be capable of addressing all possible and sometimes innovative variations in structural detailing.

10.6 Summary

There are many significant differences between the various approaches, both commercial and naval, for fatigue assessment of ship structures. These differences were summarized in Chapter 2. This chapter has reviewed these differences from the perspective of modifying one of the commercial approaches, the ABS SafeHull program, so that it can be used for design and analysis of naval ships.

The ABS SafeHull program can provide a calibrated basis for assessment of fatigue strength of naval vessels. However, the limitations in the program preclude its use for the analysis of all areas of the structure. A more general commercial approach to fatigue analysis of naval vessels is available through the ABS Dynamic Loading Approach and the associated Spectral Fatigue approach. This approach should be evaluated for application to typical naval vessels as SafeHull has been evaluated in this current project.

A principal limitation associated with any standardized and calibrated approach is that only the methodology associated with the calibration process should be considered as valid for future use. If there are significant differences between the structure and operating environment of the ship to be analyzed and the assumptions made in developing the standardized method, then that method loses validity. However, the differences between military ships and commercial ships may be so significantly different that a recalibration of the methodology may be necessary. To facilitate this, the ABS SafeHull program would have to be modified to provide more options to the user. If this were done, the ABS methodology could be used with current U.S. Navy such as the Ochi 6 parameter sea spectra, linear S-N curves, U.S. Navy operational profiles, operability, service life, and wave height probabilities. It may even be possible to include the inclusion of the U.S. Navy SPECTRA program into the SafeHull program.

11. Suggested Modifications to the SafeHull Approach for Fatigue Analysis of Naval Vessels

11.1 Purpose

The purpose of this chapter is to present the modification that should be made to the ABS fatigue design practices and approaches when applied to naval vessels. The basis for this assessment is the analysis of the hull structure of 10 current and past U.S. and Canadian naval vessels, which was described in Chapter 9.

11.2 Introduction

There are three different categories of modifications to be made: modifications of input by the user, modifications to the SafeHull output by the user, and suggested changes in the SafeHull software that would make such analyses more applicable to naval vessels. Chapter 2 discussed many of the considerations made in the development of SafeHull, which did not include creating a program sufficiently general to address any type of vessel. The following represents a minimal list of modifications to be made using the current software. Because the final analysis must be more fully calibrated that has been done in this effort, it may be more efficient in the long run to make basic changes to the software so that naval ships can be analyzed without modification of input, and then perform the calibration exercise.

11.3 Modifications of SafeHull Input by the User

The SafeHull suite of programs was developed for the analysis of three very specific types of ships. This project used the containership version of SafeHull, which was not developed for naval ships. The analysis of naval ships with SafeHull was not intended in its development. To be able to make the analysis at all, the user had to provide input that did not always correspond to the intended format. These changes are described in the draft "Guide for the use of Commercial Design Standards for Fatigue Analysis in Naval Ship Design" that is provided with the final report of this project.

11.4 Modifications of SafeHull Output by the User

The fatigue analysis results from SafeHull must, in general, be modified when applied to naval vessels for several reasons:

- The number of days of operation over the lifetime of a typical naval vessel is different than the 5,840 days that result from operating 80 percent of the time for 20 years that was assumed in the development of SafeHull.
- The typical operating environment for a naval vessel is less severe than the North Atlantic operations assumed in the SafeHull development. Designers may not wish

to make this modification for new ship design, but it should be considered when evaluating existing ships.

- Structural details are generally different than in the standard catalogue of details contained in SafeHull. In particular, naval vessels typically have the cutouts in transverse webs welded to the upper flange of longitudinals, and tee stiffeners rather than the typical flat bar details which are used in commercial vessels to help carry the shear load from the longitudinal to the transverse web and to stiffen the web.
- Differences in fabrication standards may make similar structural details more fatigue-resistant for naval vessels as compared to standard commercial practices.

11.4.1 Modification for Operability

Fatigue damage is assumed to be linear. Therefore, a simple modification can be made for years of service and percent of operability. SafeHull development assumed that containerships would operate for 80 percent of the time for 20 years, or 5,840 days. If a particular naval vessel is to operate for 35 percent of the time for 40 years, or 5,110 days, a satisfactory fatigue life computed by SafeHull would be more that satisfactory for the naval vessel. However, it would be more meaningful if the permissible stress range computed by SafeHull would be modified. This can be done by using the Weibull parameter that SafeHull computes as the "Long Term Distribution Factor."

The ABS allowable fatigue stress range is based on reducing the lifetime fatigue loading spectrum to a Weibull probability function, characterized by a parameter, γ. The parameter, γ is computed as a function of ship length and bow flare.

According to Mansour (1990), the fatigue damage, *D*, which is caused to ship structure when the loading is assumed to be characterized by a Weibull distribution and the S-N relationship given in Chapter 5, can be computed by the equation:

$$D = \frac{N_T}{A} S_0^m \left[\ln(N_T)\right]^{-\left(\frac{m}{?}\right)} G\left(\frac{m}{?} + 1\right) \qquad (11.1)$$

where:

A, m - the coefficient and slope of the linear S-N curve for the detail

S_0 - the allowable stress range for the structural detail

N_T - the total number of loading cycles that a ship will experience in its lifetime

Γ - the Gamma function

Accordingly, the ratio between the allowable stress range, S_0, and the ABS allowable stress range, S_{ABS}, is given by:

$$\frac{S_0}{S_{ABS}} = \left(\frac{N_{ABS}}{N_S}\right)^{\frac{1}{m}} \left(\frac{\ln(N_S)}{\ln(N_{ABS})}\right)^{-\frac{1}{?}} \qquad (11.2)$$

Where:

N_{ABS} = number of cycles for ABS = 20 years x 0.80 x 5 x 10^7
N_S = number of cycles for actual service = years x percent operability x 5 x 10^7
S_{ABS} = Permissible stress range by ABS
S_0 = Permissible stress range for actual service

The following result is shown in Appendix J for Ship J from the SafeHull Phase A computations:

SafeHull stiffener #11, Side Longitudinal #17,
Computed stress range — 3,013 kg/cm^2 (295 MPa)
Weibull long-term distribution factor — 0.928
Class F2 detail permissible stress range — 2,443 kg/cm^2 (239 MPa)
Ratio of stress range to permissible stress — 1.23 (MPa/MPa)

If the ship is to operate for 40 years at 35 percent operability, equation (11.2) gives the allowable stress range to be 2,572 kg/cm^2 (252 MPa) and the ratio of stress range to permissible stress as 3,013/2,572 = 1.17. In this calculation, the slope, m, for a Class F2 detail is 3.0.

Another method to account for years service and percent operability comes from integration of the Weibull function. A procedure given by Hughes (1995) divides a stress block of 5 x 10^7 cycles into 25 blocks, with the stress range for each block, SR_i, containing N_i cycles, with a Weibull parameter, γ, as

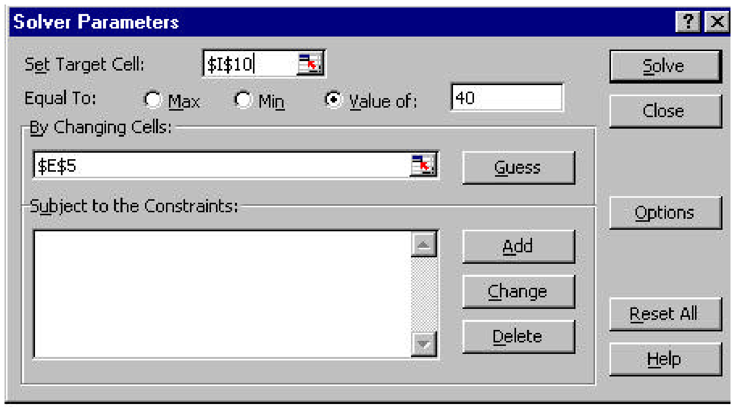
$$SR_i = S_0 \left(\frac{\ln\left(\frac{N_i}{5\times10^7}\right)}{-\ln\left(5\times10^7\right)} \right)^{\left(\frac{1}{?}\right)} \tag{11.3}$$

where S_0 is the maximum stress range. This procedure is shown in Table 11.1, which is an EXCEL spreadsheet for the computations. The following describes the computations performed in each column:

Cycles Exceeded — The exceedance curve for 5 x 10^7 cycles
Number of Cycles — The number of cycles for each block
Stress Range Factor — The fraction of the maximum stress range allocated for the block, computed using equation (11.3)
Stress Range — The average stress range for each block using the maximum stress range multiplied by the average of the factors from same row and the row above from the previous column
Cycles to Failure Upper — The number of cycles for a linear S-N curve based on the coefficients A_1 and B_1
Cycles to Failure Lower — The lower limit of a bilinear S-N curve based on the coefficients A_2 and B_2
Cycles to Failure (Bilinear) — The maximum of the previous two columns

Fatigue Damage Per Year — The ratio of the number of cycles in column 2 to the product of the cycles to failure and the basis years serviced times the basis operability.

The electronic version of this report has the spreadsheet imbedded as Table 11.1 for the reader's convenience. The user should enter the Weibull long-term distribution factor, the fatigue class for the detail, the percentage of service operability, and the desired years at service operability. The spreadsheet will use the Tools-Solver function to iterate the maximum stress range until the calculated years at service operability equal the desired years at service operability. In using the Tools-Solver function, the desired years of service must be manually input as shown in the following screen:



For the above example for a Class F2 detail with a Weibull long-term distribution factor of 0.928, the permissible stress range for a life of 40 years at 35 percent operability is 2,690 kg/cm^2 (264 MPa). If a life of 30 years at 35 percent operability were desired, the permissible stress range would be 2,958 kg/cm^2 (290 MPa). This is shown in the results for Stiffener Number 12 in Table 11.2.

Table 11.1 Computation of Permissible Stress Range

Stress Range for Fatigue Life Based on Percentage of Operability, Years Service, and Weibull Parameter								
Long-term Distribution Factor (Weibull) =			0.928				(Linear)	(Bilinear)
Maximum Stress Range (kg/mm^2)			26.88022			Basis Years Service	20	
						Basis Operability	0.80	
						Basis Days Operation	5840	
FATIGUE CLASS DETAIL			F2			Calculated Years Service at 100%	14.00	18.49
		LOG A_1	9.119			Service Operability	35%	35%
		B_1	-3			Calculated Years at Service Operability	40.00	52.82
		LOG A_2	10.53118		Desired Years at Service Operability		40	
		B_2 =	-5					
CYCLES EXCEEDED	NUMBER OF CYCLES	Stress Range Factor	Stress Range (kg/mm^2)	CYCLES TO FAILURE UPPER SN CURVE	CYCLES TO FAILURE LOWER SN CURVE	CYCLES TO FAILURE (Bilinear)	FATIGUE DAMAGE PER YEAR (Linear)	FATIGUE DAMAGE PER YEAR (Biinear)
1		1.000						
2	1	0.957	26.30	72,284	2,699	72,284	1.81E-06	1.81E-06
4	2	0.914	25.15	82,708	3,379	82,708	3.22E-06	3.22E-06
8	4	0.871	24.00	95,191	4,271	95,191	5.69E-06	5.69E-06
17	9	0.829	22.85	110,261	5,456	110,261	9.98E-06	9.98E-06
35	18	0.786	21.71	128,614	7,052	128,614	1.74E-05	1.74E-05
70	36	0.744	20.57	151,181	9,233	151,181	3.01E-05	3.01E-05
143	73	0.702	19.43	179,227	12,261	179,227	5.15E-05	5.15E-05
291	148	0.660	18.30	214,495	16,540	214,495	8.75E-05	8.75E-05
591	300	0.618	17.18	259,431	22,710	259,431	1.47E-04	1.47E-04
1,201	610	0.577	16.06	317,536	31,805	317,536	2.44E-04	2.44E-04
2,441	1,240	0.535	14.95	393,928	45,556	393,928	4.00E-04	4.00E-04
4,960	2,519	0.494	13.84	496,288	66,948	496,288	6.45E-04	6.45E-04
10,080	5,120	0.453	12.74	636,461	101,344	636,461	1.02E-03	1.02E-03
20,484	10,404	0.413	11.64	833,338	158,812	833,338	1.59E-03	1.59E-03
41,628	21,143	0.373	10.56	1,118,207	259,249	1,118,207	2.40E-03	2.40E-03
84,594	42,967	0.333	9.48	1,545,286	444,490	1,545,286	3.53E-03	3.53E-03
171,909	87,315	0.293	8.41	2,213,751	809,210	2,213,751	5.01E-03	5.01E-03
349,348	177,439	0.254	7.35	3,317,419	1,587,988	3,317,419	6.79E-03	6.79E-03
709,933	360,585	0.215	6.30	5,267,798	3,432,116	5,267,798	8.69E-03	8.69E-03
1,442,700	732,767	0.177	5.26	9,037,324	8,438,135	9,037,324	1.03E-02	1.03E-02
2,931,803	1,489,103	0.139	4.24	17,280,348	24,856,167	24,856,167	1.09E-02	7.61E-03
5,957,905	3,026,102	0.102	3.23	38,899,966	96,108,552	96,108,552	9.88E-03	4.00E-03
12,107,442	6,149,537	0.066	2.25	115,151,737	586,539,803	586,539,803	6.78E-03	1.33E-03
24,604,310	12,496,868	0.031	1.30	594,980,628	9,057,702,301	9,057,702,301	2.67E-03	1.75E-04
49,999,999	25,395,689	0.000	0.42	17,905,821,244	2,637,366,027,200	2,637,366,027,200	1.75E-04	1.18E-06
	49,999,998							
						Total Damage/Year	0.0714	0.0541
						Years	14.00	18.49

Using the above spreadsheet, the Phase A fatigue analysis of Class F2 details for ship G has been modified to reflect operation at 35 percent of the time in the North Atlantic for 30 years. The results are shown in Table 11.2

Table 11.2 Phase A Fatigue Analysis of Longitudinals for Ship G Modified to 30 Years in North Atlantic with 35 Percent Operability

STF #	Stiffener	Stress Range (kg/cm^2)			Fatigue Class	Long Term Distr. Factor	ABS SafeHull		Modified SafeHull	
		fRG	fRL	fR			Perm. Stress (kg/cm^2)	fR/PS	Perm. Stress (kg/cm^2)	fR/PS
1	Bottom Long'l 1	2249	470	2196	F2	0.889	2611	0.84	3180	0.69
12	Side Long'l 18	1472	1473	2798	F2	0.928	2443	1.15	2959	0.95
19	01 Lvl Long'l 12	2273	0	2159	F2	0.851	2827	0.76	3428	0.63
32	I.B. Long'l 1	1938	75	1912	F2	0.889	2611	0.73	3180	0.60
47	1st Plat Long'l 9	1499	0	1424	F2	0.889	2611	0.55	3180	0.45
58	2nd Plat Long'l 10	1600	0	1520	F2	0.889	2611	0.58	3180	0.48
59	I.B. Girder 2	2067	0	1963	F2	0.889	2611	0.75	3180	0.62
64	Mn. Dk Long'l 12	1766	0	1678	F2	0.909	2514	0.67	3063	0.55

With this modification for change in service life, the maximum stress range is less than the modified permissible stress range in all cases. This is consistent with the service experience of these ships, which have not experienced fatigue damage in the locations indicated by the unmodified SafeHull analysis, even though these ships have actually operated for only 15 years or less.

11.4.2 Modification for Service Environment

The ABS permissible stress ranges inherent in the SafeHull program are dependent on the assumptions of sea conditions encountered over the lifetime of the ship, as well as the ship headings and speeds in different sea conditions. In Chapter 3, it was demonstrated that changing from North Atlantic to General Atlantic conditions increased the fatigue lifetime of a typical ship by a factor of two. To consider any specific set of operational conditions or trade route, a specific fatigue loading spectrum must be developed and computations of fatigue performed with that loading spectrum.

For design purposes, the North Atlantic conditions assumed by ABS are reasonable. Even though naval ships may operate in relatively benign conditions during peacetime, they may be called upon to operate in severe conditions in time of war, and should therefore be designed for the more severe conditions.

For analysis purposes, such modifications to account for differences in operation areas or operating conditions can not be easily made to the output. For U.S. Navy ships, the discussion of Chapter 2 indicated that a change from operation in the North Atlantic to operation in a generalized Atlantic Ocean environment would double the fatigue life. Similar studies could be made with the SPECTRA program to address any specific operating scenario.

11.4.3 Other Modifications of SafeHull Output

There are other differences in methodologies for fatigue analysis that were discussed in Chapter 2 and elsewhere in the report. Many of those differences, such as changes in the S-N curves for structural details, or modification for hull girder bending moment prediction methods, can not be addressed through modification of the SafeHull Phase A output. Addressing these differences requires modifications to the SafeHull software.

11.5 Modifications that Could be Made to the SafeHull Software

The use of SafeHull programs for analysis of naval ships is inappropriate because the SafeHull programs were developed for specific ship types. In particular, the design criteria for naval vessels are significantly different than for commercial ships. However, fatigue analysis is not based on standardized design criteria, but is related to basic engineering principles. Therefore, if modifications were made to the program to accept a more general ship geometry, the program could serve as a useful tool for naval vessels. There are many improvements that are being continuously made to the program to reduce inadvertent input errors by users and otherwise improve the program. Some such difficulties are referred to in Chapter 9 and in the Guide for the use of Commercial Design Standards for Fatigue Analysis in Naval Ship Design, and will not be mentioned here.

11.5.1 Tank Definition

A great deal of difficulty in the use of SafeHull for fatigue analysis of naval vessels occurred because of the limitations of the "tanks" by which SafeHull defines loads. The following modifications should be made to the tank definition:

- Include a more general tank type that will generate live and dead loads on decks.
- Permit adjacent compartments to have the same type of tank.
- Increase the number of tanks that can be included in one cross section through the hull.

11.5.2 Structural Details

Although there are a great number of structural details that can be used in ship design, the SafeHull library is currently limited to six types of penetrations of longitudinal stiffeners through transverse webs. The following types of details should also be included in the library:

- Details with the web of the transverse frame welded to the upper flange of the longitudinal
- Cutouts with no collars or lugs
- Cutouts with fully fitted collars
- Slotted cutouts welded completely
- Details with tee or other types of web stiffeners
- Details with no flat bar or other web stiffener

11.5.3 Slamming Factor

The input of offsets for calculation of the slamming factor is required for the first five stations, defined at 0.0L, 0.05L, 0.10L 0.15L, and 0.20L from the forward perpendicular. For these locations, L is the ABS scantling length, which is generally different from the length between perpendiculars. Therefore, offsets for sections at these required locations are not generally available. It would ease the preparation of data if these calculations were conducted at regular stations defined in terms of the length between perpendiculars. Alternately, the user could input the longitudinal location of the stations used. This would be useful if the data is available in terms of faired offsets, which are generally defined at the locations of transverse frames.

Refinement in the input for slamming factor calculation may not be necessary if the minimum value of the factor, 1.0 is calculated. An initial value of the factor can be calculated with approximate offsets at stations that are only close to the required locations. If the calculated factor is significantly less than 1.0, then further refinements in the input are not necessary, because the minimum value, 1.00 will be used. The SafeHull output does not currently show the calculated value, but could be modified to do so.

11.5.4 Phase B Analysis

An improvement to the Phase B modeler is currently being developed by ABS for to ease the development of the finite element model for a containership. Therefore, no comments will be made on the current difficulties associated with transition from a Phase A analysis to a Phase B analysis. However, there are limitations in other aspects of the Phase B procedure that could be reduced.

- Eliminate the need for an inner skin in the application of loads.
- Generalize the loading so that generalized loads can be applied to decks, including both live and dead loads.
- Develop a methodology for automating Phase B fatigue analysis for standard details.

11.6 Summary

The containership version of the ABS SafeHull program can be modified so that a fatigue assessment of naval vessels can be made using the program. Slight modifications are necessary in the input because the geometry of a typical naval vessel is not the same as a containership. The SafeHull output can be modified to account for years of service and for percent of time spent underway. However, the output can not be directly modified to account for service conditions other than North Atlantic operations.

ABS can make modifications in the program to make it applicable to a wider range of ship types, including break bulk cargo ships and naval vessels. The principal change would be in the development of loads within the program, which could be modified to accept generalized loads on decks, including both live and dead loads.

12. CONCLUSIONS

The ABS SafeHull Phase A program for containerships can be applied to the fatigue design of naval ships. Fatigue fracture in service can be reduced by such use in the early stages of design. However, careful consideration should be made as to the effect of this design method on longitudinal stiffeners near the waterline. Few structural members in the hull cross section are involved, and the increases in scantlings that would be necessary to satisfy the SafeHull fatigue criteria would not be great. Therefore, the overall effect of implementation would be a small increase in the weight of ship structure. However, with weight-critical naval ships, any increase in scantlings should be carefully considered, and therefore, the subject of loading on and fatigue of side longitudinals of naval ships requires additional study.

This report describes an effort to apply a method of fatigue analysis developed for a specific class of ships to another class. In general, this idea of expansion of fatigue analysis from one class of ships to another should continue to be exploited to the maximum extent possible so that lessons learned for one type of ship can be applied to another. The limitations of the current effort lay largely in the software used to execute the methodology. Software that had been developed for a specific class of ships was adapted to a certain extent to another class of ships, but that adaptation involved compromises, which led to somewhat unsatisfactory results. In particular, all areas of concern for fatigue cracking in naval ships were not addressed in the SafeHull software for commercial containerships.

The fatigue analysis of the naval ships was not fully satisfactory because some of the assumptions that were made in developing the commercial fatigue analysis procedure did not pertain to naval ships. These assumptions include the operating environment, operational doctrine, years of intended service, and percentage of time underway. The allowable fatigue stress ranges developed by ABS and incorporated into both the rules and the SafeHull program cannot be easily adapted for changes in all of these variables. In this study, methods were found to modify the ABS allowable stress ranges for changes in service life and percentage of time underway. A method was developed to account for other changes in assumptions, such as different fatigue S-N curves, including bilinear S-N curves. However, when the analysis is performed reflecting these differences between the assumptions for commercial ships and the assumptions for naval ships, the calibration of the methodology developed by ABS for containerships not longer is valid.

A method to modify the allowable stress range for fatigue to accommodate different operational environments, such as operations in different sea states, could not be made. Such changes can only be accommodated in the commercial methodology through implementation of the ABS Spectral Fatigue Analysis procedure. However, this procedure has not been documented to the same extent as the ABS simplified fatigue procedure contained in the ABS Rules and in the SafeHull program. The U.S. Navy SPECTRA program will accommodate flexibility in operations, but this program is not in the public domain.

13. RECOMMENDATIONS

The following recommendations are based on the work of this study.

1. The SafeHull containership program should be used in the preliminary fatigue analysis of naval ships. However, detailed analysis of areas of discontinuity and stress concentration should be examined more closely, including the use of finite element analysis.

2. Further investigation of the loading on the side shell near the waterline should be conducted. Methods of analytically predicting those loads need to be further developed and made applicable to a large range of ship types and sizes. Experimental verification of the loads is needed.

3. The SafeHull program should be made more general in nature so as to enable more types of ships to be analyzed. This generalization should include the ability to impose live and dead loads on decks from cargo and from other sources.

4. The ABS Spectral Fatigue Design procedure should be documented. When that procedure is documented, the study of this report should be extended by application of the ABS Spectral Fatigue Design procedure to naval ships.

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Guide for the Use of Commercial Design Standards for Fatigue Analysis in Naval Ship Design Using ABS SAFEHULL

Report
Prepared For The
Ship Structure Committee

SSC Project SR-1403
Supplemental Commercial Design Guidance for Fatigue

USCG Research and Development Center
Contract DTCG39-99-C-E00221

1. Title

1.1 Guide for the Use of Commercial Design Standards for Fatigue Analysis in Naval Ship Design Using ABS SAFEHULL

2. Designation

2.1 To be provided by ASTM F25

3. Scope

3.1 This draft guide provides instruction for the application of the ABS computer program SafeHull, a recognized commercial design standard for fatigue analysis, to the fatigue design of naval ships.. The emphasis of the guide will be the identification of the different approaches that are necessary when applying SafeHull to ships whose configuration is significantly different than those for which SafeHull was developed. It is oriented to the minimization of differences between commercial practice and naval practice, so that those engineers who are experienced with the commercial practice will not have to spend a significant amount of time to learn the naval procedure and those who are experienced with naval practice will not have to spend excessive time to learn the commercial approach.

3.2 This guide is intended only as a supplement to the program documentation provided by SafeHull (Reference 4.1). If there is any question concerning either program input or interpretation of output, the SafeHull documentation takes preference. The ABS SafeHull staff should also be consulted concerning the use of the program. The user is urged to take one of the many SafeHull training courses available from ABS to become more familiar with the many aspects of the SafeHull program prior to its use.

4. Referenced Documents

4.1 SafeHull Documentation, American Bureau of Shipping, Houston, 2001.

4.2 Ship Structure Committee Report SR-1403, Supplemental Commercial Design Guidance for Fatigue, U.S. Coast Guard, August, 2001.

5. Summary of Practice

5.1 This Guide provides guidance on the information necessary to perform a fatigue analysis of a typical naval vessel using SafeHull Phase A and Phase B. The guidance provided should be supplemented by the SafeHull documentation, attendance at an ABS SafeHull training session, and, as necessary, consultation with the ABS SafeHull staff.

6. Significance and Use

6.1 The feasibility of using the ABS SafeHull program for fatigue analysis of naval ships was demonstrated in the Ship Structure Committee Report SR-1403, Supplemental Commercial Design Guidance for Fatigue (Reference 4.2). That report was prepared during a research project funded by the Ship Structure Committee. Shortcomings and limitations associated with the use of SafeHull for this purpose, and modifications to the results of a SafeHull fatigue analysis that are necessary for analysis of naval ships, are described in that report. Ample support for the use of SafeHull is provided by ABS in the documentation provided with the computer program (Reference 4.1). However, the emphasis of that documentation is preparation of input for the design of a containership, and not on fatigue analysis of a naval ship. For the naval ship types studied in Reference 4.2, a complete input file does not have to be developed especially for

Phase A analysis. This guide provides the information on the minimum data required for a fatigue analysis of naval combatant ship types.

6.2 The program was reinstalled on a Pentium (R) II computer with a 350 MHz processor, 320 MB RAM, and 5GB hard drive capability. Desktop computers of lesser capability can be used, but execution of the program is slow. Unlike most Windows-based computer programs, transfer of the data files created to another computer can be done only through the use of special SafeHull program modules.

7. Procedure

7.1 *Data Required for a Phase A Analysis*

7.1.1 *Basic Ship Information*

7.1.1.1 Before beginning to develop program input, the user should establish a separate working directory, or folder, for the ship to be analyzed on the hard drive of the computer being used. Although files developed for each ship analyzed will have a unique file name, many files are produced by SafeHull, and should be in one location. A ship name should be determined. It should have no more than 8 alphanumeric characters with no imbedded blanks. A unique 7-digit number is also needed for each ship.

7.1.1.2 The following particulars on the ship being analyzed are required. All dimensions are in meters unless otherwise mentioned. This information is provided to the program in the General Data module of the program.

- Length Between Perpendiculars
- ABS Rule Length (Generally 0.97 × LBP)
- Depth at Side at Midships
- Maximum Beam on Waterline
- Draft
- Block Coefficient consistent with the above rule length, draft, and beam
- Waterplane Coefficient
- Metacentric Height (GM) (If not known, SafeHull will provide default value.)
- Roll Radius of Gyration (If not known, SafeHull will provide default value.)
- Design Speed (knots)
- Height of Freeboard Deck at Side
- Height of Bulkhead Deck at Side
- Bilge Radius
- Gunwale Radius
- Transverse Web Frame Spacing
- Grade of steel used in the hull structure per ABS rules

7.1.1.3 The block coefficient is used to determine the design bending moment in accordance with the ABS rules. The coefficient should be calculated using the ABS rule length, not the length between perpendiculars. The minimum value used by SafeHull is 0.60, which is greater than the block coefficient of most high-speed combatant ships. This limitation is discussed in Reference 4.2.

7.1.1.4 For naval ships, the height of the freeboard deck is generally the height of the strength deck, but the bulkhead deck is often the deck below in larger naval ships. Naval ships generally have slack bilges, and so the concept of a defined bilge radius does not always apply. The bilge radius is used to define the vertical extent of the hull for which rule requirements for bilge structure apply, so that this dimension should not be greater than the depth of the innerbottom. If the ship has no innerbottom, some judgment should be used in defining the bilge radius, but it should be no greater than the depth of the hull that is normally wet from water in the bilges. The bilge radius entered should also be no greater than either the distance of the top of the bilge strake from the baseline, or the distance from the inboard edge of the bilge strake from the maximum beam of the ship. If this definition leads to an unreasonable size for the bilge radius, then the extent of the plating strake that is defined as a bilge strake should be reduced.

7.1.1.5 There are no other options for grade of steel other than the standard ABS Grades of Mild Steel, HS32, HS36, and HS40. ABS Grade HS 36 has a yield strength of 355 MPa (51 ksi) and is used by the U.S. Navy in Grade DH-36 as Higher Strength Steel (HSS). However, the fatigue analysis assumes that fatigue strength is independent of material grade. Designation of a grade of steel in the program with a different yield strength than that which the ship is constructed will only effect design checks in accordance with the ABS rules, which the user does not have to perform in order to do a fatigue analysis.

7.1.2 *Library Modules* There are three user-developed libraries that are used by the program: stiffeners, end connections, and hatch corners. These libraries should be developed prior to the input of other than general data, because the information will be required for data entries, such as definition of stiffened panels. However, the hatch corner library is not required for the fatigue analyses of naval vessels. The information on hatch corners is used only for an analysis of hull girder torsion, which produces high stress at the corners of the large hatches in containerships. Because naval ships do not usually have such large openings in the strength deck, the SafeHull Phase A torsional analysis normally will not pertain. Furthermore, the transverse structure as used in SafeHull for containerships is so different than typical naval vessel structure that a sensible modification of input can not be made.

7.1.2.1*Stiffener Library*

7.1.2.1.1 There are two basic stiffener libraries in SafeHull. The first is the master library of all standard structural shapes. This library is in metric dimensions and does not include any of the standard U.S. shapes defined by the American Iron and Steel Institute. The other is the ship library of shapes specifically used on the ship being analyzed. This ship library is required for analysis, and should be created before the information on the longitudinal structure is entered, as the stiffener library is used for that input. Even if the entire master library is to be used, it must be copied over into the ship library in order that stiffener shapes may be selected. The stiffener library is developed by either selecting shapes from the master library in SafeHull or a user-created master library, or by defining each stiffener using the EDIT/ADD feature of the Stiffener Library in SafeHull. When developing the stiffener library, it is recommended that the shapes be input in an orderly fashion, which will make shape selection easier when the library is used during input of stiffened plate panels.

7.1.2.1.2 If U.S. or other shapes not in the ABS library are used, there are two options available for data entry. The first is to develop a master library of all shapes possibly used for ship construction that are not in the SafeHull master library. Table 1 illustrates such a library for U.S. Tee-shapes with dimensions in millimeters. VAR 1 is the depth of the web (not the overall depth of the member). VAR 2 is the web thickness, VAR 3 is the flange width, and VAR 4 is the flange thickness. This file was begun by using the EDIT/ADD feature of the Stiffener Library in SafeHull to define a shape as a built-up section using the process described below. When this has been done for each shape type to be defined, then this SafeHull-generated file provides the template required for the correct format. This file created by SafeHull can then be edited to include the desired shapes, provided that the user follows the proper format.

Table 1 Stiffener Library Data File ShipName.SLB

#-- STIFFENER PROPERTIES;   FILE:D:\SAFEHULL\CG16R2\cg16r1.slb ; RECORDS: 551

#ID#	TYPE	ABS ID	DESCRIPTION	VAR 1	VAR 2	VAR 3	VAR 4
1	BTEE[1]	USER-DEF	WT22"X167.5	559.05	25.91	405.13	44.96
2	BTEE[1]	USER-DEF	WT22"X145	553.97	22.10	402.08	40.13

1. BTEE is a built-up tee-section, with the depth specified by the depth of the web, not the total depth of the section.

7.1.2.1.3 Alternately, a file of all of the shapes used in the ship being analyzed can be developed using the EDIT/ADD feature of the Stiffener Library in SafeHull. A variety of other shape types are available. The Edit menu offers the following options:

Inverted Angles
- Inverted Equal Angle
- Inverted Unequal Angle
- Inverted Large Angle
- Rolled Flange Welded to Plate Web

Rolled Sections
- Bulb Flat (HP)
- Rolled Flat Head Tee
- Jumbo Bulb

Built Up Sections
- Balanced Built up Tee
- Unbalanced Built up Tee
- Built Up Non Tee
- Built Up Angled Offset Face bar
- Built Up Angled Tee
- Flat Bar

Built Up Multi-Stiffener

Null Stiffener

7.1.2.1.4 If a rolled section is used, the depth entered is the total depth of the section, not the depth of the web. Rolled sections require input of the radius of the fillet at corner of the flange and the radius of fillet at the corner between the flange and web. Both fillet radii can be entered as zero.

7.1.2.1.5 With built up sections, such as a built up balanced tee, the depth entered is the depth of the web, not the total depth of the section. Built up sections do not have fillets.

7.1.2.1.6 A multi-stiffener is a profile created by combining other stiffeners and plates to form a combined stiffener. This definition can also be used if the stiffener is not normal to the plate, which is the assumed orientation for all other stiffeners. A null stiffener is used as a placeholder for stiffener locations on plating during initial ship design development. It wouldn't be used for defining an existing ship.

7.1.2.1.7 Although there are areas in the section definition screens for entering the thickness and effective breadth of plating, that information does not have to be entered. When a stiffener is defined later in the SafeHull input, it is defined with associated plating, for which the effective breadth is calculated. Therefore, each structural shape is entered only once in the stiffener library for a ship. The option of entering plate thickness and breadth is provided so that when using SafeHull in a design mode, full section properties are available to help with initial scantling selection.

7.1.2.2 *End Connection Library*

7.1.2.2.1 This library defines the structural details at the ends of stiffeners. Figure 1 illustrates the type of information that can be input. The options are for a flat bar at the transverse member, and a bracket, which can be either circular or straight, on the stiffener. Note that the intersection with another stiffener cannot be defined, and the brackets are assumed to be fitted, not lapped. If brackets are lapped, this can be accounted for by changing the Fatigue Class definition to other than F or F2, either Fatigue Class G or W. During the definition of the end connection, neither the thickness of the flat bar, the web of the transverse member, nor the thickness of the bracket is defined. This definition is made later in the program module Cut Out Library.

7.1.2.2.2 If the flat bars have no brackets attached, then the dimensions HX, HY, and R are entered as zero. When creating the end connection library, one flat bar should be entered with all dimensions equal to zero. This connection is needed for all details where there are no flat bars connecting the longitudinal stiffener to the transverse web.

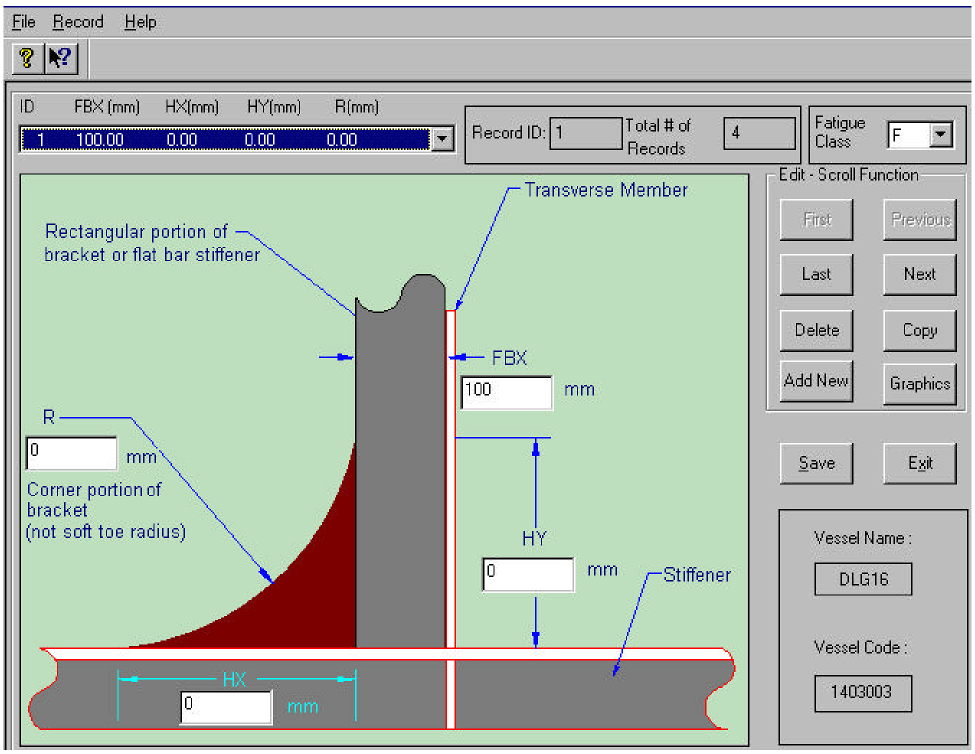


Figure 1 SafeHull End Connection Library Screen

7.1.2.2.3 Note that the SafeHull manual indicates that the radius of the bracket shown in the screen is 0, but the screen shows a very obvious non-zero radius. A radius of 0 would be equivalent to having no bracket at all.

7.1.2.3 Stiffener Cutout Library

7.1.2.3.1 This library is not entered using the tab "Library" on the main SafeHull screen, as are the other libraries. It is entered using "Window, Longitudinal Scantling, Fatigue Strength, CutOut Library." This library does not have to be created until the input for "Fatigue Strength of Flat Bars" is entered, but it may be created sooner. Only those stiffener cutouts that have flat bar stiffeners between the upper edge of the flange and the web of the transverse can be analyzed by

SafeHull, so it is not necessary to define any other cutouts than those with flat bars (or other stiffeners, such as tees).

7.1.2.3.2 The six types of cutouts defined by SafeHull, including collar plates, are illustrated in Figure 2, and a sample input menu for Type 5 is provided in Figure 3. Note that there is no option for defining the radii of the cut out corners, or for defining a cut out in which the top of the flange is welded to the web of the transverse. Completely fitted openings (slots) are not an input option either.

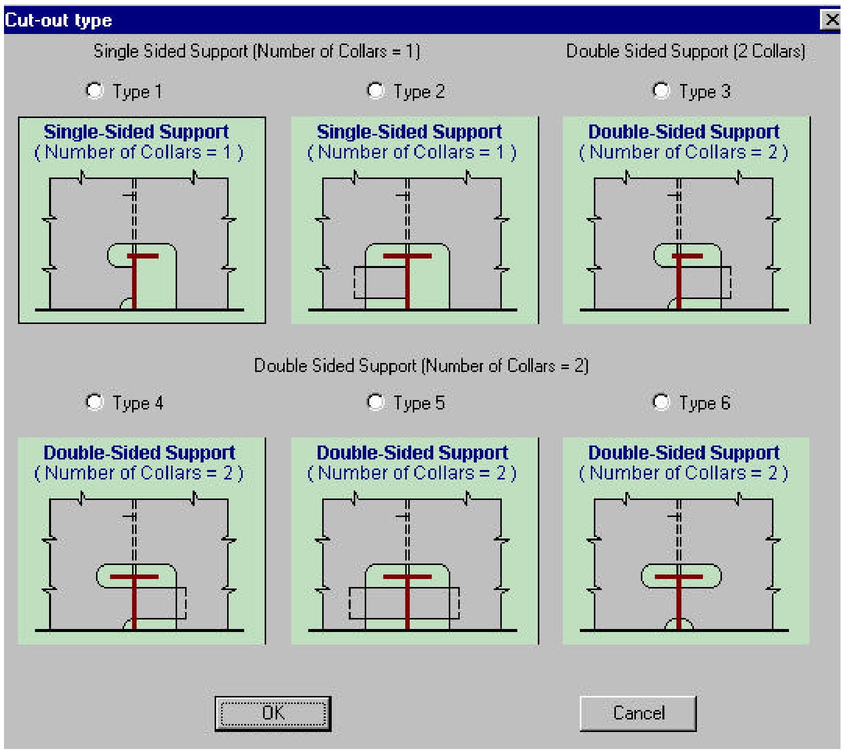


Figure 2 SafeHull Stiffener Cut Out Library Definition

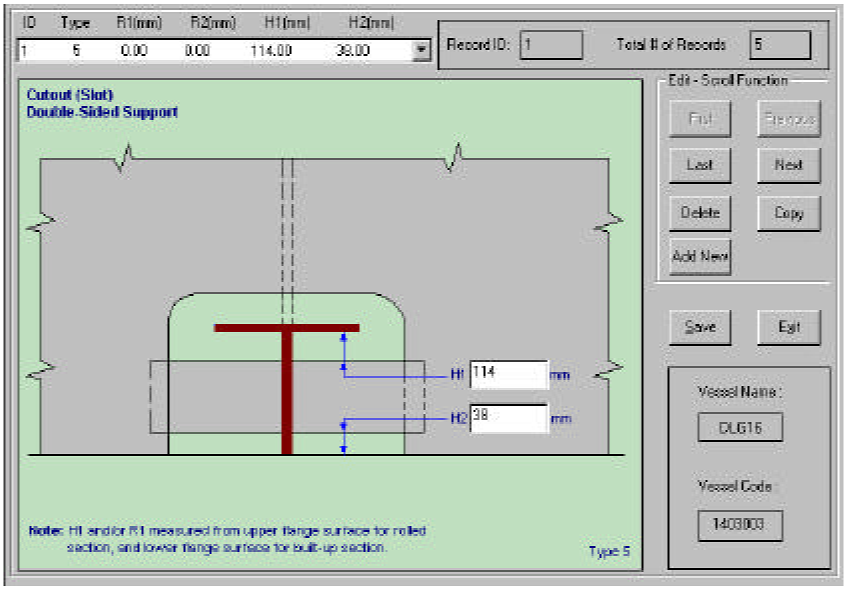


Figure 3 Input for Type 5 Stiffener Cut Out

7.1.3 *Longitudinal Scantlings*

7.1.3.1 Although the screen for "Hull/Tank Geometry" appears in the "Window" screen prior to "Longitudinal Scantling," it is best to input the data for the scantlings first, because the definition of the hull and tanks is based on this input. The "Slamming Factor" menu appears within the Longitudinal Scantling menu, but because it relates to hull geometry, it will be discussed with the "Hull/Tank Geometry" input. The second item within the Longitudinal Scantling menu is "Section Definition," which is used to define the structural configuration and scantlings of longitudinal members.

7.1.3.2 The first screen in Section Definition is shown in Figure 4. The scantlings can be input, and a fatigue analysis made for more than one cross section of the hull. Each section should have a unique description, although the section number is used by SafeHull. New sections are defined by clicking on the icon on the bottom left of the screen, and then entering the name of the new section and its distance from the after perpendicular. For a fatigue analysis of a naval vessel, the only other item on this screen for which data entry is required is the "Special Fatigue Location," which is necessary for fatigue calculations. In general, the fatigue analysis will be at the intersection of the longitudinals with the transverse frame. Therefore, the offset dimension "X Location for Fatigue" should be entered as zero. The still water hull girder bending moments and shears may be entered, but the stresses from these are added to and subtracted from the load range, so that the actual values have no effect on a fatigue analysis. Other input, such as Cross Deck and Hatch Opening, and Container Tiers and Rows may be omitted when only a fatigue analysis of longitudinals is being performed.

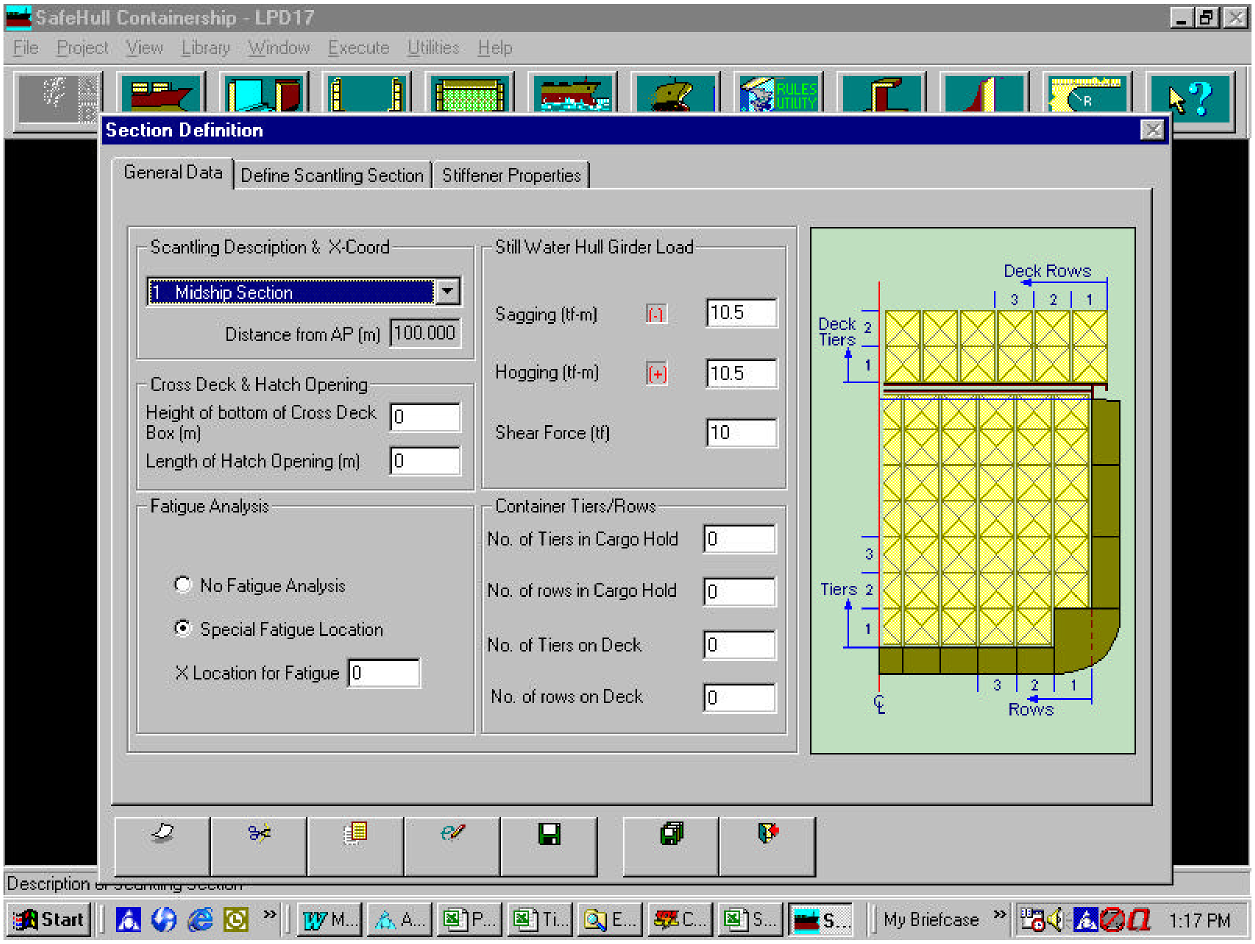


Figure 4 General Data for Section Definition

7.1.3.4 The next screen in Section Definition is shown in Figure 5. This is the screen by which the structural configuration of longitudinal members is defined. All of the sections for which analyses are desired are defined using this screen and the screens included in it.

7.1.3..5 The "Available Section List" provides the acceptable SafeHull names for portions of the hull structure. Those names are:

- Keel Plate
- Bottom
- Bilge
- Side
- Forecastle Deck
- Sheerstrake
- Gunwale
- Upper Deck
- Plating Within Line of Deck Openings
- Inner Bottom
- Watertight Flat
- Non-tight Flat
- Lower Wing Tank Sloping Plate

- Inner Skin Bulkhead
- Other Longitudinal Bulkhead
- Hatch Coaming
- Non-tight Bottom Girder
- Watertight Bottom Girder
- Non-Tight Stringer
- Watertight Stringer
- Swash Bulkhead
- Non-tight Deck Girder
- Watertight Deck Girder
- Miscellaneous Plate
- Second Deck
- Forecastle Deck
- Poop Deck

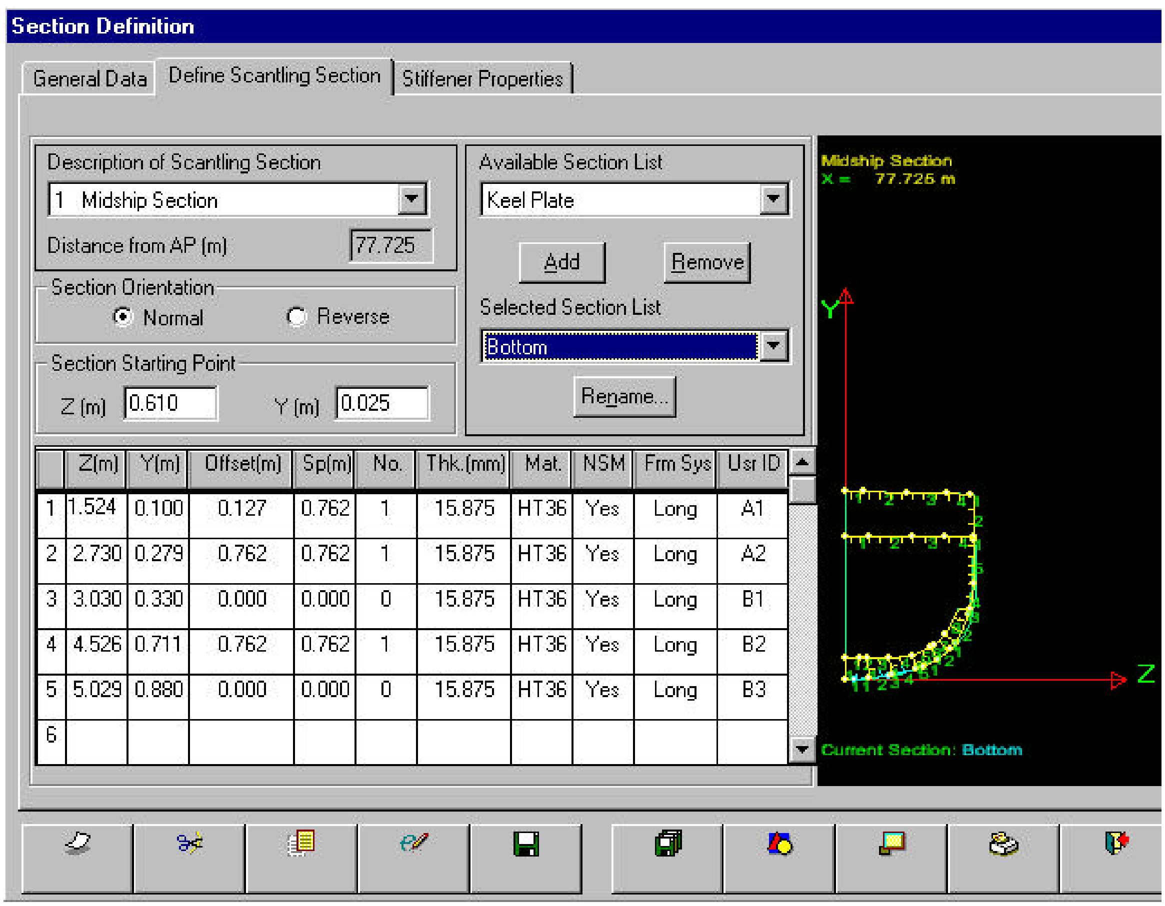


Figure 5 Input of Scantling Sections Screen

7.1.3.6 Those strakes required for fatigue analysis are the Keel Plate, Bottom, Side, Sheerstrake, Upper Deck, and Second Deck. The Upper Deck is the strength deck at the section defined. The Second Deck is the next deck below the Upper Deck. It does not appear necessary to define the Bilge, Gunwale, or Inner Bottom. If a Gunwale is defined, no special input is available for a rounded gunwale.

7.1.3.7 If there are more than two decks, they can be defined as either Watertight Flats or Non-tight Flats. Multiple instances of the same name are permitted, and are then named Watertight Flat 2, etc. Longitudinal Bulkheads should be defined as Inner Skin Bulkheads, for which there may be multiple instances. The categories of Other Longitudinal Bulkhead, Forecastle Deck, and Poop Deck may not be used except for structure forward or aft of the midships 0.4 length of the ship. The section desired is selected by scrolling through the "Available Section List" to find the desired section, and then using the "Add" button below. After other sections have been selected, the section to be entered or edited is obtained by using the "Selected Section List." In Figure 5, the selected section is the Bottom, which need not agree with the section shown in the "Available Section List," which is the Keel Plate in Figure 5.

7.1.3.8 With this menu, plating with attached stiffeners is defined. A plate may begin and end at a longitudinal butt between adjacent strakes of plating. However, a beginning or end of a plate must be defined whenever there is an intersection with any other longitudinally continuous members, except for longitudinal stiffeners. For example, the bottom shell of a ship with an innerbottom is shown in Figure 5, and the second plate ends at coordinates Z = 2.73, Y = 0.279 because this location is the first longitudinal girder in the innerbottom.

7.1.3.9The first plate within a section has the coordinates in the "Section Starting Point." The end coordinates of the first plate are in the first row in the table, which also contains other properties for that plate. Subsequent plates are entered in order in the following rows, so that the starting point of the second plate is end point of the first plate, and its end point is at the coordinates of the next row of the table.

7.1.3.10 Subsequent sections that are defined use a new starting point. For example, when the first longitudinal girder in the innerbottom is defined, its starting point is the intersection with the coordinates of the bottom, Z = 2.730, Y = 0.279.

7.1.3.11..Properties of plate that are defined in each row include the thickness (in millimeters) and the material of the plate. Only one thickness can be described, so where there is a change in plating thickness, a new plate must be defined. If the plating is effective in longitudinal strength, then the column "NSM" is marked "Yes," otherwise it is "No." Therefore, a separate plate must be defined for any area in the cross section that is not to be included in the hull girder section modulus calculation.

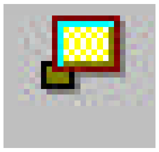
7.1.3.12 If the plate is longitudinally stiffened, then the "Frm Sys" column is indicated as "Long," otherwise it is "Trans." The last column is important for the identification of the plate in the output. However, it is limited to about eight characters, so should be descriptive and short.

7.1.3.13..Longitudinal stiffeners are defined for each plate. The number of stiffeners associated with a plate is entered in the column marked "No." The "Offset(m)" is the distance in meters between the beginning of the plate and the first stiffener on the plate. Other stiffeners on the plate are then spaced at the distance in the column "SP(m)." Note that if the plate is ineffective in longitudinal strength, then all of the attached stiffeners are also ineffective.

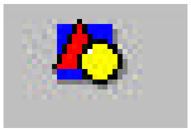
7.1.3.14 The center and side girders of the innerbottom, as shown in Figure 5, are defined with plating. Each section of plates is either a "Non-tight Bottom Girder" or a "Watertight Bottom Girder". These girders may have their own longitudinal stiffeners.

7.1.3.15 Stiffeners are oriented so that the "Normal" direction points the stiffener towards the left (from the plate beginning to end). Selecting "Reverse" will point the stiffener in the opposite direction. The direction of the stiffeners will be seen in the outline of the section shown on the screen once the save icon in the bottom center of the screen is clicked.

7.1.3.16 It is useful at this point to click on the icon at the bottom of the screen that looks like:



This icon will provide a menu for looking at the data input in more detail, including zoom and scroll buttons. Another useful feature is the icon that looks like:



Options for showing either local or global stiffener or plate sections will appear by clicking on this icon. This feature is important at later stages in the use of SafeHull, especially when difficulties in the input cause the execution of the program to fail, and the error messages refer to global stiffener or plate numbers.

7.1.3.17 Definition of the properties of the stiffeners is made by selecting the “Stiffener Properties” tab on the “Section Definition” screen. It is very important that before doing this, the “Save” icon on the bottom of the screen be used. Otherwise, section properties can be lost. The icon to the right of this, which shows multiple 3 ½ inch diskettes, will save all of the sections defined, and should also be liberally used to avoid problems.

7.1.3.18 It is possible to go through all of the transverse cross sections to be input, using screens similar to Figure 5, and define all of the sections with their plates, and then define the stiffeners. The screen in Figure 5 shows that the scantling section, individual section, and the plate can be selected prior to input of stiffener properties. However, to avoid confusion as to which stiffeners are being added, it is best to first click on the box for the number of stiffeners for a particular plate when in the “Define Scantling Section” screen, and then select the “Stiffener Properties” tab. Clicking on the “Stiffener Properties” tab will display a screen similar to Figure 6 for defining stiffener properties for a particular plate. When this is done, the darkened box marked “No. of Stiffeners” will show the number of stiffeners to be defined.

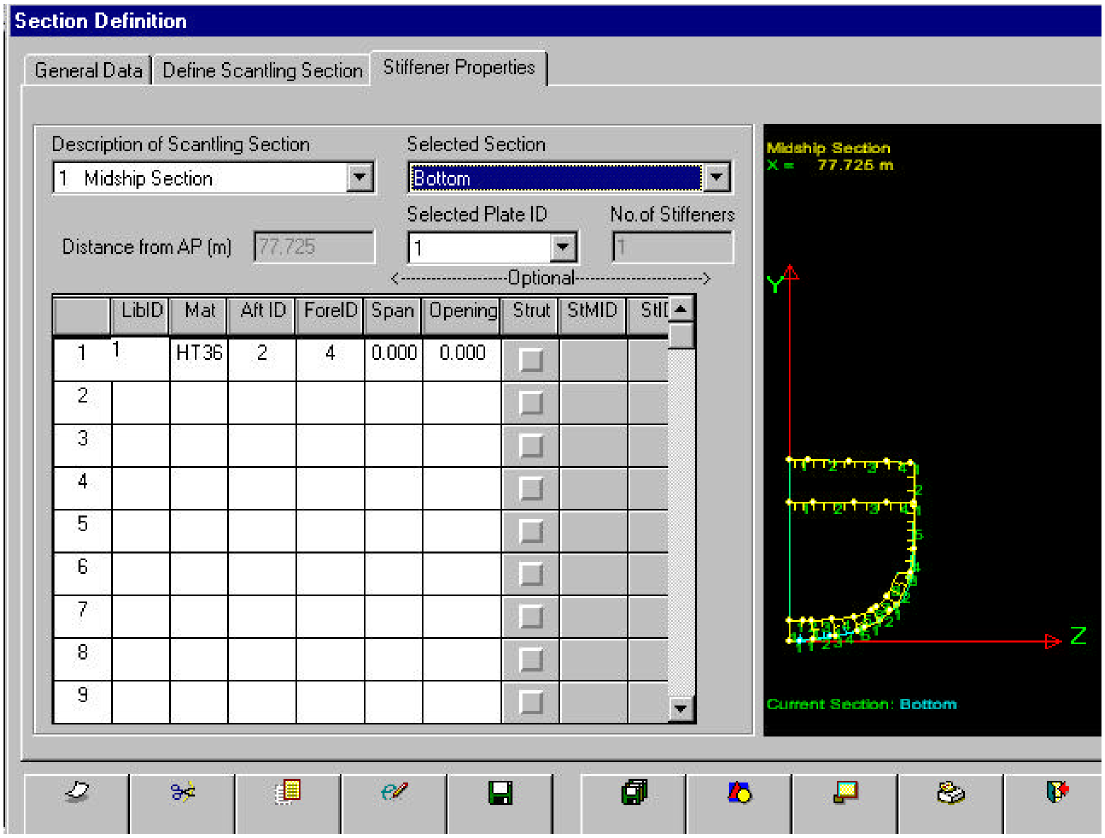


Figure 6 The Stiffener Properties Screen

7.1.3.19 Each stiffener is defined in a separate row in the table. Clicking on the box in the "LibID" column will make the stiffener library previously defined for the ship appear. Clicking on the desired structural shape will bring back the Stiffener Properties screen. The material for the stiffener can be different from the material of the plate, and is selected in the "Mat" column. The details previously defined in the End Connection Library are now selected for the forward and aft end of each stiffener in the "Aft ID" and "ForeID" columns. A stiffener is defined as spanning between two transverse frames, so that "Aft ID" refers to the detail at the first transverse frame aft of the section being defined. The cutout detail is not selected at this time.

7.1.3.20 If the spacing of transverse frames or other supporting members (other than struts) is the same as the Transverse Web Frame Spacing previously defined in the general ship data, then no entry needs to be made in the "Span" Column. If the stiffener has openings that make part of the section ineffective in longitudinal strength, then the transverse dimension of the ineffective portion is indicated in the "Opening" column.

7.1.3.21 If there are structural members connecting stiffeners in opposing sections, such as bottom and innerbottom stiffeners, they are sometimes connected at mid-span by struts. If so, clicking in the "Strut" column will permit entry of the material and structural section of such a strut. If there are no struts, then the box is not checked.

7.1.3.21 Although apparently not necessary, it is a good idea to click on the "Save" icon at the bottom of the screen before returning to the "Define Scantling Section" tab.

7.1.4 *Hull/Tank Geometry*

7.1.4.1 For a fatigue analysis of the midship section of a typical naval ship, the only offsets that must be entered, other than for bow flare, are for the midship section. If analyses are to be conducted for other sections, their offsets must be entered. The description below is just for the case of one section at midships, describing what appears to be the minimum input required for fatigue analysis. Although offsets may be available in a different format and at other points around the hull, the points used to define the shell plates provide a sufficient data set for hull definition. Furthermore, using the same points for both hull definition and structural definition avoids ambiguity in the description of the geometry.

7.1.4.2 For entry of offsets and definition of hull compartments for tank definition, it is useful at this time to have available the file ShipName.OPL. When developing the initial input for SafeHull, a working directory is defined for the ship being input. This file will be in that directory". An example of this file is shown in Table 2. The data in the file is similar to the input screen shown in Figure 5, except that now the plate numbers are the global ID numbers, and the coordinates of the start and end nodes are given. By referring to this file, the user can be certain that the offsets for the hull coordinates and tanks are the same as for the structure. It is also a good idea to review this file to make certain that intersecting members have the same coordinates.

Table 2 Input Data in File ShipName.OPL

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ABS/SAFEHULL/CPOSTGEN V6.00 (2000 Rules)
PLATE INFORMATION BASED ON SCANTLING GROUP
SHIP : DLG 16 Renamed DLG16 FILE : DLG16.OPL
Midship Section --- Scantling group 1 (x = 77.725 m from AP)

PLT #	SEC ID	FRAM	MAT	START NODE ID	START NODE Z(m)	START NODE Y(m)	END NODE ID	END NODE Z(m)	END NODE Y(m)	OFR THKG (mm)	NSTR #	SPS1 (m)	SPFR (m)	SPACE (m)	SPAN (m)	USER ID
** Keel Plate (Rule 5-5-4/11.3.1, 5-5-4/11.1.3) **																
1	KPL101	1	HT36	1	0.000	0.000	2	0.610	0.025	19.05	0	0	0	0.738	2.438	FPK
**Bottom (Rule 5-5-4/11.3.1, 5-5-0.3) **																
2	BTM101	1	HT36	2	0.610	0.025	3	1.524	0.100	15.88	1	0.127	0.762	0.790	2.438	A1
3	BTM102	1	HT36	3	1.524	0.100	4	2.730	0.279	15.88	1	0.762	0.762	0.762	2.438	A2

7.1.4.3 Figure 7 shows the input screen for the definition of the shell shape. The figure of the cross section does not appear until the "Save" icon is clicked. It is necessary to define the hull between the transverse bulkheads immediately forward and aft of midships, and the offset at those locations and at midships can be entered as three separate sections. However, if only an analysis at midships is made, then this portion of the hull can be treated as parallel midbody, with all three sections having the same offsets and therefore only entered once.

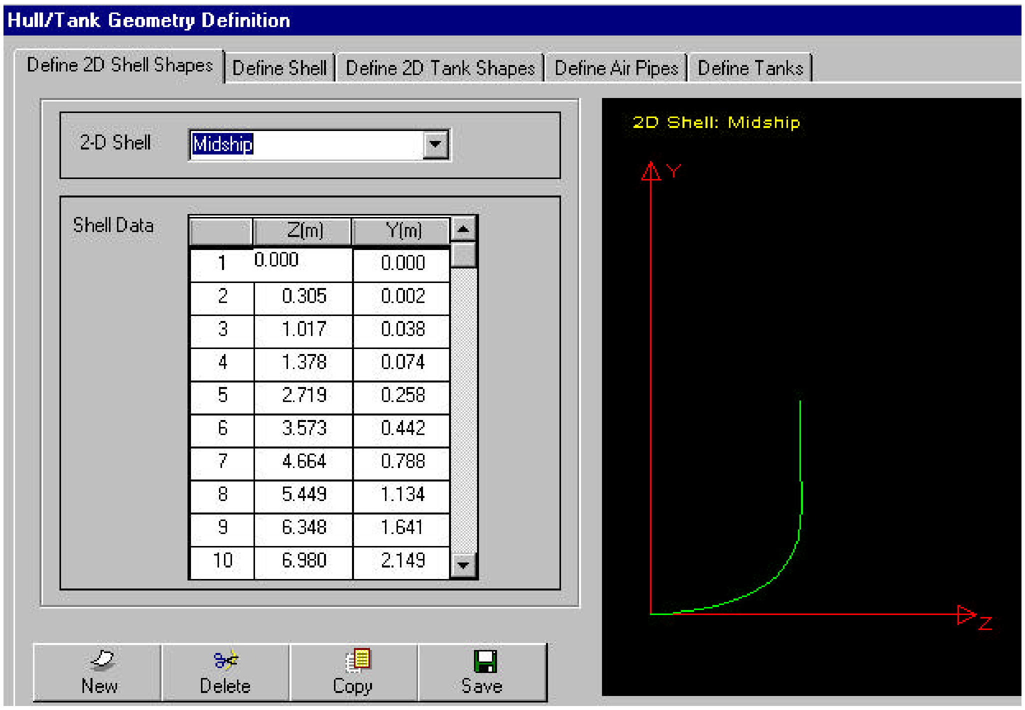

Figure 7 2-D Shell Shape Definition Screen

7.1.4.4 With only one 2-D shape defined for midships, the definition of the shell between the bulkheads forward and aft of midships is made as shown in Figure 8. Input is required for both bulkheads and for midships. The shape is selected and then the distance from the after perpendicular is defined for this shape. This is done for three locations.

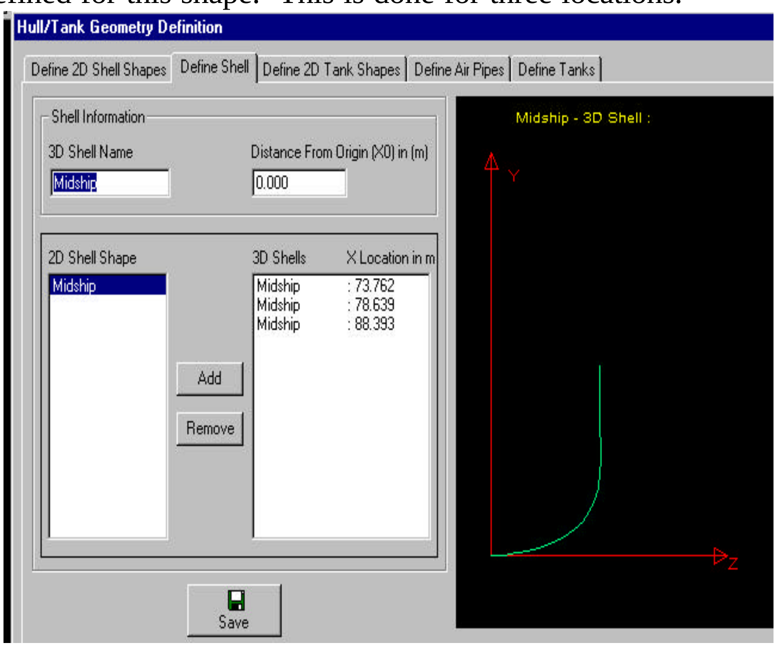

Figure 8 Shell Definition Screen

7.1.4.5 The basis for local load application in SafeHull is the tank. There are five different types of tanks that can be defined in Phase A:

- Cargo Hold
- Ballast Tank
- Void Space/ Underway Passage
- Duct Keel
- Fuel Oil Tank

7.1.4.6 For a local load to be developed for a surface, such as a deck or the side shell, that surface must be part of the boundary of a tank. This condition also includes external hydrostatic and hydrodynamic loads from wave action. The definition of the ballast tank and the fuel oil tank include air pipes that are part of the development of a hydrostatic head. The cargo tank apparently does not develop cargo loads, for the analysis of naval vessels there is no option available for defining live and dead loads on decks. The Void Space/ Underway Passage and the Duct Keel do not develop internal loads.

7.1.4.7 There is a limitation in SafeHull that two adjacent tanks in one cross section may not be cargo tanks. Therefore, if a naval vessel has several decks, then the Void Space/ Underway Passage must be used between compartments that are defined as Cargo Holds. Such definition will result in most decks not having a load applied to them. It is possible if a deck is defined as a Non-tight Flat to have a single tank defined for the compartments above and below that deck. No local loads will be developed for that deck, but that is a limitation of SafeHull.

7.1.4.8 Tanks are defined in a manner that is similar to shell definition. Two-dimensional cross sections are defined for the forward and after ends of the tanks, and then selected in a menu that defines the individual tank. As with the shell definition, the tanks may have the same cross section at both ends. The tanks should be defined having a longitudinal extent between the bulkhead immediately forward of midships and immediately aft of midships (or the longitudinal location of the ship for which the analysis is being made). However, tank 2-dimensional sections may be defined as closed curves or as open curves that are closed by the previously defined shell.

7.1.5 *Slamming Factor*

7.1.5.1 The input for computation of the magnification of loads from bow flare slamming is independent of most other input. The offsets for the first five stations of the hull above the design waterline are entered, starting with the forward perpendicular. The offsets below the waterline may be entered, but are not used in the computations. The remaining stations are at 0.05L, 0.10L, 0.15L, and 0.20 L from the forward perpendicular. For most ships where 20 stations are defined, these would be stations 0 through 4, respectively. Unfortunately, when defining these locations, SafeHull uses the rule length for L, so that interpolation of offsets between the stations for which they are available will generally be required. To avoid doing that, an initial calculation of slamming factor can be made using offsets with the available stations closest to the required stations. If the slamming factor determined by SafeHull is 1.000, then it probably is the minimum values, with the calculated value less. If such is the case, no further refinement in offsets of the forebody is needed.

7.1.5.2 Note that when the factor is computed, the user must manually enter it into the box for Slamming Factor.

7.1.6 *Fatigue Strength of Flat Bar*

7.1.6.1 Following the definition of the longitudinal scantlings, the further information on details for the connection of longitudinals to transverse frames are added through the menu "Window, Longitudinal Scantling, Fatigue Strength, Fatigue Strength of Flat Bars." This will produce a screen similar to Figure 9. Input of data to this screen can be provided only after definition of stiffeners. However, it is recommended that this data not be entered until test runs have been made of the program to ensure that all modules of the program are able to successfully execute and that there are no errors in the input. The reason for delaying this input is because changing the section definition will generally remove all data from this screen, and the information will have to be reentered. This is particularly so when a ship file has been closed and then reopened. If the screen for Fatigue Strength of Flat Bar is opened, a message will appear saying "Please Define Scantlings First." Opening the Section Definition Screen and then closing it will remove this message and permit entry of data. However, doing so will frequently cause the information previously entered to disappear.

7.1.6.2 If the information previously entered on the fatigue strength of flat bars is so lost, it generally may be found in the file ShipName.FFB. The information in this file can then be reentered manually in the Fatigue Strength of Flat Bar screen.

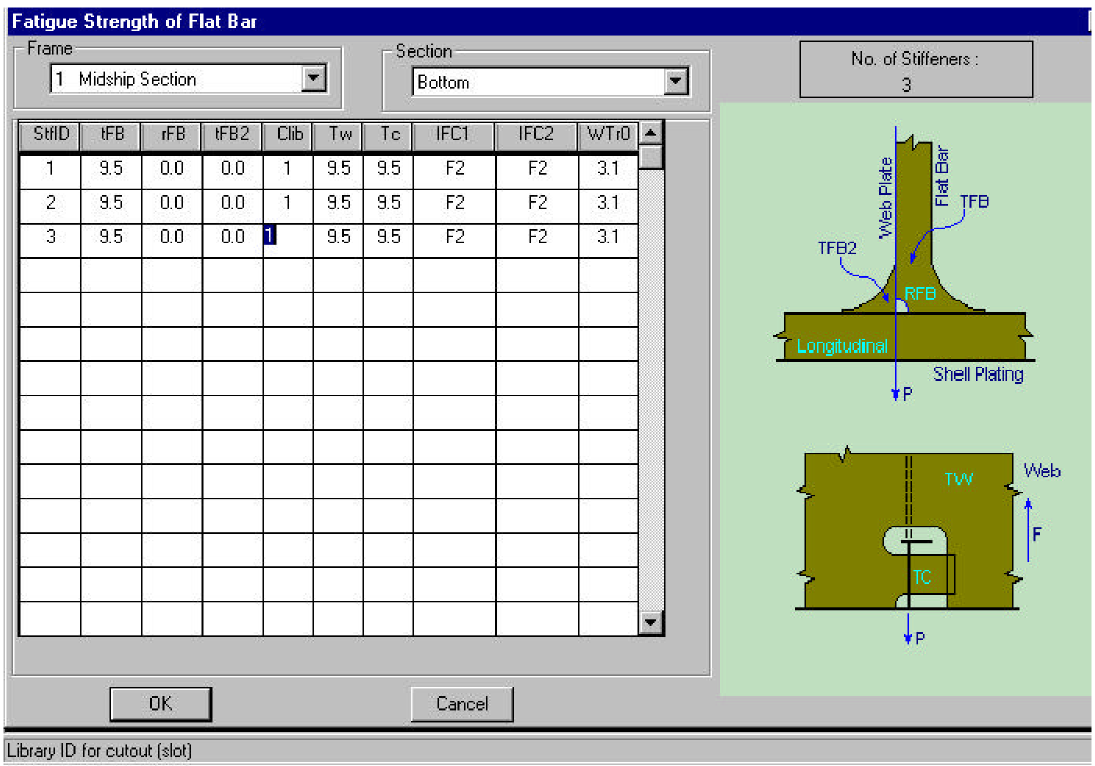

Figure 9 Fatigue Strength of Flat Bar Screen

7.1.6.3 The stiffener identification numbers in the Fatigue Strength of Flat Bar screen do not refer to either the global stiffener ID or the local stiffener ID that was used when the stiffeners were defined in the Stiffener Properties Screen. Instead, there is a sequential number for the section of the hull in which the stiffener is included. For example, Figure 5 shows that 5 plates were defined for the bottom section of the hull, but there were a total of only 3 stiffeners attached to the bottom plate. Figure 12.6 shows the definition of the stiffeners for plate number 1 of the bottom. If more than one stiffener had been attached to this bottom plate, they would have had a sequence of local stiffener numbers. Figure 9 shows the stiffeners for the bottom section to be renumbered. Therefore, caremust be used in defining these details so that the correct information becomes associated with each stiffener.

7.1.6.4 Note that the depth of the flat bar had been previously defined in the end connection library, as well as the size of any bracket attached Now with the Fatigue Strength of Flat Bar menu, the thickness of the flat bar and of the associated bracket is defined. The cutout detail is selected from the previously defined cutout library, with the thickness of the web of the transverse frame and the thickness of the collar plates also defined. The default fatigue class for these details is Class F2, but the user has the option of changing the fatigue class for every detail analyzed.

7.1.6.5 The throat thickness of the weld of the flat bar to the longitudinalis entered to perform a fatigue analysis of that weld. That weld is considered to be a Class W detail with no alternative permitted.

7.1.7 *Unnecessary Data* The above data entry is all that is required to perform a faigue analysis in Phase A of SafeHull. There are other input screens that may be ignored. It is not necessary to enter information on the transverse bulkheads. Similarly, the scantlings of transverse frames do not have to be defined except for the thickness of the web, which is part of the data entry for fatigue strength of flat bars. The longitudinal girders and stiffeners of the innerbottom are defined as part of the sectional properties. The other menus that provide for definition of the innerbottom structure, such as floors, do not have to be used. The SafeHull Phase A program does not make an analysis of the innerbottom grillage for the purpose of providing stress to use in fatigue analysis.

7.1.8 *Phase A Analysis*

7.1.8.1 When the input is complete as outlined above, the Phase A input is complete and the program should be ready for execution. To check the input, there is a tab on the SafeHull screen called "Utilities" and under it the menu item Input Files." Files can be brought up and printed to ensure that the data has been correctly entered. The format of these files is somewhat diffiecult to follow, and all information, such as global stiffener numbers, is not included. There are not files under this menu for all input items, such as the input of fatigue strength of flat bars. However, additional files are available in the project directory for the ship, and can be checked for input accuracy.

7.1.8.2 There are twelve menu items, or program modules, in the tab "Execute."

- ✠ General Ship & Tank Geometry Information
- ✠ Generate Longitudinal Scantlings
- ✠ Hull-Girder Section Modulus
- ✠ Calculate Longitudinal Scantlings
- • Calculate Torsional Properties
- ✠ Steel Weight Estimate
- • Transverse Members
- • Torsional Stiffness Assessment
- ✠ Fatigue Analysis for Longitudinal Member
- • Fatigue Analysis for Hatch Corner
- • Calculate Shear Strength
- • Calculate Fore and Afterbody Side Stringers

7.1.8.3 Of these, only six program modules, those marked with the symbol "✠", need to be executed to perform the fatigue analysis. In general, because insufficient information has been entered, the other program modules will not execute. These program modules must be executed in sequence. If errors are found in the input during execution and corrected, all of the program modules should be reexecuted.

7.1.8.3 As an aid to the user, a log file is created by the program, providing information on the successful or unsuccesful execution of each program module. Error and warning messages are entered in the log file, and are of some help in diagnosing problems. It is useful to read the log file after the execution of each program module to be certain that there were no errors found during execution. Some error messages will be shown on the screen during execution of a program module, but they usually do not stay on the screen. Most, although not all, of those messages can be found in the log file. The log file can be found under "Utilities, Log Files." If the program is reexecuted, the log file may be deleted to keep it from becoming too long. A copy can be made before deleting if desired.

7.1.8.4 All of the files under the "Utilities" tab may be printed directly, although those in tabular form may not have columns properly aligned in the print-out, depending on the printer being used. They may be copied in two ways. If the left mouse button is clicked and dragged over the file, the text can be selected and then copied using the "Control+C" keys (PC). The text can then be pasted into a word processing or spreadsheet program. Alternately,the file can be found in the project directory and opened into a word processing program.

7.1.8.5 Chapter 15 of the Containership Phase A User's Manual lists the files that are available. They have the names ShipName.*, where ShipName is the name used for the ship being analyzed, and the suffix is assigned according to file type. The files that are applicable to the Phase A fatigue analysis are:

- Stiffener Library — *.SLB
- Multi-Stiffener Library Information — *.SLC
- End Connection Library — *.DLB
- Hatch Corner Library — *.CLB
- Cutout Library — *.TLB
- General Ship Information — *.GDF
- Tank & Cargo Hold Information — *.INT
- Longitudinal Cross Section Scantlings — *.LSC
- Fore & Aft Scantling — *.CFA
- General Ship & Tank Geometry Information — *.OTK
- General Scantling Information For All Groups — *.OSG
- Plate Information For All Groups — *.OPL
- Stiffener Information For All Groups — *.OST
- Hull Girder Section Modulus For All Groups — *.OSC
- Required Longitudinal Scantlings-Detailed — *.OSL
- Required Longitudinal Scantlings-Summary — *.OSM
- Summary of Steel Weight Estimate — *.OWS
- Details of Steel Weight Estimate — *.OWD
- Fatigue Assessment of Longitudinal – Detailed — *.OF1
- Fatigue Assessment of Longitudinal – Summary — *.OF2
- Fatigue Assessment of Flat Bar — *.PRF

7.1.8.6 After execution of the Hull-Girder Section Modulus program module, the file ShipName.OSC should be examined to determine the section modulus computed by SafeHull. The section moduli are provided for the gross section as designed, and for the net section with scantlings reduced for wastage. The gross section properties should be equal to the properties available from other sources, such as a longitudinal strength study or drawing for the ship. Any differences should be reconciled in terms of effective material and input scantlings before the final program modules are executed.

7.1.8.7 When the Fatigue Analysis for Longitudinal Member program module has been successfully executed, the results of the fatigue analysis of longitudinals and of flat bars can be obtained using the Utilities, Output Files, Execute, Fatigue Assessment menu. Under Fatigue Assessment, the output for fatigue assessment of longitudinals can be obtained as either a detailed or a summary file. These fatigue analysis files are also available in the working directory as the files ShipName.OF1, ShipName.OF2, and ShipName.PRF. Their contents are described in Reference 4.1.

7.2. *Data Required for a Phase B Analysis*

7.2.1 *Phase A Considerations*

7.2.1.1..Execution of a Phase B Analysis requires execution of a Phase A analysis. However, with the current version of the Phase B Containership version of SafeHull, the Phase A input for transverse members, including transverse bulkheads, is not used in Phase B. That information is separately input by the user during Phase B, so the effort of creating transverse scantlings in Phase A is not required.

7.2.1.2 When using Phase A input for Phase B analysis, it may be best to rethink the Phase A input of the "plate" sections that describe the longitudinally continuous structure. In Phase B, each one of these "plates" is treated as a "strake" of plating and attached stiffeners. The strakes are used to form quadrilateral finite elements which for a Phase B coarse mesh analysis have the same width as the width of the strake. The length of the finite elements is a user option, but a logical choice is the spacing of transverse frames. However, during Phase A input, emphasis on correct representation of the structure can lead to poor finite element modeling. For example, a seam in the plating may be within 100 mm of a deck, and therefore a Phase A plate will be defined that is 100 mm wide. When this model is used in Phase B, it becomes a strake and finite element that is 100 mm by perhaps 2,000 mm. Such a high aspect ratio represents poor finite element modeling.

7.2.1.3 A better approach would be to reenter the Phase A data to avoid narrow plates. Where there are changes in plating thickness, such as in the side shell between two decks, the thickness should be averaged and one plate defined between decks.

7.2.1.4 Another concern in the Phase A input is to make certain that there are enough plates forming a deck so that in defining transverse bulkheads, vertical finite elements can be joined to deck elements. It may be convenient to have only one plate defined in Phase A to represent a deck, but that will represent poor modeling of a bulkhead. Likewise, the plates in decks should be aligned with those in other decks so that the elements defining transverse bulkheads are vertical.

7.2.2 *The SafeHull Modeler*

7.2.2.1 The modeler in Phase B takes the longitudinally continuous structure created in Phase B as the basis for a finite element mesh. The first step is to convert the plate and stiffener layout into Phase B through the menu File, Import Phase A Data, Plate and Stiffener Layout. An option is available for converting Phase A tank data, but this is unnecessary, as tanks have to be redefined in Phase B. With the limited data used, a message such as "File Creation Error" may be generated. This message can be ignored as long as the file ShipName.3XS is created in the directory.

7.2.2.2 Once the SafeHull Phase A has been imported, the ABS Modeler should be started with the menu item FE-Modeler, ABS Modeler. Now the command File, Import, Phase A data should be used. The file ShipName.3XS should be used to create a model of the starboard side, not the file ShipName.3XP, which creates the port side. If a coarse mesh is selected, elements will be the width of the Phase A plates. Otherwise, in the fine mesh option, there will be an element for every longitudinal stiffener. The "Module Section Length" is input, which represents the length of the finite elements. This should be the transverse frame spacing or a fraction such as one-half or one-third of it. Note that the Phase B units are centimeters, not meters as in Phase A. In Phase B, the model generated should extend from the second transverse bulkhead aft of midships to the second transverse bulkhead forward of midships, so that there are four transverse bulkheads forming three compartments, or holds. Therefore, the number of sections per module should be equal to the length of the model divided by the module section length. If the transverse frames are irregularly spaced, then adjustments to the model will be needed. Figure 10 shows the model generated at this point.

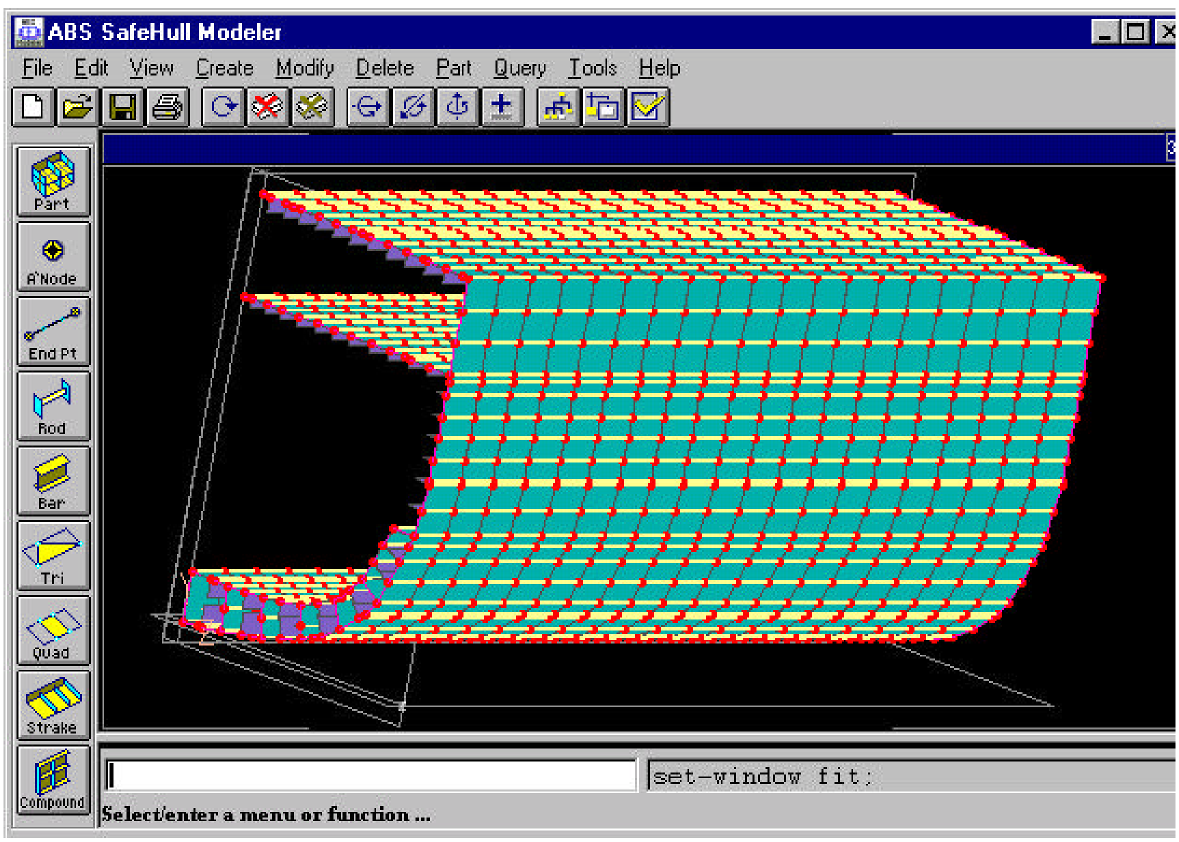

Figure 10 ABS SafeHull Modeler

7.2.2.3 Various commands are available in the ABS Modeler for the input of transverse frames and bulkheads. Other features, such as openings can be made by adding or deleting elements. For stiffeners, the shapes that are in the stiffener library that was created in Phase A are available now. If additional shapes are needed, then the library will have to be edited.

7.2.2.4 There are some differences between the conventions used in the ABS Modeler and in NASTRAN. For example, in the ABS Modeler, the web of a bar element is contained in the plate that is defined by the three points used to define the element. In NASTRAN, the principal axis of a member is normal to that plane. Therefore, the menu and help screens must be read carefully by the user when entering data.

7.2.2.5 The strake element used in the ABS Modeler is convenient because it includes longitudinal and transverse stiffeners. To create the model shown in Figure 10, strake elements with the same properties are placed at every one of the sections along the length of the ship. Therefore, if a transverse frame is added to one strake, it is reproduced at every section along the length of the model. This is a convenient feature if the spacing of the sections in the model is equal to the spacing of transverse frames. However, if the sections of the model are spaced more closely than the transverse frames of the ship, extra transverse frames will be added and will have to be removed from the model.

7.2.2.6 When the ABS Modeler file is completed, it should be saved in the project directory, and then exported as a NASTRAN file. This is done with the command File, Export, NASTRAN. Execution will produce a blank screen similar to Figure 11, which can be ignored.

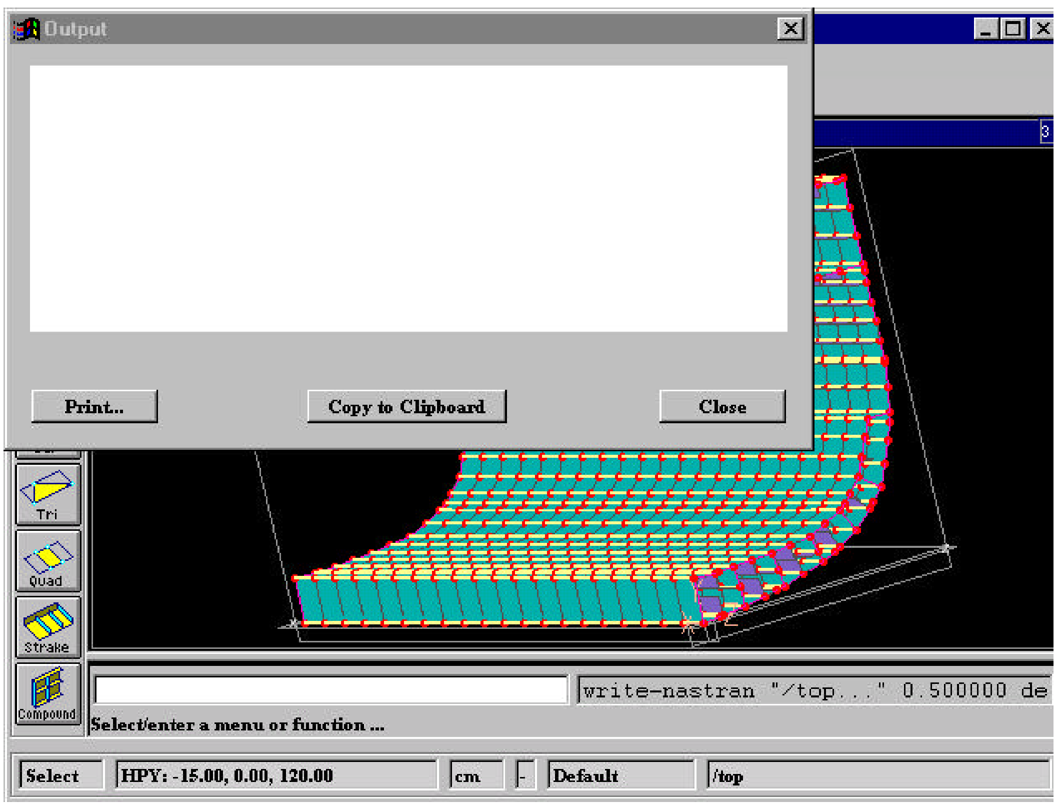

Figure 11 SafeHull Screen after Export of Modeler File to NASTRAN File

7.3 *Limitations when Applying SafeHull to U.S. Navy Ships*

7.3.1 The SafeHull program was developed for the design and analysis of very specific ship types, and not for application to naval vessels. If the above guidance is used to analyze a naval ship, then a successful analysis using the ABS SafeHull program will result. However, there are many limitations associated with this procedure which will diminish the usefulness of the resulting analysis.

7.3.2 There are basic differences in methods of fatigue analysis and factors that must be considered in the development of standardized methods for fatigue analysis, either commercial or military. These differences are outlined below.

I. Technical differences in fatigue analysis
   A. Approach,
      1. S-N fatigue crack initiation analysis
      2. da/dN fatigue crack growth analysis
   B. Loading Analysis
      1. Spectral Fatigue Analysis
      2. Weibull Distribution
      3. Standardized Loads
         a. Hull Girder Bending moments
         b. Side Loads
         c. Generalized RAO's
   C. Fatigue Detail Database
      1. Specialized database
      2. Standardized curves
   D. Hot-Spot stress approach
   E. Inclusion of Hull Girder Whipping
   F. Acceptable Probability of Failure
   G. Standardized Operating Conditions

II. Commercial vs. Military
   A. Calibration of Weibull Loading Spectra for Ship Types and Operating Conditions
   B. Development of Standard Bending Moments for ship Types
   C. Development of RAO's and Whipping Moments for Ship Types
   D. Differences in Assumed Operating Conditions

III. Standardization of Method
   A. Selection of Methodology
   B. Adaptation to Specific Conditions

7.3.3 There are considerable differences between the historical approaches to the structural design of military and commercial ships for environmental loads. These differences have diminished in recent years as the commercial procedures have evolved to include structural design based on analytically developed loads and detailed stress analysis. Both the ABS DLA approach and the current U.S. Navy approach use definition of loads made by analysis of typical ships, and generalize the results for future designs. The approaches, in general, provide for direct computation of ship response and for differences in assumed operational profiles. The differences between procedures may diminish in the future as the classification societies develop rules for military ships and the military authorities adopt these rules. The degree of difference will not be able to be ascertained until ships are designed using the new rules, and the scantlings so developed are compared to equivalent ships designed under the old approach. An important difference as far as fatigue life of structure will be which approach will result in heavier scantlings, and thus have an inherently greater fatigue life. In either case, because fatigue assessment has now become standard practice for both commercial and military ship design, either approach should result in satisfactory fatigue lives.

7.3.4 There is nothing inherent in either a commercial or military ship that should affect the overall methodology. However, the current commercial and military fatigue philosophy is different. The ABS approach is to prevent fatigue cracking, in general, and assess details in highly stressed areas important to safety. The U.S. Navy approach is to prevent fatigue cracking (safe life). These differences in approach come from historical development and preferences in the organizations developing the methods. There are unique features associated with specific ship types and operating environments that can affect a standardized method. The objective of this study is to determine if a standardized method developed from a set of assumptions on hull form, operating environment, and type of structural details can be used in conditions in which those assumptions have changed.

7.3.5 If a methodology developed for commercial ships is applied to military ships, a determination is needed to as to how much difference there will be in results. A broader question can be asked as to the degree of accuracy of any methodology. The paucity of real data points of well- documented service experience combined with the inherent variability in analyses makes calibration poor. Application of fatigue analysis to design and assessment of existing ships seems to be pointing in the right direction for identification of bad actors in the structure that should be fixed, but there is still a lot of inconsistency in results between areas that have cracked and the fatigue predictions. However, comparison of analysis with service failures on operating ships is somewhat shaky, with both unpredicted failures and predictions that are not borne out by experience.

8. Keywords

8.1 SafeHull

8.2 Ship Fatigue

APPENDIX A

FATIGUE ANALYSIS SUMMARY FOR SHIP A

Table A.1 SafeHull Phase A Fatigue Analysis of Class F2 Longitudinals for Ship A

ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : F2 Detailes Length 124.18 m
LxBxDxd = 124.18x 14.42x 7.57x 4.59(m)
Hull-Girder Moment of Inertia Ivert. 76210.(cm2-m2) Ihoriz. 168609.(cm2-m2)
Neutral Axis Height 3.88(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Range of Wave-induced Bending Moment MW(vert.) 56290.(tf-m) MW(horiz.) 31972.(tf-m)

"Net" Ship Cf=0.95 Cw=0.75

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
1	KPL10101	A/	1	0	3959	2.44	1	1	1	1&2	4.25	2414	45	1986	F2	0.912	2503	0.79	24x14x130# I-T	CVKFPK01
		F/	1	0	3959	2.44	1	1	1	1&2	4.25	2414	45	1986	F2	0.912	2503	0.79		CVKFPK01
2	BTM10101	A/	1	0.03	225	2.44	1	1	1	1&2	4.25	2659	728	2735	F2	0.912	2503	1.09	10 X 4 X 15# I/T	S1 01
		F/	1	0.03	225	2.44	1	1	1	1&2	4.25	2659	728	2735	F2	0.912	2503	1.09		S1 01
3	BTM10202	A/	2	0.08	225	2.34	1	1	1	1&2	4.25	2623	607	2607	F2	0.912	2503	1.04	10 X 4 X 15# I/T	S2 02
		F/	1	0.08	225	2.34	1	1	1	1&2	4.25	2623	607	2607	F2	0.912	2503	1.04		S2 02
4	BTM10303	A/	1	0.2	225	2.44	1	1	1	1&2	4.25	2534	668	2586	F2	0.912	2503	1.03	10 X 4 X 15# I/T	S3 03
		F/	1	0.2	225	2.44	1	1	1	1&2	4.25	2534	668	2586	F2	0.912	2503	1.03		S3 03
5	BTM10404	A/	1	0.43	1120	2.44	1	1	1	1&2	4.25	2206	140	1894	F2	0.912	2503	0.76	18x7x12.75#/17.85#	S4 04
		F/	1	0.43	1120	2.44	1	1	1	1&2	4.25	2206	140	1894	F2	0.912	2503	0.76		S4 04
6	BTM10505	A/	1	0.77	163	2.44	1	1	1	1&2	4.25	2115	928	2457	F2	0.912	2503	0.98	10 X 4 X 12# I/T	S5 05
		F/	1	0.77	163	2.44	1	1	1	1&2	4.25	2115	928	2457	F2	0.912	2503	0.98		S5 05
7	BLG10101	A/	2	1.24	163	2.34	1	1	1	TZONE		1805	1167	2823	F2	0.912	2503	1.13	10 X 4 X 12# I/T	S6 01
		F/	1	1.24	163	2.34	1	1	1	TZONE		1805	1167	2823	F2	0.912	2503	1.13		S6 01

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
8	SHL10101	A/	1	1.91	177	2.44	1	1	1	F1&F2	7.69	1713	1519	3071	F2	0.949	2360	1.3	10 X 4 X 12# I/T	S7 01
		F/	1	1.91	177	2.44	1	1	1	F1&F2	7.69	1713	1519	3071	F2	0.949	2360	1.3		S7 01
9	SHL10202	A/	2	2.63	176	2.34	1	1	1	F1&F2	8.55	1589	1418	2857	F2	0.949	2360	1.21	10 X 4 X 12# I/T	S8 02
		F/	1	2.63	176	2.34	1	1	1	F1&F2	8.55	1589	1418	2857	F2	0.949	2360	1.21		S8 02
10	SHL10303	A/	1	3.39	98	2.44	1	1	1	5&6	13.14	496	4043	4312	F2	0.949	2360	1.83	WT6 x 4 x 7 #T	S9 03
		F/	1	3.39	98	2.44	1	1	1	5&6	13.14	496	4043	4312	F2	0.949	2360	1.83		S9 03
11	SHL10404	A/	1	4.15	98	2.44	1	0.98	1	F1&F2	11.44	1395	3445	4598	F2	0.949	2360	1.95	WT6 x 4 x 7 #T	S10 04
		F/	1	4.15	98	2.44	1	0.98	1	F1&F2	11.44	1395	3445	4598	F2	0.949	2360	1.95		S10 04
12	SHS10101	A/	1	4.95	251	2.44	1	1	1	F1&F2	10.91	1612	1440	2899	F2	0.949	2360	1.23	12 X 4 X 14# I/T	S11 01
		F/	1	4.95	251	2.44	1	1	1	F1&F2	10.91	1612	1440	2899	F2	0.949	2360	1.23		S11 01
13	SHS10202	A/	1	5.82	100	2.44	1	1	1	TZONE		1785	2339	3917	F2	0.94	2396	1.64	WT6 x 4 x 7 #T	S12 02
		F/	1	5.82	100	2.44	1	1	1	TZONE		1785	2339	3917	F2	0.94	2396	1.64		S12 02
14	SHS10303	A/	2	6.67	173	2.34	1	1	1	TZONE		2068	334	2282	F2	0.885	2636	0.87	8 X 4 X 13# I/T	S13 03
		F/	1	6.67	173	2.34	1	1	1	TZONE		2068	334	2282	F2	0.885	2636	0.87		S13 03
15	DEC10201	A/	2	7.67	171	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.67	171	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
16	DEC10302	A/	1	7.71	171	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.71	171	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
17	DEC10403	A/	2	7.77	169	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.77	169	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
18	DEC10504	A/	1	7.81	169	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.81	169	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
19	DEC10605	A/	2	7.85	169	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.85	169	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
20	DEC10706	A/	1	7.86	169	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.86	169	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
21	DEC10807	A/	2	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
22	DEC10908	A/	1	7.87	160	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
		F/	1	7.87	160	2.44	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
23	DEC10909	A/	2	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91	8 X 4 X 13# I/T	
		F/	1	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F2	0.875	2688	0.91		
24	SDK10101	A/	1	4.95	70	2.44	1	1	1	F1&F2	0	1525	0	1448	F2	0.949	2360	0.61	WT5 x 4 x 6# T	1st Pl01
		F/	1	4.95	70	2.44	1	1	1	F1&F2	0	1525	0	1448	F2	0.949	2360	0.61		1st Pl01
25	SDK10202	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	1327	0	1260	F2	0.949	2360	0.53	WT5 x 4 x 6# T	1stPl_02
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	1327	0	1260	F2	0.949	2360	0.53		1stPl_02
26	SDK10203	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	1182	0	1123	F2	0.949	2360	0.48	WT5 x 4 x 6# T	1stPl_03
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	1182	0	1123	F2	0.949	2360	0.48		1stPl_03
27	SDK10204	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	1038	0	986	F2	0.949	2360	0.42	WT5 x 4 x 6# T	1stPl_04
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	1038	0	986	F2	0.949	2360	0.42		1stPl_04
28	SDK10205	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	893	0	849	F2	0.949	2360	0.36	WT5 x 4 x 6# T	1stPl_05
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	893	0	849	F2	0.949	2360	0.36		1stPl_05
29	SDK10206	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	749	0	711	F2	0.949	2360	0.3	WT5 x 4 x 6# T	1stPl_06
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	749	0	711	F2	0.949	2360	0.3		1stPl_06
30	SDK10207	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	604	0	574	F2	0.949	2360	0.24	WT5 x 4 x 6# T	1stPl_07
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	604	0	574	F2	0.949	2360	0.24		1stPl_07
31	SDK10208	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	460	0	437	F2	0.949	2360	0.19	WT5 x 4 x 6# T	1stPl_08
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	460	0	437	F2	0.949	2360	0.19		1stPl_08
32	SDK10209	A/	1	4.95	65	2.44	1	1	1	7&8	0	315	0	300	F2	0.949	2360	0.13	WT5 x 4 x 6# T	1stPl_09
		F/	1	4.95	65	2.44	1	1	1	7&8	0	315	0	300	F2	0.949	2360	0.13		1stPl_09

Table A.2 SafeHull Phase A Fatigue Analysis of Class F2 Flat Bars for Ship A

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)

SHIP : F2 DetaIes Length 124.18 m

LxBxDxd = 124.18x 14.42x 7.57x 4.59(m)

Hull-Girder Moment of Inertia Ivert. 76210.(cm2-m2) Ihoriz. 168609.(cm2-m2)

Neutral Axis Height 3.88(m) above baseline

Slamming factor for deck and bottom structures, ms= 1.000

FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS

S U M M A R Y

Special Location at 64.01m from AP (0.485 L from aft end of L)

Scantling Group # 1

Range of Wave-induced Bending Moment MW(vert.) 56290.(tf-m) MW(horiz.) 31972.(tf-m)

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range Head (m)	Local Load Range Force (tf)	Support Areas As (cm^2)	Support Areas Ac	SCF	Stress Range (kg/cm2) fs	Stress Range (kg/cm2) fL	fRi	FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
BLG10101	1	1	1.24	0.927	2.34	5.84	12.99	7.9	38.8	1.5	265	2823	2851	F2	0.912	2503	1.14
		2	1.24	0.927	2.34	5.84	12.99	7.9	38.8	1.25	265	2823	2843	F2	0.912	2503	1.14
[Weld Throat]			1.24	0.927	2.34	5.84	12.99	[Asw]=	8	1.25	265	0	326	W	0.912	1805	0.18
SHS10303	2	1	6.67	0.878	2.34	1.87	3.94	7.9	23.2	1.5	121	2282	2289	F2	0.885	2636	0.87
		2	6.67	0.878	2.34	1.87	3.94	7.9	23.2	1.25	121	2282	2287	F2	0.885	2636	0.87
[Weld Throat]			6.67	0.878	2.34	1.87	3.94	[Asw]=	8	1.25	121	0	149	W	0.885	1900	0.08
DEC10201	2	1	7.67	0.804	2.34	0	0	6.3	0	1.5	0	2445	2445	F2	0.875	2688	0.91
		2	7.67	0.804	2.34	0	0	6.3	0	1.25	0	2445	2445	F2	0.875	2688	0.91
[Weld Throat]			7.67	0.804	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10403	2	1	7.77	0.807	2.34	0	0	6.3	0	1.5	0	2445	2445	F2	0.875	2688	0.91
		2	7.77	0.807	2.34	0	0	6.3	0	1.25	0	2445	2445	F2	0.875	2688	0.91
[Weld Throat]			7.77	0.807	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10605	2	1	7.85	0.836	2.34	0	0	6.3	0	1.5	0	2445	2445	F2	0.875	2688	0.91

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2)	Ac		fs	fL	fRi				
		2	7.85	0.836	2.34	0	0	6.3	0	1.25	0	2445	2445	F2	0.875	2688	0.91
[Weld Throat]			7.85	0.836	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10807	2	1	7.87	0.735	2.34	0	0	6.3	0	1.5	0	2445	2445	F2	0.875	2688	0.91
		2	7.87	0.735	2.34	0	0	6.3	0	1.25	0	2445	2445	F2	0.875	2688	0.91
[Weld Throat]			7.87	0.735	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10909	2	1	7.87	0.66	2.34	0	0	6.3	0	1.5	0	2445	2445	F2	0.875	2688	0.91
		2	7.87	0.66	2.34	0	0	6.3	0	1.25	0	2445	2445	F2	0.875	2688	0.91
[Weld Throat]			7.87	0.66	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0

Table A.3 SafeHull Phase A Fatigue Analysis of Class F Longitudinals for Ship A

15 MARCH 2001 14:57:10 PAGE: 1
ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : Class F Details Length 124.18 m
LxBxDxd = 124.18x 14.42x 7.57x 4.59(m)
Hull-Girder Moment of Inertia Ivert. 76210.(cm2-m2) Ihoriz. 168609.(cm2-m2)
Neutral Axis Height 3.88(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 64.01m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 56290.(tf-m) MW(horiz.) 31972.(tf-m)
******** "Net" Ship ******** Local Cf=0.95 Cw=0.75 Long Perm.

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/ cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
1	KPL10101	A/	1	0	3959	2.44	1	1	1	1&2	4.25	2414	45	1986	F	0.912	2846	0.7	24x14x130# I-T	CVKFPK01
		F/	1	0	3959	2.44	1	1	1	1&2	4.25	2414	45	1986	F	0.912	2846	0.7		CVKFPK01
2	BTM10101	A/	1	0.03	225	2.44	1	1	1	1&2	4.25	2659	728	2735	F	0.912	2846	0.96	10 X 4 X 15# I/T	S1 01
		F/	1	0.03	225	2.44	1	1	1	1&2	4.25	2659	728	2735	F	0.912	2846	0.96		S1 01
3	BTM10202	A/	2	0.08	225	2.34	1	1	1	1&2	4.25	2623	607	2607	F	0.912	2846	0.92	10 X 4 X 15# I/T	S2 02
		F/	1	0.08	225	2.34	1	1	1	1&2	4.25	2623	607	2607	F	0.912	2846	0.92		S2 02
4	BTM10303	A/	1	0.2	225	2.44	1	1	1	1&2	4.25	2534	668	2586	F	0.912	2846	0.91	10 X 4 X 15# I/T	S3 03
		F/	1	0.2	225	2.44	1	1	1	1&2	4.25	2534	668	2586	F	0.912	2846	0.91		S3 03
5	BTM10404	A/	1	0.43	1120	2.44	1	1	1	1&2	4.25	2206	140	1894	F	0.912	2846	0.67	18x7x12.75#/17.85#	S4 04
		F/	1	0.43	1120	2.44	1	1	1	1&2	4.25	2206	140	1894	F	0.912	2846	0.67		S4 04

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/ cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
6	BTM10505	A/	1	0.77	163	2.44	1	1	1	1&2	4.25	2115	928	2457	F	0.912	2846	0.86	10 X 4 X 12# I/T	S5 05
		F/	1	0.77	163	2.44	1	1	1	1&2	4.25	2115	928	2457	F	0.912	2846	0.86		S5 05
7	BLG10101	A/	2	1.24	163	2.34	1	1	1	TZONE		1805	1167	2823	F	0.912	2846	0.99	10 X 4 X 12# I/T	S6 01
		F/	1	1.24	163	2.34	1	1	1	TZONE		1805	1167	2823	F	0.912	2846	0.99		S6 01
8	SHL10101	A/	1	1.91	177	2.44	1	1	1	F1&F2	7.69	1713	1519	3071	F	0.949	2680	1.15	10 X 4 X 12# I/T	S7 01
		F/	1	1.91	177	2.44	1	1	1	F1&F2	7.69	1713	1519	3071	F	0.949	2680	1.15		S7 01
9	SHL10202	A/	2	2.63	176	2.34	1	1	1	F1&F2	8.55	1589	1418	2857	F	0.949	2680	1.07	10 X 4 X 12# I/T	S8 02
		F/	1	2.63	176	2.34	1	1	1	F1&F2	8.55	1589	1418	2857	F	0.949	2680	1.07		S8 02
10	SHL10303	A/	1	3.39	98	2.44	1	1	1	5&6	13.14	496	4043	4312	F	0.949	2680	1.61	WT6 x 4 x 7 #T	S9 03
		F/	1	3.39	98	2.44	1	1	1	5&6	13.14	496	4043	4312	F	0.949	2680	1.61		S9 03
11	SHL10404	A/	1	4.15	98	2.44	1	0.98	1	F1&F2	11.44	1395	3445	4598	F	0.949	2680	1.72	WT6 x 4 x 7 #T	S10 04
		F/	1	4.15	98	2.44	1	0.98	1	F1&F2	11.44	1395	3445	4598	F	0.949	2680	1.72		S10 04
12	SHS10101	A/	1	4.95	251	2.44	1	1	1	F1&F2	10.91	1612	1440	2899	F	0.949	2680	1.08	12 X 4 X 14# I/T	S11 01
		F/	1	4.95	251	2.44	1	1	1	F1&F2	10.91	1612	1440	2899	F	0.949	2680	1.08		S11 01
13	SHS10202	A/	1	5.82	100	2.44	1	1	1	TZONE		1785	2339	3917	F	0.94	2722	1.44	WT6 x 4 x 7 #T	S12 02
		F/	1	5.82	100	2.44	1	1	1	TZONE		1785	2339	3917	F	0.94	2722	1.44		S12 02
14	SHS10303	A/	2	6.67	173	2.34	1	1	1	TZONE		2068	334	2282	F	0.885	2997	0.76	8 X 4 X 13# I/T	S13 03
		F/	1	6.67	173	2.34	1	1	1	TZONE		2068	334	2282	F	0.885	2997	0.76		S13 03
15	DEC10201	A/	2	7.67	171	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.67	171	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
16	DEC10302	A/	1	7.71	171	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.71	171	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
17	DEC10403	A/	2	7.77	169	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.77	169	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
18	DEC10504	A/	1	7.81	169	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.81	169	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
19	DEC10605	A/	2	7.85	169	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.85	169	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/ cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
20	DEC10706	A/	1	7.86	169	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.86	169	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
21	DEC10807	A/	2	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
22	DEC10908	A/	1	7.87	160	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.87	160	2.44	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
23	DEC10909	A/	2	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8	8 X 4 X 13# I/T	
		F/	1	7.87	159	2.34	1	1	1	1&2	0	2574	0	2445	F	0.875	3055	0.8		
24	SDK10101	A/	1	4.95	70	2.44	1	1	1	F1&F2	0	1525	0	1448	F	0.949	2680	0.54	WT5 x 4 x 6# T	1st Pl01
		F/	1	4.95	70	2.44	1	1	1	F1&F2	0	1525	0	1448	F	0.949	2680	0.54		1st Pl01
25	SDK10202	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	1327	0	1260	F	0.949	2680	0.47	WT5 x 4 x 6# T	1stPl_02
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	1327	0	1260	F	0.949	2680	0.47		1stPl_02
26	SDK10203	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	1182	0	1123	F	0.949	2680	0.42	WT5 x 4 x 6# T	1stPl_03
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	1182	0	1123	F	0.949	2680	0.42		1stPl_03
27	SDK10204	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	1038	0	986	F	0.949	2680	0.37	WT5 x 4 x 6# T	1stPl_04
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	1038	0	986	F	0.949	2680	0.37		1stPl_04
28	SDK10205	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	893	0	849	F	0.949	2680	0.32	WT5 x 4 x 6# T	1stPl_05
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	893	0	849	F	0.949	2680	0.32		1stPl_05
29	SDK10206	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	749	0	711	F	0.949	2680	0.27	WT5 x 4 x 6# T	1stPl_06
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	749	0	711	F	0.949	2680	0.27		1stPl_06
30	SDK10207	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	604	0	574	F	0.949	2680	0.21	WT5 x 4 x 6# T	1stPl_07
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	604	0	574	F	0.949	2680	0.21		1stPl_07
31	SDK10208	A/	1	4.95	65	2.44	1	1	1	F1&F2	0	460	0	437	F	0.949	2680	0.16	WT5 x 4 x 6# T	1stPl_08
		F/	1	4.95	65	2.44	1	1	1	F1&F2	0	460	0	437	F	0.949	2680	0.16		1stPl_08
32	SDK10209	A/	1	4.95	65	2.44	1	1	1	7&8	0	315	0	300	F	0.949	2680	0.11	WT5 x 4 x 6# T	1stPl_09
		F/	1	4.95	65	2.44	1	1	1	7&8	0	315	0	300	F	0.949	2680	0.11		1stPl_09

Table A.4 SafeHull Phase A Fatigue Analysis of Class F Flat Bars for Ship A

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : Class F Details Length 124.18 m
LxBxDxd = 124.18x 14.42x 7.57x 4.59(m)
Hull-Girder Moment of Inertia Ivert. 76210.(cm2-m2) Ihoriz. 168609.(cm2-m2)
Neutral Axis Height 3.88(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 64.01m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 56290.(tf-m) MW(horiz.) 31972.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2)	Ac		fs	fL	fRi				
BLG10101	1	1	1.24	0.927	2.34	5.84	12.99	7.9	38.8	1.5	265	2823	2851	F	0.912	2846	1
		2	1.24	0.927	2.34	5.84	12.99	7.9	38.8	1.25	265	2823	2843	F	0.912	2846	1
[Weld Throat]			1.24	0.927	2.34	5.84	12.99	[Asw]=	8	1.25	265	0	326	W	0.912	1805	0.18
SHS10303	2	1	6.67	0.878	2.34	1.87	3.94	7.9	23.2	1.5	121	2282	2289	F	0.885	2997	0.76
		2	6.67	0.878	2.34	1.87	3.94	7.9	23.2	1.25	121	2282	2287	F	0.885	2997	0.76
[Weld Throat]			6.67	0.878	2.34	1.87	3.94	[Asw]=	8	1.25	121	0	149	W	0.885	1900	0.08
DEC10201	2	1	7.67	0.804	2.34	0	0	6.3	0	1.5	0	2445	2445	F	0.875	3055	0.8
		2	7.67	0.804	2.34	0	0	6.3	0	1.25	0	2445	2445	F	0.875	3055	0.8
[Weld Throat]			7.67	0.804	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10403	2	1	7.77	0.807	2.34	0	0	6.3	0	1.5	0	2445	2445	F	0.875	3055	0.8
		2	7.77	0.807	2.34	0	0	6.3	0	1.25	0	2445	2445	F	0.875	3055	0.8
[Weld Throat]			7.77	0.807	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissibl eStress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2)	Ac		fs	fL	fRi				
DEC10605	2	1	7.85	0.836	2.34	0	0	6.3	0	1.5	0	2445	2445	F	0.875	3055	0.8
		2	7.85	0.836	2.34	0	0	6.3	0	1.25	0	2445	2445	F	0.875	3055	0.8
[Weld Throat]			7.85	0.836	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10807	2	1	7.87	0.735	2.34	0	0	6.3	0	1.5	0	2445	2445	F	0.875	3055	0.8
		2	7.87	0.735	2.34	0	0	6.3	0	1.25	0	2445	2445	F	0.875	3055	0.8
[Weld Throat]			7.87	0.735	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0
DEC10909	2	1	7.87	0.66	2.34	0	0	6.3	0	1.5	0	2445	2445	F	0.875	3055	0.8
		2	7.87	0.66	2.34	0	0	6.3	0	1.25	0	2445	2445	F	0.875	3055	0.8
[Weld Throat]			7.87	0.66	2.34	0	0	[Asw]=	8	1.25	0	0	0	W	0.875	1936	0

APPENDIX B

FATIGUE ANALYSIS SUMMARY FOR SHIP B

Table B.1 SafeHull Phase A Fatigue Analysis of Class F2 Longitudinals for Ship B

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midships
LxBxDxd = 162.02x 25.67x 16.61x 6.55(m)
Hull-Girder Moment of Inertia Ivert. 883156.(cm2-m2) Ihoriz. 1958098.(cm2-m2)
Neutral Axis Height 7.57(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 83.51m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 180100.(tf-m) MW(horiz.) 122681.(tf-m)

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
1	BTM10801	A/	1	0.24	509	2.362	1	1	2	1&2	4.86	1434	266	1373	F2	0.885	2631	0.52	12 x 6.5 x 27# I-	Strake01
		F/	2	0.24	509	2.362	1	1	2	1&2	4.86	1434	266	1373	F2	0.885	2631	0.52		Strake01
2	BTM10802	A/	1	0.28	509	2.362	1	1	2	1&2	4.86	1424	261	1360	F2	0.885	2631	0.52	12 x 6.5 x 27# I-	Strake02
		F/	2	0.28	509	2.362	1	1	2	1&2	4.86	1424	261	1360	F2	0.885	2631	0.52		Strake02
3	BLG10201	A/	1	0.73	509	2.362	1	1	2	1&2	4.81	1334	306	1325	F2	0.885	2631	0.5	12 x 6.5 x 27# I-	Strake01
		F/	2	0.73	509	2.362	1	1	2	1&2	4.81	1334	306	1325	F2	0.885	2631	0.5		Strake01
4	BLG10302	A/	1	1.22	509	2.362	1	1	2	1&2	5.08	1233	335	1266	F2	0.885	2631	0.48	12 x 6.5 x 27# I-	Strake02
		F/	2	1.22	509	2.362	1	1	2	1&2	5.08	1233	335	1266	F2	0.885	2631	0.48		Strake02
5	BLG10303	A/	1	2.08	509	2.362	1	1	2	TZONE		1092	424	1440	F2	0.885	2631	0.55	12 x 6.5 x 27# I-	Strake03
		F/	2	2.08	509	2.362	1	1	2	TZONE		1092	424	1440	F2	0.885	2631	0.55		Strake03
6	BLG10304	A/	1	2.93	509	2.362	1	1	2	TZONE		1085	559	1561	F2	0.885	2631	0.59	12 x 6.5 x 27# I-	Strake04
		F/	2	2.93	509	2.362	1	1	2	TZONE		1085	559	1561	F2	0.885	2631	0.59		Strake04

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm 2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
7	SHL10101	A/	1	3.87	418	2.362	1	1	2	F1&F2	9.67	1059	659	1632	F2	0.924	2456	0.66	12 x 4 x 22# I-T	G Stra01
		F/	2	3.87	418	2.362	1	1	2	F1&F2	9.67	1059	659	1632	F2	0.924	2456	0.66		G Stra01
8	SHL10202	A/	1	4.51	223	2.362	1	1	2	F1&F2	9.94	1014	1239	2140	F2	0.924	2456	0.87	10 x 4 x 15# I-T	H Stra02
		F/	2	4.51	223	2.362	1	1	2	F1&F2	9.94	1014	1239	2140	F2	0.924	2456	0.87		H Stra02
9	SHL10203	A/	1	5.42	223	2.362	1	1	2	F1&F2	11.02	944	1607	2423	F2	0.924	2456	0.99	10 x 4 x 15# I-T	H Stra03
		F/	2	5.42	223	2.362	1	1	2	F1&F2	11.02	944	1607	2423	F2	0.924	2456	0.99		H Stra03
10	SHL10204	A/	1	6.33	223	2.362	1	0.75	2	F1&F2	12.11	874	1474	2231	F2	0.924	2456	0.91	10 x 4 x 15# I-T	H Stra04
		F/	2	6.33	223	2.362	1	0.75	2	F1&F2	12.11	874	1474	2231	F2	0.924	2456	0.91		H Stra04
11	SHL10305	A/	1	7.43	200	2.362	1	0.4	2	F1&F2	11.21	786	815	1521	F2	0.924	2456	0.62	10 x 4 x 15# I-T	J1 Str05
		F/	2	7.43	200	2.362	1	0.4	2	F1&F2	11.21	786	815	1521	F2	0.924	2456	0.62		J1 Str05
12	SHL10506	A/	1	9.23	102	2.438	1	0.3	1	F1&F2	8.88	920	825	1658	F2	0.924	2456	0.68	6 X 4 X 7# T	K Stra06
		F/	1	9.23	102	2.438	1	0.3	1	F1&F2	8.88	920	825	1658	F2	0.924	2456	0.68		K Stra06
13	SHL10507	A/	1	10.04	102	2.438	1	0.3	1	F1&F2	7.91	988	704	1607	F2	0.924	2456	0.65	6 X 4 X 7# T	K Stra07
		F/	1	10.04	102	2.438	1	0.3	1	F1&F2	7.91	988	704	1607	F2	0.924	2456	0.65		K Stra07
14	SHL10708	A/	1	11.76	102	2.438	1	0.3	1	F1&F2	5.84	1130	614	1657	F2	0.924	2456	0.67	6 X 4 X 7# T	L2 Str08
		F/	1	11.76	102	2.438	1	0.3	1	F1&F2	5.84	1130	614	1657	F2	0.924	2456	0.67		L2 Str08
15	SHL10809	A/	1	12.7	102	2.438	1	0.3	1	TZONE		1163	429	1513	F2	0.917	2485	0.61	6 X 4 X 7# T	M1 Str09
		F/	1	12.7	102	2.438	1	0.3	1	TZONE		1163	429	1513	F2	0.917	2485	0.61		M1 Str09
16	SHL11010	A/	1	14.17	446	2.438	1	0.3	1	TZONE		1340	19	1291	F2	0.871	2713	0.48	10 x 5.75 x 25# I-T	N Stra10
		F/	1	14.17	446	2.438	1	0.3	1	TZONE		1340	19	1291	F2	0.871	2713	0.48		N Stra10
17	SHS10101	A/	1	15.01	446	2.438	1	1	1	1&2	0	1517	0	1441	F2	0.847	2848	0.51	10 x 5.75 x 25# I-T	Shr St01
		F/	1	15.01	446	2.438	1	1	1	1&2	0	1517	0	1441	F2	0.847	2848	0.51		Shr St01
18	SHS10102	A/	1	15.81	446	2.438	1	1	1	1&2	0	1680	0	1596	F2	0.847	2848	0.56	10 x 5.75 x 25# I-T	Shr St02
		F/	1	15.81	446	2.438	1	1	1	1&2	0	1680	0	1596	F2	0.847	2848	0.56		Shr St02
19	DEC10101	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O01
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O01
20	DEC10102	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O02
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O02

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
21	DEC10103	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O03
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O03
22	DEC10104	A/	1	16.61	920	4.877	1	1	1	1&2	0	1792	0	1702	F2	0.847	2848	0.6	10 x 10 x 49 # I	MnDk O04
		F/	1	16.61	920	4.877	1	1	1	1&2	0	1792	0	1702	F2	0.847	2848	0.6		MnDk O04
23	DEC10105	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O05
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O05
24	DEC10106	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O06
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O06
25	DEC10107	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O07
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O07
26	DEC10108	A/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk O08
		F/	1	16.61	388	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk O08
27	DEC10209	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I09
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I09
28	DEC10210	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I10
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I10
29	DEC10211	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I11
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I11
30	DEC10212	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I12
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I12
31	DEC10213	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I13
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I13
32	DEC10214	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I14
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I14
33	DEC10215	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I15
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I15
34	DEC10216	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I16
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I16

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
35	DEC10217	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I17
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I17
36	DEC10218	A/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I18
		F/	1	16.61	383	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I18
37	DEC10319	A/	1	16.61	119	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I19
		F/	1	16.61	119	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I19
38	DEC10320	A/	1	16.61	119	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I20
		F/	1	16.61	119	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I20
39	DEC10321	A/	1	16.61	119	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59	12 x 4 x 19# I-T	MnDk I21
		F/	1	16.61	119	4.877	1	1	1	1&2	0	1781	0	1692	F2	0.847	2848	0.59		MnDk I21
40	WTF10101	A/	1	7.24	204	2.362	1	1	1	F1&F2	0	27	0	26	F2	0.847	2848	0.01	8 x 5.25 x 17# I-T	4tdDkI01
		F/	2	7.24	204	2.362	1	1	1	F1&F2	0	27	0	26	F2	0.847	2848	0.01		4tdDkI01
41	WTF10102	A/	1	7.24	204	2.362	1	1	1	F1&F2	0	87	0	83	F2	0.847	2848	0.03	8 x 5.25 x 17# I-T	4tdDkI02
		F/	2	7.24	204	2.362	1	1	1	F1&F2	0	87	0	83	F2	0.847	2848	0.03		4tdDkI02
42	WTF10103	A/	1	7.24	204	2.438	1	1	1	F1&F2	0	147	0	140	F2	0.847	2848	0.05	8 x 5.25 x 17# I-T	4tdDkI03
		F/	1	7.24	204	2.438	1	1	1	F1&F2	0	147	0	140	F2	0.847	2848	0.05		4tdDkI03
43	WTF10104	A/	1	7.24	204	2.438	1	1	1	F1&F2	0	207	0	197	F2	0.847	2848	0.07	8 x 5.25 x 17# I-T	4tdDkI04
		F/	1	7.24	204	2.438	1	1	1	F1&F2	0	207	0	197	F2	0.847	2848	0.07		4tdDkI04
44	WTF10105	A/	1	7.24	204	2.438	1	1	1	F1&F2	0	267	0	254	F2	0.847	2848	0.09	8 x 5.25 x 17# I-T	4tdDkI05
		F/	1	7.24	204	2.438	1	1	1	F1&F2	0	267	0	254	F2	0.847	2848	0.09		4tdDkI05
45	WTF10106	A/	1	7.24	204	2.438	1	1	1	F1&F2	0	327	0	311	F2	0.847	2848	0.11	8 x 5.25 x 17# I-T	4tdDkI06
		F/	1	7.24	204	2.438	1	1	1	F1&F2	0	327	0	311	F2	0.847	2848	0.11		4tdDkI06
46	WTF10107	A/	1	7.24	204	2.438	1	1	1	F1&F2	0	387	0	368	F2	0.847	2848	0.13	8 x 5.25 x 17# I-T	4tdDkI07
		F/	1	7.24	204	2.438	1	1	1	F1&F2	0	387	0	368	F2	0.847	2848	0.13		4tdDkI07
47	WTF10108	A/	1	7.24	204	2.362	1	1	1	F1&F2	0	447	0	425	F2	0.847	2848	0.15	8 x 5.25 x 17# I-T	4tdDkI08
		F/	2	7.24	204	2.362	1	1	1	F1&F2	0	447	0	425	F2	0.847	2848	0.15		4tdDkI08
48	WTF20201	A/	1	8.38	105	2.438	1	1	1	F1&F2	0.84	546	139	651	F2	0.847	2848	0.23	6 x 4 x 12# T	4thDkO01
		F/	1	8.38	105	2.438	1	1	1	F1&F2	0.84	546	139	651	F2	0.847	2848	0.23		4thDkO01

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
49	WTF20202	A/	1	8.38	105	2.438	1	1	1	F1&F2	0.72	575	120	660	F2	0.847	2848	0.23	6 x 4 x 12# T	4thDkO02
		F/	1	8.38	105	2.438	1	1	1	F1&F2	0.72	575	120	660	F2	0.847	2848	0.23		4thDkO02
50	WTF20203	A/	1	8.38	105	2.438	1	1	1	F1&F2	0.61	603	101	668	F2	0.847	2848	0.23	6 x 4 x 12# T	4thDkO03
		F/	1	8.38	105	2.438	1	1	1	F1&F2	0.61	603	101	668	F2	0.847	2848	0.23		4thDkO03
51	WTF20204	A/	1	8.38	105	2.438	1	1	1	F1&F2	0.49	632	81	677	F2	0.847	2848	0.24	6 x 4 x 12# T	4thDkO04
		F/	1	8.38	105	2.438	1	1	1	F1&F2	0.49	632	81	677	F2	0.847	2848	0.24		4thDkO04
52	WTF20205	A/	1	8.38	105	2.438	1	1	1	F1&F2	0.37	660	62	686	F2	0.847	2848	0.24	6 x 4 x 12# T	4thDkO05
		F/	1	8.38	105	2.438	1	1	1	F1&F2	0.37	660	62	686	F2	0.847	2848	0.24		4thDkO05
53	WTF20306	A/	1	8.38	81	2.438	1	1	1	F1&F2	0.77	751	354	1049	F2	0.847	2848	0.37	5 x 4 x 7.5 # T	4thDkO06
		F/	1	8.38	81	2.438	1	1	1	F1&F2	0.77	751	354	1049	F2	0.847	2848	0.37		4thDkO06
54	WTF20307	A/	1	8.38	81	2.438	1	1	1	F1&F2	0.52	811	212	972	F2	0.847	2848	0.34	5 x 4 x 7.5 # T	4thDkO07
		F/	1	8.38	81	2.438	1	1	1	F1&F2	0.52	811	212	972	F2	0.847	2848	0.34		4thDkO07
55	WTF30501	A/	1	10.82	1557	2.438	1	1	1	F1&F2	0	387	0	367	F2	0.847	2848	0.13	18 x 8.75 x 70# I-T	3rdDkI01
		F/	1	10.82	1557	2.438	1	1	1	F1&F2	0	387	0	367	F2	0.847	2848	0.13		3rdDkI01
56	WTF30502	A/	1	10.82	204	2.438	1	1	1	F1&F2	0	446	0	424	F2	0.847	2848	0.15	8 x 5.25 x 17# I-T	3rdDkI02
		F/	1	10.82	204	2.438	1	1	1	F1&F2	0	446	0	424	F2	0.847	2848	0.15		3rdDkI02
57	WTF30503	A/	1	10.82	204	2.438	1	1	1	F1&F2	0	506	0	481	F2	0.847	2848	0.17	8 x 5.25 x 17# I-T	3rdDkI03
		F/	1	10.82	204	2.438	1	1	1	F1&F2	0	506	0	481	F2	0.847	2848	0.17		3rdDkI03
58	WTF30504	A/	1	10.82	204	2.438	1	1	1	F1&F2	0	566	0	538	F2	0.847	2848	0.19	8 x 5.25 x 17# I-T	3rdDkI04
		F/	1	10.82	204	2.438	1	1	1	F1&F2	0	566	0	538	F2	0.847	2848	0.19		3rdDkI04
59	WTF30505	A/	1	10.82	204	2.438	1	1	1	F1&F2	0	626	0	594	F2	0.847	2848	0.21	8 x 5.25 x 17# I-T	3rdDkI05
		F/	1	10.82	204	2.438	1	1	1	F1&F2	0	626	0	594	F2	0.847	2848	0.21		3rdDkI05
60	WTF30506	A/	1	10.82	204	2.438	1	1	1	F1&F2	0	685	0	651	F2	0.847	2848	0.23	8 x 5.25 x 17# I-T	3rdDkI06
		F/	1	10.82	204	2.438	1	1	1	F1&F2	0	685	0	651	F2	0.847	2848	0.23		3rdDkI06
61	WTF30607	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	780	0	741	F2	0.847	2848	0.26	6 X 4 X 7# T	3rdDkO07
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	780	0	741	F2	0.847	2848	0.26		3rdDkO07
62	WTF30608	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	816	0	775	F2	0.847	2848	0.27	6 X 4 X 7# T	3rdDkO08
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	816	0	775	F2	0.847	2848	0.27		3rdDkO08

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
63	WTF30609	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	851	0	808	F2	0.847	2848	0.28	6 X 4 X 7# T	3rdDkO09
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	851	0	808	F2	0.847	2848	0.28		3rdDkO09
64	WTF30610	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	886	0	842	F2	0.847	2848	0.3	6 X 4 X 7# T	3rdDkO10
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	886	0	842	F2	0.847	2848	0.3		3rdDkO10
65	WTF30611	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	922	0	876	F2	0.847	2848	0.31	6 X 4 X 7# T	3rdDkO11
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	922	0	876	F2	0.847	2848	0.31		3rdDkO11
66	WTF30612	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	957	0	909	F2	0.847	2848	0.32	6 X 4 X 7# T	3rdDkO12
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	957	0	909	F2	0.847	2848	0.32		3rdDkO12
67	WTF30613	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	992	0	943	F2	0.847	2848	0.33	6 X 4 X 7# T	3rdDkO13
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	992	0	943	F2	0.847	2848	0.33		3rdDkO13
68	WTF30614	A/	1	10.82	79	2.438	1	1	1	F1&F2	0	1027	0	976	F2	0.847	2848	0.34	6 X 4 X 7# T	3rdDkO14
		F/	1	10.82	79	2.438	1	1	1	F1&F2	0	1027	0	976	F2	0.847	2848	0.34		3rdDkO14
69	INS10201	A/	1	1.6	290	2.438	1	1	2	1&2	0.56	1217	45	1199	F2	0.885	2631	0.46	12 x 4 x 16.5# I-T	BhdIB-01
		F/	1	1.6	290	2.438	1	1	2	1&2	0.56	1217	45	1199	F2	0.885	2631	0.46		BhdIB-01
70	INS10202	A/	1	2.21	290	2.438	1	1	2	TZONE		1041	38	1025	F2	0.898	2560	0.4	12 x 4 x 16.5# I-T	BhdIB-02
		F/	1	2.21	290	2.438	1	1	2	TZONE		1041	38	1025	F2	0.898	2560	0.4		BhdIB-02
71	INS10203	A/	1	2.82	290	2.438	1	1	2	TZONE		911	31	895	F2	0.912	2501	0.36	12 x 4 x 16.5# I-T	BhdIB-03
		F/	1	2.82	290	2.438	1	1	2	TZONE		911	31	895	F2	0.912	2501	0.36		BhdIB-03
72	INS10304	A/	1	3.45	284	2.438	1	1	2	F1&F2	0.3	835	22	815	F2	0.924	2456	0.33	12 x 4 x 16.5# I-T	BhdIB-04
		F/	1	3.45	284	2.438	1	1	2	F1&F2	0.3	835	22	815	F2	0.924	2456	0.33		BhdIB-04
73	INS10305	A/	1	3.95	284	2.438	1	1	1	F1&F2	0.29	794	20	773	F2	0.924	2456	0.31	12 x 4 x 16.5# I-T	BhdIB-05
		F/	1	3.95	284	2.438	1	1	1	F1&F2	0.29	794	20	773	F2	0.924	2456	0.31		BhdIB-05
74	INS10306	A/	1	4.45	224	2.438	1	1	1	F1&F2	0.36	750	31	742	F2	0.924	2456	0.3	10 x 4 x 15# I-T	BhdIB-06
		F/	1	4.45	224	2.438	1	1	1	F1&F2	0.36	750	31	742	F2	0.924	2456	0.3		BhdIB-06
75	INS10307	A/	1	4.95	224	2.438	1	1	1	F1&F2	0.42	710	36	708	F2	0.924	2456	0.29	10 x 4 x 15# I-T	BhdIB-07
		F/	1	4.95	224	2.438	1	1	1	F1&F2	0.42	710	36	708	F2	0.924	2456	0.29		BhdIB-07
76	INS10308	A/	1	5.45	224	2.438	1	1	1	F1&F2	0.49	669	41	675	F2	0.924	2456	0.27	10 x 4 x 15# I-T	BhdIB-08
		F/	1	5.45	224	2.438	1	1	1	F1&F2	0.49	669	41	675	F2	0.924	2456	0.27		BhdIB-08

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
77	INS10309	A/	1	5.95	224	2.438	1	1	1	F1&F2	0.55	628	47	641	F2	0.924	2456	0.26	10 x 4 x 15# I-T	BhdIB-09
		F/	1	5.95	224	2.438	1	1	1	F1&F2	0.55	628	47	641	F2	0.924	2456	0.26		BhdIB-09
78	INS10310	A/	1	6.45	224	2.438	1	1	1	F1&F2	0.61	587	52	607	F2	0.924	2456	0.25	10 x 4 x 15# I-T	BhdIB-10
		F/	1	6.45	224	2.438	1	1	1	F1&F2	0.61	587	52	607	F2	0.924	2456	0.25		BhdIB-10
79	INS10311	A/	1	6.95	201	2.438	1	1	1	F1&F2	0.67	546	64	580	F2	0.924	2456	0.24	10 x 4 x 15# I-T	BhdIB-11
		F/	1	6.95	201	2.438	1	1	1	F1&F2	0.67	546	64	580	F2	0.924	2456	0.24		BhdIB-11
80	INS10312	A/	1	7.45	201	2.438	1	1	1	F1&F2	0.73	506	69	546	F2	0.924	2456	0.22	10 x 4 x 15# I-T	BhdIB-12
		F/	1	7.45	201	2.438	1	1	1	F1&F2	0.73	506	69	546	F2	0.924	2456	0.22		BhdIB-12
81	INS10413	A/	1	7.81	198	2.438	1	1	1	F1&F2	0.77	515	85	570	F2	0.924	2456	0.23	10 x 4 x 15# I-T	Bhd4-413
		F/	1	7.81	198	2.438	1	1	1	F1&F2	0.77	515	85	570	F2	0.924	2456	0.23		Bhd4-413
82	INS10514	A/	1	9.19	101	2.438	1	1	1	F1&F2	0	622	0	590	F2	0.924	2456	0.24	6 X 4 X 7# T	Bhd4-314
		F/	1	9.19	101	2.438	1	1	1	F1&F2	0	622	0	590	F2	0.924	2456	0.24		Bhd4-314
83	INS10515	A/	1	10	101	2.438	1	1	1	F1&F2	0	688	0	653	F2	0.924	2456	0.27	6 X 4 X 7# T	Bhd4-315
		F/	1	10	101	2.438	1	1	1	F1&F2	0	688	0	653	F2	0.924	2456	0.27		Bhd4-315
84	INS10616	A/	2	11.68	102	2.286	1	1	1	F1&F2	0	825	0	783	F2	0.924	2456	0.32	6 X 4 X 7# T	Bhd3-216
		F/	2	11.68	102	2.286	1	1	1	F1&F2	0	825	0	783	F2	0.924	2456	0.32		Bhd3-216
85	INS10617	A/	2	12.54	102	2.286	1	1	1	TZONE		899	0	854	F2	0.922	2466	0.35	6 X 4 X 7# T	Bhd3-217
		F/	2	12.54	102	2.286	1	1	1	TZONE		899	0	854	F2	0.922	2466	0.35		Bhd3-217
86	INS10718	A/	1	14.21	448	2.438	1	1	1	TZONE		1260	0	1197	F2	0.87	2720	0.44	10 x 5.75 x 25# I-T	Bhd2-M18
		F/	1	14.21	448	2.438	1	1	1	TZONE		1260	0	1197	F2	0.87	2720	0.44		Bhd2-M18
87	INS10719	A/	1	15.01	448	2.438	1	1	1	1&2	0	1517	0	1441	F2	0.847	2848	0.51	10 x 5.75 x 25# I-T	Bhd2-M19
		F/	1	15.01	448	2.438	1	1	1	1&2	0	1517	0	1441	F2	0.847	2848	0.51		Bhd2-M19
88	INS10720	A/	1	15.81	448	2.438	1	1	1	1&2	0	1680	0	1596	F2	0.847	2848	0.56	10 x 5.75 x 25# I-T	Bhd2-M20
		F/	1	15.81	448	2.438	1	1	1	1&2	0	1680	0	1596	F2	0.847	2848	0.56		Bhd2-M20
89	INS20801	A/	1	1.13	540	2.438	1	1	1	1&2	0	1313	0	1248	F2	0.885	2631	0.47	12 x 6.5 x 27# I-	OutrBh01
		F/	1	1.13	540	2.438	1	1	1	1&2	0	1313	0	1248	F2	0.885	2631	0.47		OutrBh01
90	INS20802	A/	1	1.93	540	2.438	1	1	1	TZONE		1142	9	1093	F2	0.892	2596	0.42	12 x 6.5 x 27# I-	OutrBh02
		F/	1	1.93	540	2.438	1	1	1	TZONE		1142	9	1093	F2	0.892	2596	0.42		OutrBh02

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm (cm3)	Unsup Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	f_R/P_S	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R			P_S			
91	INS20803	A/	1	2.73	630	2.438	1	1	1	TZONE		1019	29	996	F2	0.91	2510	0.4	12 x 6.5 x 31# I-T	OutrBh03
		F/	1	2.73	630	2.438	1	1	1	TZONE		1019	29	996	F2	0.91	2510	0.4		OutrBh03
92	INS20804	A/	1	3.53	419	2.438	1	1	1	F1&F2	0.92	972	71	991	F2	0.924	2456	0.4	12 x 4 x 22# I-T	OutrBh04
		F/	1	3.53	419	2.438	1	1	1	F1&F2	0.92	972	71	991	F2	0.924	2456	0.4		OutrBh04
93	INS20905	A/	1	4.43	419	2.438	1	1	1	F1&F2	0.89	898	78	928	F2	0.924	2456	0.38	12 x 4 x 22# I-T	OutrBh05
		F/	1	4.43	419	2.438	1	1	1	F1&F2	0.89	898	78	928	F2	0.924	2456	0.38		OutrBh05
94	INS20906	A/	1	5.45	419	2.438	1	1	1	F1&F2	0.87	815	80	851	F2	0.924	2456	0.35	12 x 4 x 22# I-T	OutrBh06
		F/	1	5.45	419	2.438	1	1	1	F1&F2	0.87	815	80	851	F2	0.924	2456	0.35		OutrBh06
95	INS20907	A/	1	6.47	419	2.438	1	1	1	F1&F2	0.84	732	78	769	F2	0.924	2456	0.31	12 x 4 x 22# I-T	OutrBh07
		F/	1	6.47	419	2.438	1	1	1	F1&F2	0.84	732	78	769	F2	0.924	2456	0.31		OutrBh07
96	INS20908	A/	1	7.49	392	2.438	1	1	1	F1&F2	0.8	649	74	687	F2	0.924	2456	0.28	12 x 4 x 22# I-T	OutrBh08
		F/	1	7.49	392	2.438	1	1	1	F1&F2	0.8	649	74	687	F2	0.924	2456	0.28		OutrBh08
97	SDK10101	A/	1	13.41	165	2.438	1	1	1	TZONE		1224	0	1162	F2	0.895	2580	0.45	8 x 4 x 13# I-T	2nd Dk01
		F/	1	13.41	165	2.438	1	1	1	TZONE		1224	0	1162	F2	0.895	2580	0.45		2nd Dk01
98	SDK10102	A/	1	13.41	165	2.438	1	1	1	TZONE		1201	0	1141	F2	0.895	2580	0.44	8 x 4 x 13# I-T	2nd Dk02
		F/	1	13.41	165	2.438	1	1	1	TZONE		1201	0	1141	F2	0.895	2580	0.44		2nd Dk02
99	SDK10103	A/	1	13.41	165	2.438	1	1	1	TZONE		1179	0	1120	F2	0.895	2580	0.43	8 x 4 x 13# I-T	2nd Dk03
		F/	1	13.41	165	2.438	1	1	1	TZONE		1179	0	1120	F2	0.895	2580	0.43		2nd Dk03
100	SDK10104	A/	1	13.41	165	2.438	1	1	1	TZONE		1157	0	1099	F2	0.895	2580	0.43	8 x 4 x 13# I-T	2nd Dk04
		F/	1	13.41	165	2.438	1	1	1	TZONE		1157	0	1099	F2	0.895	2580	0.43		2nd Dk04
101	SDK10105	A/	1	13.41	165	2.438	1	1	1	TZONE		1135	0	1078	F2	0.895	2580	0.42	8 x 4 x 13# I-T	2nd Dk05
		F/	1	13.41	165	2.438	1	1	1	TZONE		1135	0	1078	F2	0.895	2580	0.42		2nd Dk05
102	SDK10106	A/	1	13.41	165	2.438	1	1	1	TZONE		1113	0	1057	F2	0.895	2580	0.41	8 x 4 x 13# I-T	2nd Dk06
		F/	1	13.41	165	2.438	1	1	1	TZONE		1113	0	1057	F2	0.895	2580	0.41		2nd Dk06
103	SDK10107	A/	1	13.41	165	2.438	1	1	1	TZONE		1090	0	1036	F2	0.895	2580	0.4	8 x 4 x 13# I-T	2nd Dk07
		F/	1	13.41	165	2.438	1	1	1	TZONE		1090	0	1036	F2	0.895	2580	0.4		2nd Dk07
104	SDK10108	A/	1	13.41	165	2.438	1	1	1	TZONE		1068	0	1015	F2	0.895	2580	0.39	8 x 4 x 13# I-T	2nd Dk08
		F/	1	13.41	165	2.438	1	1	1	TZONE		1068	0	1015	F2	0.895	2580	0.39		2nd Dk08

Table B.2 SafeHull Phase A Fatigue Analysis of Class F2 Flat Bars for Ship B

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midships
LxBxDxd = 162.02x 25.67x 16.61x 6.55(m)
Hull-Girder Moment of Inertia   Ivert.   883156.(cm2-m2) Ihoriz.   1958098.(cm2-m2)
Neutral Axis Height 7.57(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at   83.51m from AP (0.485 L from aft end of L)
Scantling Group #   1
Range of Wave-induced Bending Moment MW(vert.)   180100.(tf-m) MW(horiz.)   122681.(tf-m)

Cutout						Local Load Range		Support Areas		Cf=0.95 Cw=0.75					Long Term Distr. Factor	Permissible Stress (kg/cm2)	
			Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Head (m)	Force (tf)	As (cm2)	Ac	SCF	Stress Range (kg/cm2)			FATIG			
LABEL	ID	LOC									fs	fL	fRi	CLASS		PS	fR/PS
BTM10801	1	1	0.24	0.78	2.362	4.86	9.18	0	57.7	1.5	151	1373	1391	F2	0.885	2631	0.53
		2	0.24	0.78	2.362	4.86	9.18	0	57.7	1	151	1373	1381	F2	0.885	2631	0.52
[Weld Throat]			0.24	0.78	2.362	4.86	9.18	[Asw]=	0	1.25	151	0	*****	W	0.885	1897	NaN
BTM10802	1	1	0.28	0.764	2.362	4.86	8.99	0	57.7	1.5	148	1360	1378	F2	0.885	2631	0.52
		2	0.28	0.764	2.362	4.86	8.99	0	57.7	1	148	1360	1368	F2	0.885	2631	0.52
[Weld Throat]			0.28	0.764	2.362	4.86	8.99	[Asw]=	0	1.25	148	0	*****	W	0.885	1897	NaN
BLG10201	1	1	0.73	0.907	2.362	4.81	10.56	0	57.7	1.5	174	1325	1350	F2	0.885	2631	0.51
		2	0.73	0.907	2.362	4.81	10.56	0	57.7	1	174	1325	1336	F2	0.885	2631	0.51
[Weld Throat]			0.73	0.907	2.362	4.81	10.56	[Asw]=	0	1.25	174	0	*****	W	0.885	1897	NaN
BLG10302	1	1	1.22	0.937	2.362	5.08	11.53	0	57.7	1.5	190	1266	1297	F2	0.885	2631	0.49
		2	1.22	0.937	2.362	5.08	11.53	0	57.7	1	190	1266	1280	F2	0.885	2631	0.49
[Weld Throat]			1.22	0.937	2.362	5.08	11.53	[Asw]=	0	1.25	190	0	*****	W	0.885	1897	NaN

Cutout LABEL	Cutout ID	Cutout LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range Head (m)	Local Load Range Force (tf)	Support Areas As (cm2)	Support Areas Ac	Cf=0.95 Cw=0.75 SCF	Stress Range (kg/cm 2) fs	Stress Range fL	fRi	FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	Permissible Stress fR/PS
BLG10303	1	1	2.08	0.94	2.362	6.42	14.62	0	57.7	1.5	241	1440	1485	F2	0.885	2631	0.56
		2	2.08	0.94	2.362	6.42	14.62	0	57.7	1	241	1440	1460	F2	0.885	2631	0.55
[Weld T			2.08	0.94	2.362	6.42	14.62	[Asw]=	0	1.25	241	0	*****	W	0.885	1897	NaN
BLG10304	1	1	2.93	0.944	2.362	8.43	19.26	0	57.7	1.5	317	1561	1632	F2	0.885	2631	0.62
		2	2.93	0.944	2.362	8.43	19.26	0	57.7	1	317	1561	1593	F2	0.885	2631	0.61
SHL10101	1	1	3.87	0.797	2.362	9.67	18.66	0	59.4	1.5	298	1632	1692	F2	0.924	2456	0.69
		2	3.87	0.797	2.362	9.67	18.66	0	59.4	1	298	1632	1659	F2	0.924	2456	0.68
[Weld T			3.87	0.797	2.362	9.67	18.66	[Asw]=	0	1.25	298	0	*****	W	0.924	1770	NaN
SHL10202	2	1	4.51	0.778	2.362	9.94	18.73	0	41	1.5	433	2140	2237	F2	0.924	2456	0.91
		2	4.51	0.778	2.362	9.94	18.73	0	41	1	433	2140	2183	F2	0.924	2456	0.89
SHL10203	2	1	5.42	0.91	2.362	11.02	24.29	0	41	1.5	562	2423	2565	F2	0.924	2456	1.04
		2	5.42	0.91	2.362	11.02	24.29	0	41	1	562	2423	2487	F2	0.924	2456	1.01
[Weld Throat]			5.42	0.91	2.362	11.02	24.29	[Asw]=	0	1.25	562	0	*****	W	0.924	1770	NaN
SHL10204	2	1	6.33	1.008	2.362	12.11	29.54	0	41	1.5	516	2231	2361	F2	0.924	2456	0.96
		2	6.33	1.008	2.362	12.11	29.54	0	41	1	516	2231	2289	F2	0.924	2456	0.93
[Weld Throat]			6.33	1.008	2.362	12.11	29.54	[Asw]=	0	1.25	516	0	*****	W	0.924	1770	NaN
SHL10305	2	1	7.43	1.028	2.362	11.21	27.91	0	41	1.5	256	1521	1569	F2	0.924	2456	0.64
		2	7.43	1.028	2.362	11.21	27.91	0	41	1	256	1521	1542	F2	0.924	2456	0.63
[Weld Throat]			7.43	1.028	2.362	11.21	27.91	[Asw]=	0	1.25	256	0	*****	W	0.924	1770	NaN

APPENDIX C

FATIGUE ANALYSIS SUMMARY FOR SHIP C

Table C.1 SafeHull Phase A Fatigue Analysis of Class F2 Longitudinals for Ship C

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with LBP = 124.5 m, updated Cutout Details
LxBxDxd = 120.77x 14.80x 11.10x 4.99(m)
Hull-Girder Moment of Inertia Ivert. 105555.(cm2-m2) Ihoriz. 181783.(cm2-m2)
Neutral Axis Height 5.47(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 62.25m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52100.(tf-m) MW(horiz.) 42594.(tf-m)
******** "Net" Ship ******** Local Cf=0.95 Cw=0.75 Long Perm.

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
1	BTM10101	A/	1	0.04	99	0.9	1	1	1	1&2	4.14	2619	92	2189	F2	0.915	2492	0.88	127 x 102 T	A Stra01
		F/	2	0.04	99	0.9	1	1	1	1&2	4.14	2619	92	2189	F2	0.915	2492	0.88		A Stra01
2	BTM10102	A/	1	0.11	1643	1	1	1	1	1&2	4.14	2339	6	1894	F2	0.915	2492	0.76	600 x 200 Girder	A Stra02
		F/	1	0.11	1643	1	1	1	1	1&2	4.14	2339	6	1894	F2	0.915	2492	0.76		A Stra02
3	BTM10103	A/	1	0.17	99	0.9	1	1	1	1&2	4.14	2554	91	2136	F2	0.915	2492	0.86	127 x 102 T	A Stra03
		F/	2	0.17	99	0.9	1	1	1	1&2	4.14	2554	91	2136	F2	0.915	2492	0.86		A Stra03
4	BTM10204	A/	1	0.24	97	0.9	1	1	1	1&2	4.14	2523	101	2119	F2	0.915	2492	0.85	127 x 102 T	B Stra04
		F/	2	0.24	97	0.9	1	1	1	1&2	4.14	2523	101	2119	F2	0.915	2492	0.85		B Stra04
5	BTM10205	A/	1	0.29	97	0.9	1	1	1	1&2	4.14	2494	102	2097	F2	0.915	2492	0.84	127 x 102 T	B Stra05
		F/	2	0.29	97	0.9	1	1	1	1&2	4.14	2494	102	2097	F2	0.915	2492	0.84		B Stra05
6	BTM10206	A/	1	0.35	97	0.9	1	1	1	1&2	4.14	2465	102	2073	F2	0.915	2492	0.83	127 x 102 T	B Stra06
		F/	2	0.35	97	0.9	1	1	1	1&2	4.14	2465	102	2073	F2	0.915	2492	0.83		B Stra06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
7	BTM10207	A/	1	0.41	997	1	1	1	1	1&2	4.14	2197	9	1782	F2	0.915	2492	0.71	600 x 150 Girder	B Stra07
		F/	1	0.41	997	1	1	1	1	1&2	4.14	2197	9	1782	F2	0.915	2492	0.71		B Stra07
8	BTM10308	A/	1	0.45	97	0.9	1	1	1	1&2	4.14	2415	71	2007	F2	0.915	2492	0.81	127 x 102 T	C1 Str08
		F/	2	0.45	97	0.9	1	1	1	1&2	4.14	2415	71	2007	F2	0.915	2492	0.81		C1 Str08
9	BTM10309	A/	1	0.56	97	0.9	1	1	1	1&2	4.14	2361	89	1978	F2	0.915	2492	0.79	127 x 102 T	C1 Str09
		F/	2	0.56	97	0.9	1	1	1	1&2	4.14	2361	89	1978	F2	0.915	2492	0.79		C1 Str09
10	BTM10310	A/	1	0.67	527	1	1	1	1	1&2	4.14	2211	20	1801	F2	0.915	2492	0.72	310 x 150 Girder	C1 Str10
		F/	1	0.67	527	1	1	1	1	1&2	4.14	2211	20	1801	F2	0.915	2492	0.72		C1 Str10
11	BTM10311	A/	1	0.78	97	0.9	1	1	1	1&2	4.14	2252	99	1899	F2	0.915	2492	0.76	127 x 102 T	C1 Str11
		F/	2	0.78	97	0.9	1	1	1	1&2	4.14	2252	99	1899	F2	0.915	2492	0.76		C1 Str11
12	BTM10412	A/	1	0.99	97	0.9	1	1	1	1&2	4.14	2151	107	1823	F2	0.915	2492	0.73	127 x 102 T	C2 Str12
		F/	2	0.99	97	0.9	1	1	1	1&2	4.14	2151	107	1823	F2	0.915	2492	0.73		C2 Str12
13	BTM10413	A/	1	1.2	97	0.9	1	1	1	1&2	4.14	2046	104	1737	F2	0.915	2492	0.70	127 x 102 T	C2 Str13
		F/	2	1.2	97	0.9	1	1	1	1&2	4.14	2046	104	1737	F2	0.915	2492	0.70		C2 Str13
14	BTM10414	A/	1	1.41	98	1	1	1	1	1&2	3.98	1942	81	1634	F2	0.915	2492	0.66	127 x 102 T	C2 Str14
		F/	1	1.41	98	1	1	1	1	1&2	3.98	1942	81	1634	F2	0.915	2492	0.66		C2 Str14
15	BLG10101	A/	1	1.77	186	1	1	1	1	TZONE		1981	90	1967	F2	0.915	2492	0.79	203 x 140 T	D Stra01
		F/	1	1.77	186	1	1	1	1	TZONE		1981	90	1967	F2	0.915	2492	0.79		D Stra01
16	BLG10102	A/	1	2.16	96	1	1	1	1	TZONE		2110	187	2182	F2	0.915	2492	0.88	127 x 102 T	D Stra02
		F/	1	2.16	96	1	1	1	1	TZONE		2110	187	2182	F2	0.915	2492	0.88		D Stra02
17	BLG10103	A/	1	2.56	96	1	1	1	1	F1&F2	6.48	2126	207	2217	F2	0.915	2492	0.89	127 x 102 T	D Stra03
		F/	1	2.56	96	1	1	1	1	F1&F2	6.48	2126	207	2217	F2	0.915	2492	0.89		D Stra03
18	BLG10104	A/	1	2.95	96	1	1	1	1	F1&F2	7.11	2114	227	2225	F2	0.915	2492	0.89	127 x 102 T	D Stra04
		F/	1	2.95	96	1	1	1	1	F1&F2	7.11	2114	227	2225	F2	0.915	2492	0.89		D Stra04
19	BLG10105	A/	1	3.34	96	1	1	1	1	F1&F2	7.75	2102	222	2208	F2	0.915	2492	0.89	127 x 102 T	D Stra05
		F/	1	3.34	96	1	1	1	1	F1&F2	7.75	2102	222	2208	F2	0.915	2492	0.89		D Stra05
20	SHL10101	A/	1	3.71	182	1	1	1	1	F1&F2	8.73	1994	133	2021	F2	0.951	2350	0.86	203 x 140 T	E Stra01
		F/	1	3.71	182	1	1	1	1	F1&F2	8.73	1994	133	2021	F2	0.951	2350	0.86		E Stra01
21	SHL10102	A/	1	4.2	47	1	1	1	1	F1&F2	10	1934	671	2475	F2	0.951	2350	1.05	127 x 70 T	E Stra02

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
		F/	1	4.2	47	1	1	1	1	F1&F2	10	1934	671	2475	F2	0.951	2350	1.05		E Stra02
22	SHL10103	A/	1	4.68	47	1	1	0.85	1	F1&F2	11.26	1858	650	2383	F2	0.951	2350	1.01	127 x 70 T	E Stra03
		F/	1	4.68	47	1	1	0.85	1	F1&F2	11.26	1858	650	2383	F2	0.951	2350	1.01		E Stra03
23	SHL10204	A/	1	5.18	45	1	1	0.57	1	F1&F2	11.7	1777	472	2137	F2	0.951	2350	0.91	127 x 70 T	F1 Str04
		F/	1	5.18	45	1	1	0.57	1	F1&F2	11.7	1777	472	2137	F2	0.951	2350	0.91		F1 Str04
24	SHL10205	A/	1	5.67	45	1	1	0.39	1	F1&F2	10.72	1773	308	1977	F2	0.951	2350	0.84	127 x 70 T	F1 Str05
		F/	1	5.67	45	1	1	0.39	1	F1&F2	10.72	1773	308	1977	F2	0.951	2350	0.84		F1 Str05
25	SHL10406	A/	1	6.63	47	2	1	0.3	1	F1&F2	8.84	1990	653	2511	F2	0.951	2350	1.07	127 x 70 T	G1 Str06
		F/	1	6.63	47	2	1	0.3	1	F1&F2	8.84	1990	653	2511	F2	0.951	2350	1.07		G1 Str06
26	SHL10407	A/	1	7.1	47	2	1	0.3	1	F1&F2	7.9	2099	614	2578	F2	0.951	2350	1.10	127 x 70 T	G1 Str07
		F/	1	7.1	47	2	1	0.3	1	F1&F2	7.9	2099	614	2578	F2	0.951	2350	1.10		G1 Str07
27	SHL10408	A/	1	7.58	47	2	1	0.3	1	F1&F2	6.96	2208	541	2612	F2	0.951	2350	1.11	127 x 70 T	G1 Str08
		F/	1	7.58	47	2	1	0.3	1	F1&F2	6.96	2208	541	2612	F2	0.951	2350	1.11		G1 Str08
28	SHL10409	A/	1	8.06	47	2	1	0.3	1	F1&F2	6.02	2317	526	2701	F2	0.951	2350	1.15	127 x 70 T	G1 Str09
		F/	1	8.06	47	2	1	0.3	1	F1&F2	6.02	2317	526	2701	F2	0.951	2350	1.15		G1 Str09
29	SHL10610	A/	1	9.1	49	2	1	0.3	1	TZONE		2199	190	2270	F2	0.917	2482	0.91	127 x 70 T	H Stra10
		F/	1	9.1	49	2	1	0.3	1	TZONE		2199	190	2270	F2	0.917	2482	0.91		H Stra10
30	SHL10611	A/	1	9.57	49	2	1	0.3	1	TZONE		2183	90	2160	F2	0.897	2569	0.84	127 x 70 T	H Stra11
		F/	1	9.57	49	2	1	0.3	1	TZONE		2183	90	2160	F2	0.897	2569	0.84		H Stra11
31	SHS10101	A/	1	10.06	50	2	1	1	1	1&2	0.11	2262	27	2175	F2	0.878	2672	0.81	127 x 70 T	J Stra01
		F/	1	10.06	50	2	1	1	1	1&2	0.11	2262	27	2175	F2	0.878	2672	0.81		J Stra01
32	SHS10102	A/	1	10.53	50	2	1	1	1	1&2	0	2498	0	2373	F2	0.878	2672	0.89	127 x 70 T	J Stra02
		F/	1	10.53	50	2	1	1	1	1&2	0	2498	0	2373	F2	0.878	2672	0.89		J Stra02
33	DEC10101	A/	1	11.13	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D01
		F/	1	11.13	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D01
34	DEC10102	A/	1	11.15	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D02
		F/	1	11.15	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D02
35	DEC10103	A/	1	11.18	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D03
		F/	1	11.18	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
36	DEC10104	A/	1	11.21	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D04
		F/	1	11.21	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D04
37	DEC10105	A/	1	11.24	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D05
		F/	1	11.24	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D05
38	DEC10106	A/	1	11.26	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D06
		F/	1	11.26	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D06
39	DEC10107	A/	1	11.29	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D07
		F/	1	11.29	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D07
40	DEC10108	A/	1	11.32	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No 1 D08
		F/	1	11.32	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No 1 D08
41	DEC10309	A/	1	11.37	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No1 In09
		F/	1	11.37	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No1 In09
42	DEC10310	A/	1	11.38	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No1 In10
		F/	1	11.38	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No1 In10
43	DEC10311	A/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No1 In11
		F/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No1 In11
44	DEC10312	A/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No1 In12
		F/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No1 In12
45	DEC10313	A/	1	11.4	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97	127 x 102 T	No1 In13
		F/	1	11.4	108	2	1	1	1	1&2	0	2714	0	2579	F2	0.878	2672	0.97		No1 In13
46	NTF10101	A/	1	6.2	13	2	1	1	1	7&8	0	143	0	136	F2	0.878	2672	0.05	76 x 26T	No 3 I01
		F/	1	6.2	13	2	1	1	1	7&8	0	143	0	136	F2	0.878	2672	0.05		No 3 I01
47	NTF10102	A/	1	6.2	13	2	1	1	1	F1&F2	0	293	0	279	F2	0.878	2672	0.10	76 x 26T	No 3 I02
		F/	1	6.2	13	2	1	1	1	F1&F2	0	293	0	279	F2	0.878	2672	0.10		No 3 I02
48	NTF10103	A/	1	6.2	13	2	1	1	1	F1&F2	0	443	0	421	F2	0.878	2672	0.16	76 x 26T	No 3 I03
		F/	1	6.2	13	2	1	1	1	F1&F2	0	443	0	421	F2	0.878	2672	0.16		No 3 I03
49	NTF10104	A/	1	6.2	13	2	1	1	1	F1&F2	0	593	0	564	F2	0.878	2672	0.21	76 x 26T	No 3 I04
		F/	1	6.2	13	2	1	1	1	F1&F2	0	593	0	564	F2	0.878	2672	0.21		No 3 I04
50	NTF10105	A/	1	6.2	13	2	1	1	1	F1&F2	0	743	0	706	F2	0.878	2672	0.26	76 x 26T	No 3 I05

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
		F/	1	6.2	13	2	1	1	1	F1&F2	0	743	0	706	F2	0.878	2672	0.26		No 3 I05
51	NTF10206	A/	1	6.2	172	2	1	1	1	F1&F2	0	893	0	849	F2	0.878	2672	0.32	203 x 140 T	No 3 D06
		F/	1	6.2	172	2	1	1	1	F1&F2	0	893	0	849	F2	0.878	2672	0.32		No 3 D06
52	NTF10307	A/	1	6.2	13	2	1	1	1	F1&F2	0	1045	0	993	F2	0.878	2672	0.37	76 x 26T	No 3 D07
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1045	0	993	F2	0.878	2672	0.37		No 3 D07
53	NTF10308	A/	1	6.2	13	2	1	1	1	F1&F2	0	1174	0	1116	F2	0.878	2672	0.42	76 x 26T	No 3 D08
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1174	0	1116	F2	0.878	2672	0.42		No 3 D08
54	NTF10309	A/	1	6.2	13	2	1	1	1	F1&F2	0	1303	0	1238	F2	0.878	2672	0.46	76 x 26T	No 3 D09
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1303	0	1238	F2	0.878	2672	0.46		No 3 D09
55	NTF10310	A/	1	6.2	13	2	1	1	1	F1&F2	0	1432	0	1360	F2	0.878	2672	0.51	76 x 26T	No 3 D10
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1432	0	1360	F2	0.878	2672	0.51		No 3 D10
56	NTF10311	A/	1	6.2	13	2	1	1	1	F1&F2	0	1561	0	1483	F2	0.878	2672	0.56	76 x 26T	No 3 D11
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1561	0	1483	F2	0.878	2672	0.56		No 3 D11
57	NTF10312	A/	1	6.2	13	2	1	1	1	F1&F2	0	1690	0	1605	F2	0.878	2672	0.60	76 x 26T	No 3 D12
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1690	0	1605	F2	0.878	2672	0.60		No 3 D12
58	NTF10313	A/	1	6.2	13	2	1	1	1	F1&F2	0	1819	0	1728	F2	0.878	2672	0.65	76 x 26T	No 3 D13
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1819	0	1728	F2	0.878	2672	0.65		No 3 D13
59	SDK10101	A/	1	8.65	14	2	1	1	1	TZONE		2159	0	2051	F2	0.937	2405	0.85	76 x 26T	No 2 D01
		F/	1	8.65	14	2	1	1	1	TZONE		2159	0	2051	F2	0.937	2405	0.85		No 2 D01
60	SDK10102	A/	1	8.65	14	2	1	1	1	TZONE		2055	0	1953	F2	0.937	2405	0.81	76 x 26T	No 2 D02
		F/	1	8.65	14	2	1	1	1	TZONE		2055	0	1953	F2	0.937	2405	0.81		No 2 D02
61	SDK10103	A/	1	8.65	14	2	1	1	1	TZONE		1952	0	1854	F2	0.937	2405	0.77	76 x 26T	No 2 D03
		F/	1	8.65	14	2	1	1	1	TZONE		1952	0	1854	F2	0.937	2405	0.77		No 2 D03
62	SDK10104	A/	1	8.65	14	2	1	1	1	TZONE		1848	0	1755	F2	0.937	2405	0.73	76 x 26T	No 2 D04
		F/	1	8.65	14	2	1	1	1	TZONE		1848	0	1755	F2	0.937	2405	0.73		No 2 D04
63	SDK10105	A/	1	8.65	14	2	1	1	1	TZONE		1744	0	1657	F2	0.937	2405	0.69	76 x 26T	No 2 D05
		F/	1	8.65	14	2	1	1	1	TZONE		1744	0	1657	F2	0.937	2405	0.69		No 2 D05
64	SDK10106	A/	1	8.65	14	2	1	1	1	TZONE		1640	0	1558	F2	0.937	2405	0.65	76 x 26T	No 2 D06
		F/	1	8.65	14	2	1	1	1	TZONE		1640	0	1558	F2	0.937	2405	0.65		No 2 D06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
65	SDK10107	A/	1	8.65	14	2	1	1	1	TZONE		1537	0	1460	F2	0.937	2405	0.61	76 x 26T	No 2 D07
		F/	1	8.65	14	2	1	1	1	TZONE		1537	0	1460	F2	0.937	2405	0.61		No 2 D07
66	SDK10208	A/	1	8.65	193	2	1	1	1	TZONE		1414	0	1343	F2	0.937	2405	0.56	203 x 140 T	No 2 D08
		F/	1	8.65	193	2	1	1	1	TZONE		1414	0	1343	F2	0.937	2405	0.56		No 2 D08
67	SDK10309	A/	1	8.65	14	2	1	1	1	TZONE		1293	0	1229	F2	0.937	2405	0.51	76 x 26T	No 2 I09
		F/	1	8.65	14	2	1	1	1	TZONE		1293	0	1229	F2	0.937	2405	0.51		No 2 I09
68	SDK10310	A/	1	8.65	14	2	1	1	1	TZONE		1173	0	1114	F2	0.937	2405	0.46	76 x 26T	No 2 I10
		F/	1	8.65	14	2	1	1	1	TZONE		1173	0	1114	F2	0.937	2405	0.46		No 2 I10
69	SDK10311	A/	1	8.65	14	2	1	1	1	TZONE		1052	0	999	F2	0.937	2405	0.42	76 x 26T	No 2 I11
		F/	1	8.65	14	2	1	1	1	TZONE		1052	0	999	F2	0.937	2405	0.42		No 2 I11
70	SDK10312	A/	1	8.65	14	2	1	1	1	TZONE		931	0	885	F2	0.937	2405	0.37	76 x 26T	No 2 I12
		F/	1	8.65	14	2	1	1	1	TZONE		931	0	885	F2	0.937	2405	0.37		No 2 I12
71	SDK10313	A/	1	8.65	14	2	1	1	1	TZONE		811	0	770	F2	0.937	2405	0.32	76 x 26T	No 2 I13
		F/	1	8.65	14	2	1	1	1	TZONE		811	0	770	F2	0.937	2405	0.32		No 2 I13

Table C.2 SafeHull Phase A Fatigue Analysis of Class F2 Flat Bars for Ship C

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with LBP = 124.5 m, updated Cutout Details
LxBxDxd = 120.77x 14.80x 11.10x 4.99(m)
Hull-Girder Moment of Inertia Ivert. 105555.(cm2-m2) Ihoriz. 181783.(cm2-m2)
Neutral Axis Height 5.47(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 62.25m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52100.(tf-m) MW(horiz.) 42594.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas (cm^2)		SCF	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
						Head (m)	Force (tf)	As	Ac		fs	fL	fRi				
BTM10101	1	1	0.04	0.425	0.9	4.14	1.62	0	26.9	1.5	57	2189	2191	F2	0.915	2492	0.88
		2	0.04	0.425	0.9	4.14	1.62	0	26.9	1	57	2189	2190	F2	0.915	2492	0.88
[Weld Throat}			0.04	0.425	0.9	4.14	1.62	[Asw]=	0	1.25	57	0	*****	W	0.915	1797	NaN
BTM10103	1	1	0.17	0.423	0.9	4.14	1.62	0	26.9	1.5	57	2136	2138	F2	0.915	2492	0.86
		2	0.17	0.423	0.9	4.14	1.62	0	26.9	1	57	2136	2137	F2	0.915	2492	0.86
[Weld Throat}			0.17	0.423	0.9	4.14	1.62	[Asw]=	0	1.25	57	0	*****	W	0.915	1797	NaN
BTM10204	1	1	0.24	0.453	0.9	4.14	1.73	0	26.9	1.5	61	2119	2121	F2	0.915	2492	0.85
		2	0.24	0.453	0.9	4.14	1.73	0	26.9	1	61	2119	2120	F2	0.915	2492	0.85
[Weld Throat}			0.24	0.453	0.9	4.14	1.73	[Asw]=	0	1.25	61	0	*****	W	0.915	1797	NaN
BTM10205	1	1	0.29	0.46	0.9	4.14	1.76	0	26.9	1.5	62	2097	2099	F2	0.915	2492	0.84
		2	0.29	0.46	0.9	4.14	1.76	0	26.9	1	62	2097	2097	F2	0.915	2492	0.84

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas (cm^2)		SCF	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
						Head (m)	Force (tf)	As	Ac		fs	fL	fRi				
[Weld Throat}			0.29	0.46	0.9	4.14	1.76	[Asw]=	0	1.25	62	0	*****	W	0.915	1797	NaN
BTM10206	1	1	0.35	0.46	0.9	4.14	1.76	0	26.9	1.5	62	2073	2075	F2	0.915	2492	0.83
		2	0.35	0.46	0.9	4.14	1.76	0	26.9	1	62	2073	2074	F2	0.915	2492	0.83
[Weld Throat}			0.35	0.46	0.9	4.14	1.76	[Asw]=	0	1.25	62	0	*****	W	0.915	1797	NaN
BTM10308	1	1	0.45	0.317	0.9	4.14	1.21	0	26.9	1.5	43	2007	2008	F2	0.915	2492	0.81
		2	0.45	0.317	0.9	4.14	1.21	0	26.9	1	43	2007	2007	F2	0.915	2492	0.81
[Weld Throat}			0.45	0.317	0.9	4.14	1.21	[Asw]=	0	1.25	43	0	*****	W	0.915	1797	NaN
BTM10309	1	1	0.56	0.4	0.9	4.14	1.53	0	26.9	1.5	54	1978	1980	F2	0.915	2492	0.79
		2	0.56	0.4	0.9	4.14	1.53	0	26.9	1	54	1978	1979	F2	0.915	2492	0.79
[Weld Throat}			0.56	0.4	0.9	4.14	1.53	[Asw]=	0	1.25	54	0	*****	W	0.915	1797	NaN
BTM10311	1	1	0.78	0.447	0.9	4.14	1.71	0	26.9	1.5	60	1899	1901	F2	0.915	2492	0.76
		2	0.78	0.447	0.9	4.14	1.71	0	26.9	1	60	1899	1900	F2	0.915	2492	0.76
[Weld Throat}			0.78	0.447	0.9	4.14	1.71	[Asw]=	0	1.25	60	0	*****	W	0.915	1797	NaN
BTM10412	1	1	0.99	0.482	0.9	4.14	1.84	0	26.9	1.5	65	1823	1826	F2	0.915	2492	0.73
		2	0.99	0.482	0.9	4.14	1.84	0	26.9	1	65	1823	1824	F2	0.915	2492	0.73
[Weld Throat}			0.99	0.482	0.9	4.14	1.84	[Asw]=	0	1.25	65	0	*****	W	0.915	1797	NaN
BTM10413	1	1	1.2	0.47	0.9	4.14	1.79	0	26.9	1.5	63	1737	1739	F2	0.915	2492	0.7
		2	1.2	0.47	0.9	4.14	1.79	0	26.9	1	63	1737	1738	F2	0.915	2492	0.7
[Weld Throat}			1.2	0.47	0.9	4.14	1.79	[Asw]=	0	1.25	63	0	*****	W	0.915	1797	NaN

Table C.3 SafeHull Phase A Fatigue Analysis of Class F Longitudinals for Ship C

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with LBP = 124.5 m, Class F Details
LxBxDxd = 120.77x 14.80x 11.10x 4.99(m)
Hull-Girder Moment of Inertia Ivert. 105555.(cm2-m2) Ihoriz. 181783.(cm2-m2)
Neutral Axis Height 5.47(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 62.25m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52100.(tf-m) MW(horiz.) 42594.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
1	BTM10101	A/	1	0.04	99	0.9	1	1	1	1&2	4.14	2619	92	2189	F	0.915	2833	0.77	127 x 102 T	A Stra01
		F/	2	0.04	99	0.9	1	1	1	1&2	4.14	2619	92	2189	F	0.915	2833	0.77		A Stra01
2	BTM10102	A/	1	0.11	1643	1	1	1	1	1&2	4.14	2339	6	1894	F	0.915	2833	0.67	600 x 200 Girder	A Stra02
		F/	1	0.11	1643	1	1	1	1	1&2	4.14	2339	6	1894	F	0.915	2833	0.67		A Stra02
3	BTM10103	A/	1	0.17	99	0.9	1	1	1	1&2	4.14	2554	91	2136	F	0.915	2833	0.75	127 x 102 T	A Stra03
		F/	2	0.17	99	0.9	1	1	1	1&2	4.14	2554	91	2136	F	0.915	2833	0.75		A Stra03
4	BTM10204	A/	1	0.24	97	0.9	1	1	1	1&2	4.14	2523	101	2119	F	0.915	2833	0.75	127 x 102 T	B Stra04
		F/	2	0.24	97	0.9	1	1	1	1&2	4.14	2523	101	2119	F	0.915	2833	0.75		B Stra04
5	BTM10205	A/	1	0.29	97	0.9	1	1	1	1&2	4.14	2494	102	2097	F	0.915	2833	0.74	127 x 102 T	B Stra05
		F/	2	0.29	97	0.9	1	1	1	1&2	4.14	2494	102	2097	F	0.915	2833	0.74		B Stra05
6	BTM10206	A/	1	0.35	97	0.9	1	1	1	1&2	4.14	2465	102	2073	F	0.915	2833	0.73	127 x 102 T	B Stra06
		F/	2	0.35	97	0.9	1	1	1	1&2	4.14	2465	102	2073	F	0.915	2833	0.73		B Stra06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
7	BTM10207	A/	1	0.41	997	1	1	1	1	1&2	4.14	2197	9	1782	F	0.915	2833	0.63	600 x 150 Girder	B Stra07
		F/	1	0.41	997	1	1	1	1	1&2	4.14	2197	9	1782	F	0.915	2833	0.63		B Stra07
8	BTM10308	A/	1	0.45	97	0.9	1	1	1	1&2	4.14	2415	71	2007	F	0.915	2833	0.71	127 x 102 T	C1 Str08
		F/	2	0.45	97	0.9	1	1	1	1&2	4.14	2415	71	2007	F	0.915	2833	0.71		C1 Str08
9	BTM10309	A/	1	0.56	97	0.9	1	1	1	1&2	4.14	2361	89	1978	F	0.915	2833	0.7	127 x 102 T	C1 Str09
		F/	2	0.56	97	0.9	1	1	1	1&2	4.14	2361	89	1978	F	0.915	2833	0.7		C1 Str09
10	BTM10310	A/	1	0.67	527	1	1	1	1	1&2	4.14	2211	20	1801	F	0.915	2833	0.64	310 x 150 Girder	C1 Str10
		F/	1	0.67	527	1	1	1	1	1&2	4.14	2211	20	1801	F	0.915	2833	0.64		C1 Str10
11	BTM10311	A/	1	0.78	97	0.9	1	1	1	1&2	4.14	2252	99	1899	F	0.915	2833	0.67	127 x 102 T	C1 Str11
		F/	2	0.78	97	0.9	1	1	1	1&2	4.14	2252	99	1899	F	0.915	2833	0.67		C1 Str11
12	BTM10412	A/	1	0.99	97	0.9	1	1	1	1&2	4.14	2151	107	1823	F	0.915	2833	0.64	127 x 102 T	C2 Str12
		F/	2	0.99	97	0.9	1	1	1	1&2	4.14	2151	107	1823	F	0.915	2833	0.64		C2 Str12
13	BTM10413	A/	1	1.2	97	0.9	1	1	1	1&2	4.14	2046	104	1737	F	0.915	2833	0.61	127 x 102 T	C2 Str13
		F/	2	1.2	97	0.9	1	1	1	1&2	4.14	2046	104	1737	F	0.915	2833	0.61		C2 Str13
14	BTM10414	A/	1	1.41	98	1	1	1	1	1&2	3.98	1942	81	1634	F	0.915	2833	0.58	127 x 102 T	C2 Str14
		F/	1	1.41	98	1	1	1	1	1&2	3.98	1942	81	1634	F	0.915	2833	0.58		C2 Str14
15	BLG10101	A/	1	1.77	186	1	1	1	1	TZONE		1981	90	1967	F	0.915	2833	0.69	203 x 140 T	D Stra01
		F/	1	1.77	186	1	1	1	1	TZONE		1981	90	1967	F	0.915	2833	0.69		D Stra01
16	BLG10102	A/	1	2.16	96	1	1	1	1	TZONE		2110	187	2182	F	0.915	2833	0.77	127 x 102 T	D Stra02
		F/	1	2.16	96	1	1	1	1	TZONE		2110	187	2182	F	0.915	2833	0.77		D Stra02
17	BLG10103	A/	1	2.56	96	1	1	1	1	F1&F2	6.48	2126	207	2217	F	0.915	2833	0.78	127 x 102 T	D Stra03
		F/	1	2.56	96	1	1	1	1	F1&F2	6.48	2126	207	2217	F	0.915	2833	0.78		D Stra03
18	BLG10104	A/	1	2.95	96	1	1	1	1	F1&F2	7.11	2114	227	2225	F	0.915	2833	0.79	127 x 102 T	D Stra04
		F/	1	2.95	96	1	1	1	1	F1&F2	7.11	2114	227	2225	F	0.915	2833	0.79		D Stra04
19	BLG10105	A/	1	3.34	96	1	1	1	1	F1&F2	7.75	2102	222	2208	F	0.915	2833	0.78	127 x 102 T	D Stra05
		F/	1	3.34	96	1	1	1	1	F1&F2	7.75	2102	222	2208	F	0.915	2833	0.78		D Stra05
20	SHL10101	A/	1	3.71	182	1	1	1	1	F1&F2	8.73	1994	133	2021	F	0.951	2669	0.76	203 x 140 T	E Stra01
		F/	1	3.71	182	1	1	1	1	F1&F2	8.73	1994	133	2021	F	0.951	2669	0.76		E Stra01
21	SHL10102	A/	1	4.2	47	1	1	1	1	F1&F2	10	1934	671	2475	F	0.951	2669	0.93	127 x 70 T	E Stra02

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
		F/	1	4.2	47	1	1	1	1	F1&F2	10	1934	671	2475	F	0.951	2669	0.93		E Stra02
22	SHL10103	A/	1	4.68	47	1	1	0.85	1	F1&F2	11.26	1858	650	2383	F	0.951	2669	0.89	127 x 70 T	E Stra03
		F/	1	4.68	47	1	1	0.85	1	F1&F2	11.26	1858	650	2383	F	0.951	2669	0.89		E Stra03
23	SHL10204	A/	1	5.18	45	1	1	0.57	1	F1&F2	11.7	1777	472	2137	F	0.951	2669	0.8	127 x 70 T	F1 Str04
		F/	1	5.18	45	1	1	0.57	1	F1&F2	11.7	1777	472	2137	F	0.951	2669	0.8		F1 Str04
24	SHL10205	A/	1	5.67	45	1	1	0.39	1	F1&F2	10.72	1773	308	1977	F	0.951	2669	0.74	127 x 70 T	F1 Str05
		F/	1	5.67	45	1	1	0.39	1	F1&F2	10.72	1773	308	1977	F	0.951	2669	0.74		F1 Str05
25	SHL10406	A/	1	6.63	47	2	1	0.3	1	F1&F2	8.84	1990	653	2511	F	0.951	2669	0.94	127 x 70 T	G1 Str06
		F/	1	6.63	47	2	1	0.3	1	F1&F2	8.84	1990	653	2511	F	0.951	2669	0.94		G1 Str06
26	SHL10407	A/	1	7.1	47	2	1	0.3	1	F1&F2	7.9	2099	614	2578	F	0.951	2669	0.97	127 x 70 T	G1 Str07
		F/	1	7.1	47	2	1	0.3	1	F1&F2	7.9	2099	614	2578	F	0.951	2669	0.97		G1 Str07
27	SHL10408	A/	1	7.58	47	2	1	0.3	1	F1&F2	6.96	2208	541	2612	F	0.951	2669	0.98	127 x 70 T	G1 Str08
		F/	1	7.58	47	2	1	0.3	1	F1&F2	6.96	2208	541	2612	F	0.951	2669	0.98		G1 Str08
28	SHL10409	A/	1	8.06	47	2	1	0.3	1	F1&F2	6.02	2317	526	2701	F	0.951	2669	1.01	127 x 70 T	G1 Str09
		F/	1	8.06	47	2	1	0.3	1	F1&F2	6.02	2317	526	2701	F	0.951	2669	1.01		G1 Str09
29	SHL10610	A/	1	9.1	49	2	1	0.3	1	TZONE		2199	190	2270	F	0.917	2821	0.8	127 x 70 T	H Stra10
		F/	1	9.1	49	2	1	0.3	1	TZONE		2199	190	2270	F	0.917	2821	0.8		H Stra10
30	SHL10611	A/	1	9.57	49	2	1	0.3	1	TZONE		2183	90	2160	F	0.897	2922	0.74	127 x 70 T	H Stra11
		F/	1	9.57	49	2	1	0.3	1	TZONE		2183	90	2160	F	0.897	2922	0.74		H Stra11
31	SHS10101	A/	1	10.06	50	2	1	1	1	1&2	0.11	2262	27	2175	F	0.878	3037	0.72	127 x 70 T	J Stra01
		F/	1	10.06	50	2	1	1	1	1&2	0.11	2262	27	2175	F	0.878	3037	0.72		J Stra01
32	SHS10102	A/	1	10.53	50	2	1	1	1	1&2	0	2498	0	2373	F	0.878	3037	0.78	127 x 70 T	J Stra02
		F/	1	10.53	50	2	1	1	1	1&2	0	2498	0	2373	F	0.878	3037	0.78		J Stra02
33	DEC10101	A/	1	11.13	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D01
		F/	1	11.13	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D01
34	DEC10102	A/	1	11.15	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D02
		F/	1	11.15	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D02
35	DEC10103	A/	1	11.18	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D03
		F/	1	11.18	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
36	DEC10104	A/	1	11.21	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D04
		F/	1	11.21	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D04
37	DEC10105	A/	1	11.24	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D05
		F/	1	11.24	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D05
38	DEC10106	A/	1	11.26	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D06
		F/	1	11.26	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D06
39	DEC10107	A/	1	11.29	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D07
		F/	1	11.29	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D07
40	DEC10108	A/	1	11.32	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No 1 D08
		F/	1	11.32	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No 1 D08
41	DEC10309	A/	1	11.37	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No1 In09
		F/	1	11.37	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No1 In09
42	DEC10310	A/	1	11.38	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No1 In10
		F/	1	11.38	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No1 In10
43	DEC10311	A/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No1 In11
		F/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No1 In11
44	DEC10312	A/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No1 In12
		F/	1	11.39	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No1 In12
45	DEC10313	A/	1	11.4	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85	127 x 102 T	No1 In13
		F/	1	11.4	108	2	1	1	1	1&2	0	2714	0	2579	F	0.878	3037	0.85		No1 In13
46	NTF10101	A/	1	6.2	13	2	1	1	1	7&8	0	143	0	136	F	0.878	3037	0.04	76 x 26T	No 3 I01
		F/	1	6.2	13	2	1	1	1	7&8	0	143	0	136	F	0.878	3037	0.04		No 3 I01
47	NTF10102	A/	1	6.2	13	2	1	1	1	F1&F2	0	293	0	279	F	0.878	3037	0.09	76 x 26T	No 3 I02
		F/	1	6.2	13	2	1	1	1	F1&F2	0	293	0	279	F	0.878	3037	0.09		No 3 I02
48	NTF10103	A/	1	6.2	13	2	1	1	1	F1&F2	0	443	0	421	F	0.878	3037	0.14	76 x 26T	No 3 I03
		F/	1	6.2	13	2	1	1	1	F1&F2	0	443	0	421	F	0.878	3037	0.14		No 3 I03
49	NTF10104	A/	1	6.2	13	2	1	1	1	F1&F2	0	593	0	564	F	0.878	3037	0.19	76 x 26T	No 3 I04
		F/	1	6.2	13	2	1	1	1	F1&F2	0	593	0	564	F	0.878	3037	0.19		No 3 I04
50	NTF10105	A/	1	6.2	13	2	1	1	1	F1&F2	0	743	0	706	F	0.878	3037	0.23	76 x 26T	No 3 I05

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
		F/	1	6.2	13	2	1	1	1	F1&F2	0	743	0	706	F	0.878	3037	0.23		No 3 I05
51	NTF10206	A/	1	6.2	172	2	1	1	1	F1&F2	0	893	0	849	F	0.878	3037	0.28	203 x 140 T	No 3 D06
		F/	1	6.2	172	2	1	1	1	F1&F2	0	893	0	849	F	0.878	3037	0.28		No 3 D06
52	NTF10307	A/	1	6.2	13	2	1	1	1	F1&F2	0	1045	0	993	F	0.878	3037	0.33	76 x 26T	No 3 D07
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1045	0	993	F	0.878	3037	0.33		No 3 D07
53	NTF10308	A/	1	6.2	13	2	1	1	1	F1&F2	0	1174	0	1116	F	0.878	3037	0.37	76 x 26T	No 3 D08
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1174	0	1116	F	0.878	3037	0.37		No 3 D08
54	NTF10309	A/	1	6.2	13	2	1	1	1	F1&F2	0	1303	0	1238	F	0.878	3037	0.41	76 x 26T	No 3 D09
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1303	0	1238	F	0.878	3037	0.41		No 3 D09
55	NTF10310	A/	1	6.2	13	2	1	1	1	F1&F2	0	1432	0	1360	F	0.878	3037	0.45	76 x 26T	No 3 D10
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1432	0	1360	F	0.878	3037	0.45		No 3 D10
56	NTF10311	A/	1	6.2	13	2	1	1	1	F1&F2	0	1561	0	1483	F	0.878	3037	0.49	76 x 26T	No 3 D11
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1561	0	1483	F	0.878	3037	0.49		No 3 D11
57	NTF10312	A/	1	6.2	13	2	1	1	1	F1&F2	0	1690	0	1605	F	0.878	3037	0.53	76 x 26T	No 3 D12
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1690	0	1605	F	0.878	3037	0.53		No 3 D12
58	NTF10313	A/	1	6.2	13	2	1	1	1	F1&F2	0	1819	0	1728	F	0.878	3037	0.57	76 x 26T	No 3 D13
		F/	1	6.2	13	2	1	1	1	F1&F2	0	1819	0	1728	F	0.878	3037	0.57		No 3 D13
59	SDK10101	A/	1	8.65	14	2	1	1	1	TZONE		2159	0	2051	F	0.937	2733	0.75	76 x 26T	No 2 D01
		F/	1	8.65	14	2	1	1	1	TZONE		2159	0	2051	F	0.937	2733	0.75		No 2 D01
60	SDK10102	A/	1	8.65	14	2	1	1	1	TZONE		2055	0	1953	F	0.937	2733	0.71	76 x 26T	No 2 D02
		F/	1	8.65	14	2	1	1	1	TZONE		2055	0	1953	F	0.937	2733	0.71		No 2 D02
61	SDK10103	A/	1	8.65	14	2	1	1	1	TZONE		1952	0	1854	F	0.937	2733	0.68	76 x 26T	No 2 D03
		F/	1	8.65	14	2	1	1	1	TZONE		1952	0	1854	F	0.937	2733	0.68		No 2 D03
62	SDK10104	A/	1	8.65	14	2	1	1	1	TZONE		1848	0	1755	F	0.937	2733	0.64	76 x 26T	No 2 D04
		F/	1	8.65	14	2	1	1	1	TZONE		1848	0	1755	F	0.937	2733	0.64		No 2 D04
63	SDK10105	A/	1	8.65	14	2	1	1	1	TZONE		1744	0	1657	F	0.937	2733	0.61	76 x 26T	No 2 D05
		F/	1	8.65	14	2	1	1	1	TZONE		1744	0	1657	F	0.937	2733	0.61		No 2 D05
64	SDK10106	A/	1	8.65	14	2	1	1	1	TZONE		1640	0	1558	F	0.937	2733	0.57	76 x 26T	No 2 D06
		F/	1	8.65	14	2	1	1	1	TZONE		1640	0	1558	F	0.937	2733	0.57		No 2 D06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
65	SDK10107	A/	1	8.65	14	2	1	1	1	TZONE		1537	0	1460	F	0.937	2733	0.53	76 x 26T	No 2 D07
		F/	1	8.65	14	2	1	1	1	TZONE		1537	0	1460	F	0.937	2733	0.53		No 2 D07
66	SDK10208	A/	1	8.65	193	2	1	1	1	TZONE		1414	0	1343	F	0.937	2733	0.49	203 x 140 T	No 2 D08
		F/	1	8.65	193	2	1	1	1	TZONE		1414	0	1343	F	0.937	2733	0.49		No 2 D08
67	SDK10309	A/	1	8.65	14	2	1	1	1	TZONE		1293	0	1229	F	0.937	2733	0.45	76 x 26T	No 2 I09
		F/	1	8.65	14	2	1	1	1	TZONE		1293	0	1229	F	0.937	2733	0.45		No 2 I09
68	SDK10310	A/	1	8.65	14	2	1	1	1	TZONE		1173	0	1114	F	0.937	2733	0.41	76 x 26T	No 2 I10
		F/	1	8.65	14	2	1	1	1	TZONE		1173	0	1114	F	0.937	2733	0.41		No 2 I10
69	SDK10311	A/	1	8.65	14	2	1	1	1	TZONE		1052	0	999	F	0.937	2733	0.37	76 x 26T	No 2 I11
		F/	1	8.65	14	2	1	1	1	TZONE		1052	0	999	F	0.937	2733	0.37		No 2 I11
70	SDK10312	A/	1	8.65	14	2	1	1	1	TZONE		931	0	885	F	0.937	2733	0.32	76 x 26T	No 2 I12
		F/	1	8.65	14	2	1	1	1	TZONE		931	0	885	F	0.937	2733	0.32		No 2 I12
71	SDK10313	A/	1	8.65	14	2	1	1	1	TZONE		811	0	770	F	0.937	2733	0.28	76 x 26T	No 2 I13
		F/	1	8.65	14	2	1	1	1	TZONE		811	0	770	F	0.937	2733	0.28		No 2 I13

Table C.4 SafeHull Phase A Fatigue Analysis of Class F Flat Bars for Ship C

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)

SHIP : with LBP = 124.5 m, Class F Details

LxBxDxd = 120.77x 14.80x 11.10x 4.99(m)

Hull-Girder Moment of Inertia Ivert. 105555.(cm2-m2) Ihoriz. 181783.(cm2-m2)

Neutral Axis Height 5.47(m) above baseline

Slamming factor for deck and bottom structures, ms= 1.000

FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS

S U M M A R Y

Special Location at 62.25m from AP (0.485 L from aft end of L)

Scantling Group # 1

Range of Wave-induced Bending Moment MW(vert.) 52100.(tf-m) MW(horiz.) 42594.(tf-m)

******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas (cm^2)		SCF	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
						Head (m)	Force (tf)	As	Ac		fs	fL	fRi				
BTM10204	1	1	0.24	0.453	0.9	4.14	1.73	0	26.9	1.5	61	2119	2121	F	0.915	2833	0.75
		2	0.24	0.453	0.9	4.14	1.73	0	26.9	1	61	2119	2120	F	0.915	2833	0.75
[Weld Throat]			0.24	0.453	0.9	4.14	1.73	[Asw]=	0	1.25	61	0	*****	W	0.915	1797	NaN
BTM10205	1	1	0.29	0.46	0.9	4.14	1.76	0	26.9	1.5	62	2097	2099	F	0.915	2833	0.74
		2	0.29	0.46	0.9	4.14	1.76	0	26.9	1	62	2097	2097	F	0.915	2833	0.74
[Weld Throat]			0.29	0.46	0.9	4.14	1.76	[Asw]=	0	1.25	62	0	*****	W	0.915	1797	NaN
BTM10206	1	1	0.35	0.46	0.9	4.14	1.76	0	26.9	1.5	62	2073	2075	F	0.915	2833	0.73
		2	0.35	0.46	0.9	4.14	1.76	0	26.9	1	62	2073	2074	F	0.915	2833	0.73
[Weld Throat]			0.35	0.46	0.9	4.14	1.76	[Asw]=	0	1.25	62	0	*****	W	0.915	1797	NaN
BTM10308	1	1	0.45	0.317	0.9	4.14	1.21	0	26.9	1.5	43	2007	2008	F	0.915	2833	0.71
		2	0.45	0.317	0.9	4.14	1.21	0	26.9	1	43	2007	2007	F	0.915	2833	0.71

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas (cm^2)		SCF	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
						Head (m)	Force (tf)	As	Ac		fs	fL	fRi				
[Weld Throat]			0.45	0.317	0.9	4.14	1.21	[Asw]=	0	1.25	43	0	*****	W	0.915	1797	NaN
BTM10309	1	1	0.56	0.4	0.9	4.14	1.53	0	26.9	1.5	54	1978	1980	F	0.915	2833	0.7
		2	0.56	0.4	0.9	4.14	1.53	0	26.9	1	54	1978	1979	F	0.915	2833	0.7
[Weld Throat]			0.56	0.4	0.9	4.14	1.53	[Asw]=	0	1.25	54	0	*****	W	0.915	1797	NaN
BTM10311	1	1	0.78	0.447	0.9	4.14	1.71	0	26.9	1.5	60	1899	1901	F	0.915	2833	0.67
		2	0.78	0.447	0.9	4.14	1.71	0	26.9	1	60	1899	1900	F	0.915	2833	0.67
[Weld Throat]			0.78	0.447	0.9	4.14	1.71	[Asw]=	0	1.25	60	0	*****	W	0.915	1797	NaN
BTM10412	1	1	0.99	0.482	0.9	4.14	1.84	0	26.9	1.5	65	1823	1826	F	0.915	2833	0.64
		2	0.99	0.482	0.9	4.14	1.84	0	26.9	1	65	1823	1824	F	0.915	2833	0.64
[Weld Throat]			0.99	0.482	0.9	4.14	1.84	[Asw]=	0	1.25	65	0	*****	W	0.915	1797	NaN
BTM10413	1	1	1.2	0.47	0.9	4.14	1.79	0	26.9	1.5	63	1737	1739	F	0.915	2833	0.61
		2	1.2	0.47	0.9	4.14	1.79	0	26.9	1	63	1737	1738	F	0.915	2833	0.61
[Weld Throat]			1.2	0.47	0.9	4.14	1.79	[Asw]=	0	1.25	63	0	*****	W	0.915	1797	NaN

APPENDIX D

FATIGUE ANALYSIS SUMMARY FOR SHIP D

Table D.1 SafeHull Phase A Fatigue Analysis of Class F2 Longitudinals for Ship D

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with L 117.66
LxBxDxd = 117.66x 15.24x 11.50x 4.94(m)
Hull-Girder Moment of Inertia Ivert. 108103.(cm2-m2) Ihoriz. 222700.(cm2-m2)
Neutral Axis Height 5.35(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 60.65m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52115.(tf-m) MW(horiz.) 42070.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
1	BTM10101	A/	1	0.08	255	1.829	1	1	1	1&2	4.02	2420	222	2133	F2	0.917	2482	0.86	10 x 4 T	A Stra01
		F/	1	0.08	255	1.829	1	1	1	1&2	4.02	2420	222	2133	F2	0.917	2482	0.86		A Stra01
2	BTM10102	A/	1	0.18	255	1.829	1	1	1	1&2	4.02	2373	233	2105	F2	0.917	2482	0.85	10 x 4 T	A Stra02
		F/	1	0.18	255	1.829	1	1	1	1&2	4.02	2373	233	2105	F2	0.917	2482	0.85		A Stra02
3	BTM10103	A/	1	0.27	255	1.829	1	1	1	1&2	4.02	2327	238	2071	F2	0.917	2482	0.83	10 x 4 T	A Stra03
		F/	1	0.27	255	1.829	1	1	1	1&2	4.02	2327	238	2071	F2	0.917	2482	0.83		A Stra03
4	BTM10204	A/	1	0.39	1108	1.829	1	1	1	1&2	4.02	2142	55	1774	F2	0.917	2482	0.71	Mn Eng Seat	B Stra04
		F/	1	0.39	1108	1.829	1	1	1	1&2	4.02	2142	55	1774	F2	0.917	2482	0.71		B Stra04
5	BTM10205	A/	1	0.51	1108	1.829	1	1	1	1&2	4.02	2083	53	1725	F2	0.917	2482	0.69	Mn Eng Seat	B Stra05
		F/	1	0.51	1108	1.829	1	1	1	1&2	4.02	2083	53	1725	F2	0.917	2482	0.69		B Stra05
6	BTM10306	A/	1	0.63	255	1.829	1	1	1	1&2	4.02	2153	228	1922	F2	0.917	2482	0.77	10 x 4 T	C1 Str06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
		F/	1	0.63	255	1.829	1	1	1	1&2	4.02	2153	228	1922	F2	0.917	2482	0.77		C1 Str06
7	BTM10407	A/	1	0.89	253	1.702	1	1	1	1&2	4.02	2030	176	1781	F2	0.917	2482	0.72	10 x 4 T	C2 Str07
		F/	3	0.89	253	1.702	1	1	1	1&2	4.02	2030	176	1781	F2	0.917	2482	0.72		C2 Str07
8	BLG10101	A/	1	1.14	253	1.702	1	1	1	1&2	4.02	1909	173	1681	F2	0.917	2482	0.68	10 x 4 T	D Stra01
		F/	3	1.14	253	1.702	1	1	1	1&2	4.02	1909	173	1681	F2	0.917	2482	0.68		D Stra01
9	BLG10102	A/	1	1.51	254	1.727	1	1	1	TZONE		1793	209	1902	F2	0.917	2482	0.77	10 x 4 T	D Stra02
		F/	2	1.51	254	1.727	1	1	1	TZONE		1793	209	1902	F2	0.917	2482	0.77		D Stra02
10	BLG10103	A/	1	1.87	188	1.727	1	1	1	TZONE		1811	329	2033	F2	0.917	2482	0.82	8 x 4 T	D Stra03
		F/	2	1.87	188	1.727	1	1	1	TZONE		1811	329	2033	F2	0.917	2482	0.82		D Stra03
11	SHL10101	A/	1	2.39	201	1.829	1	1	1	F1&F2	5.83	1880	406	2171	F2	0.954	2341	0.93	8 x 4 T	E Stra01
		F/	1	2.39	201	1.829	1	1	1	F1&F2	5.83	1880	406	2171	F2	0.954	2341	0.93		E Stra01
12	SHL10102	A/	1	3	201	1.829	1	1	1	F1&F2	6.85	1796	467	2149	F2	0.954	2341	0.92	8 x 4 T	E Stra02
		F/	1	3	201	1.829	1	1	1	F1&F2	6.85	1796	467	2149	F2	0.954	2341	0.92		E Stra02
13	SHL10103	A/	1	3.61	201	1.829	1	1	1	F1&F2	8.19	1712	542	2142	F2	0.954	2341	0.91	8 x 4 T	E Stra03
		F/	1	3.61	201	1.829	1	1	1	F1&F2	8.19	1712	542	2142	F2	0.954	2341	0.91		E Stra03
14	SHL10204	A/	1	4.21	204	1.727	1	1	1	F1&F2	9.78	1612	538	2042	F2	0.954	2341	0.87	8 x 4 T	F Stra04
		F/	2	4.21	204	1.727	1	1	1	F1&F2	9.78	1612	538	2042	F2	0.954	2341	0.87		F Stra04
15	SHL10205	A/	1	4.78	205	1.829	1	0.75	1	F1&F2	11.29	1508	505	1913	F2	0.954	2341	0.82	8 x 4 T	F Stra05
		F/	1	4.78	205	1.829	1	0.75	1	F1&F2	11.29	1508	505	1913	F2	0.954	2341	0.82		F Stra05
16	SHL10306	A/	1	5.35	192	1.829	1	0.48	1	F1&F2	10.99	1401	337	1652	F2	0.954	2341	0.71	8 x 4 T	G1 Str06
		F/	1	5.35	192	1.829	1	0.48	1	F1&F2	10.99	1401	337	1652	F2	0.954	2341	0.71		G1 Str06
17	SHL10307	A/	1	5.93	192	1.829	1	0.32	1	F1&F2	9.95	1512	211	1637	F2	0.954	2341	0.7	8 x 4 T	G1 Str07
		F/	1	5.93	192	1.829	1	0.32	1	F1&F2	9.95	1512	211	1637	F2	0.954	2341	0.7		G1 Str07
18	SHL10508	A/	1	7.12	151	1.829	1	0.3	1	F1&F2	7.83	1747	194	1843	F2	0.954	2341	0.79	7 x 4 T	H Stra08
		F/	1	7.12	151	1.829	1	0.3	1	F1&F2	7.83	1747	194	1843	F2	0.954	2341	0.79		H Stra08
19	SHL10509	A/	1	7.72	151	1.829	1	0.3	1	F1&F2	6.75	1862	172	1933	F2	0.954	2341	0.83	7 x 4 T	H Stra09
		F/	1	7.72	151	1.829	1	0.3	1	F1&F2	6.75	1862	172	1933	F2	0.954	2341	0.83		H Stra09
20	SHL10510	A/	1	8.32	151	1.829	1	0.3	1	F1&F2	5.68	1978	157	2028	F2	0.954	2341	0.87	7 x 4 T	H Stra10
		F/	1	8.32	151	1.829	1	0.3	1	F1&F2	5.68	1978	157	2028	F2	0.954	2341	0.87		H Stra10

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
21	SHL10711	A/	1	9.61	151	1.829	1	0.3	1	TZONE		2127	41	2060	F2	0.912	2503	0.82	7 x 4 T	I2 Str11
		F/	1	9.61	151	1.829	1	0.3	1	TZONE		2127	41	2060	F2	0.912	2503	0.82		I2 Str11
22	SHL10812	A/	1	10.21	158	1.829	1	0.3	1	TZONE		2341	5	2228	F2	0.887	2623	0.85	7 x 4 T	J Stra12
		F/	1	10.21	158	1.829	1	0.3	1	TZONE		2341	5	2228	F2	0.887	2623	0.85		J Stra12
23	SHL10813	A/	1	10.8	158	1.829	1	0.3	1	1&2	0	2625	0	2494	F2	0.881	2656	0.94	7 x 4 T	J Stra13
		F/	1	10.8	158	1.829	1	0.3	1	1&2	0	2625	0	2494	F2	0.881	2656	0.94		J Stra13
24	DEC10101	A/	1	11.52	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02	8 x 4 T	No 1 D01
		F/	1	11.52	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02		No 1 D01
25	DEC10102	A/	1	11.56	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02	8 x 4 T	No 1 D02
		F/	1	11.56	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02		No 1 D02
26	DEC10103	A/	1	11.59	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02	8 x 4 T	No 1 D03
		F/	1	11.59	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02		No 1 D03
27	DEC10104	A/	1	11.62	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02	8 x 4 T	No 1 D04
		F/	1	11.62	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02		No 1 D04
28	DEC10105	A/	1	11.65	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02	8 x 4 T	No 1 D05
		F/	1	11.65	185	1.829	1	1	1	1&2	0	2864	0	2721	F2	0.881	2656	1.02		No 1 D05
29	NTF10101	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1010	0	959	F2	0.881	2656	0.36	5 x 4 T	No 3 D01
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1010	0	959	F2	0.881	2656	0.36		No 3 D01
30	NTF10102	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1142	0	1085	F2	0.881	2656	0.41	5 x 4 T	No 3 D02
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1142	0	1085	F2	0.881	2656	0.41		No 3 D02
31	NTF10103	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1274	0	1210	F2	0.881	2656	0.46	5 x 4 T	No 3 D03
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1274	0	1210	F2	0.881	2656	0.46		No 3 D03
32	NTF10104	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1406	0	1336	F2	0.881	2656	0.5	5 x 4 T	No 3 D04
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1406	0	1336	F2	0.881	2656	0.5		No 3 D04
33	NTF10105	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1538	0	1462	F2	0.881	2656	0.55	5 x 4 T	No 3 D05
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1538	0	1462	F2	0.881	2656	0.55		No 3 D05
34	SDK10101	A/	1	9.02	71	1.829	1	1	1	TZONE		1958	0	1860	F2	0.937	2406	0.77	5 x 4 T	No 2 D01
		F/	1	9.02	71	1.829	1	1	1	TZONE		1958	0	1860	F2	0.937	2406	0.77		No 2 D01
35	SDK10102	A/	1	9.02	71	1.829	1	1	1	TZONE		1856	0	1763	F2	0.937	2406	0.73	5 x 4 T	No 2 D02

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
		F/	1	9.02	71	1.829	1	1	1	TZONE		1856	0	1763	F2	0.937	2406	0.73		No 2 D02
36	SDK10103	A/	1	9.02	71	1.829	1	1	1	TZONE		1754	0	1667	F2	0.937	2406	0.69	5 x 4 T	No 2 D03
		F/	1	9.02	71	1.829	1	1	1	TZONE		1754	0	1667	F2	0.937	2406	0.69		No 2 D03
37	SDK10104	A/	1	9.02	71	1.829	1	1	1	TZONE		1652	0	1570	F2	0.937	2406	0.65	5 x 4 T	No 2 D04
		F/	1	9.02	71	1.829	1	1	1	TZONE		1652	0	1570	F2	0.937	2406	0.65		No 2 D04
38	SDK10105	A/	1	9.02	71	1.829	1	1	1	TZONE		1551	0	1473	F2	0.937	2406	0.61	5 x 4 T	No 2 D05
		F/	1	9.02	71	1.829	1	1	1	TZONE		1551	0	1473	F2	0.937	2406	0.61		No 2 D05

Table D.2 SafeHull Phase A Fatigue Analysis of Class F2 Flat Bars for Ship D

15 MARCH 2001 15:10:29 PAGE: 1
ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with L 117.66
LxBxDxd = 117.66x 15.24x 11.50x 4.94(m)
Hull-Girder Moment of Inertia Ivert. 108103.(cm2-m2) Ihoriz. 222700.(cm2-m2)
Neutral Axis Height 5.35(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 60.65m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52115.(tf-m) MW(horiz.) 42070.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas (cm^2)		SCF	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
						Head (m)	Force (tf)	As	Ac		fs	fL	fRi				
BLG10102	1	1	1.51	0.6	1.727	4.63	4.91	0	25	1.5	187	1902	1922	F2	0.917	2482	0.77
		2	1.51	0.6	1.727	4.63	4.91	0	25	1	187	1902	1911	F2	0.917	2482	0.77
[Weld Throat]			1.51	0.6	1.727	4.63	4.91	[Asw]=	0	1.25	187	0	*****	W	0.917	1790	NaN
BLG10103	1	1	1.87	0.634	1.727	5.11	5.74	0	18.6	1.5	293	2033	2080	F2	0.917	2482	0.84
		2	1.87	0.634	1.727	5.11	5.74	0	18.6	1	293	2033	2054	F2	0.917	2482	0.83
[Weld Throat]			1.87	0.634	1.727	5.11	5.74	[Asw]=	0	1.25	293	0	*****	W	0.917	1790	NaN
SHL10204	1	1	4.21	0.587	1.727	9.78	10.16	0	18.6	1.5	518	2042	2185	F2	0.954	2341	0.93
		2	4.21	0.587	1.727	9.78	10.16	0	18.6	1	518	2042	2107	F2	0.954	2341	0.9
[Weld Throat]			4.21	0.587	1.727	9.78	10.16	[Asw]=	0	1.25	518	0	*****	W	0.954	1684	NaN

Table D.3 SafeHull Phase A Fatigue Analysis of Class F Longitudinals for Ship D

15 MARCH 2001 15:19:20 PAGE: 1
ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with Class F Details, L = 117.66
LxBxDxd = 117.66x 15.24x 11.50x 4.94(m)
Hull-Girder Moment of Inertia Ivert. 108103.(cm2-m2) Ihoriz. 222700.(cm2-m2)
Neutral Axis Height 5.35(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS

Special Location at 60.65m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52115.(tf-m) MW(horiz.) 42070.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
1	BTM10101	A/	1	0.08	255	1.829	1	1	1	1&2	4.02	2420	222	2133	F	0.917	2822	0.76	10 x 4 T	A Stra01
		F/	1	0.08	255	1.829	1	1	1	1&2	4.02	2420	222	2133	F	0.917	2822	0.76		A Stra01
2	BTM10102	A/	1	0.18	255	1.829	1	1	1	1&2	4.02	2373	233	2105	F	0.917	2822	0.75	10 x 4 T	A Stra02
		F/	1	0.18	255	1.829	1	1	1	1&2	4.02	2373	233	2105	F	0.917	2822	0.75		A Stra02
3	BTM10103	A/	1	0.27	255	1.829	1	1	1	1&2	4.02	2327	238	2071	F	0.917	2822	0.73	10 x 4 T	A Stra03
		F/	1	0.27	255	1.829	1	1	1	1&2	4.02	2327	238	2071	F	0.917	2822	0.73		A Stra03
4	BTM 10204	A/	1	0.39	1108	1.829	1	1	1	1&2	4.02	2142	55	1774	F	0.917	2822	0.63	Mn Eng Seat	B Stra04
		F/	1	0.39	1108	1.829	1	1	1	1&2	4.02	2142	55	1774	F	0.917	2822	0.63		B Stra04
5	BTM10205	A/	1	0.51	1108	1.829	1	1	1	1&2	4.02	2083	53	1725	F	0.917	2822	0.61	Mn Eng Seat	B Stra05
		F/	1	0.51	1108	1.829	1	1	1	1&2	4.02	2083	53	1725	F	0.917	2822	0.61		B Stra05

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
6	BTM10306	A/	1	0.63	255	1.829	1	1	1	1&2	4.02	2153	228	1922	F	0.917	2822	0.68	10 x 4 T	C1 Str06
		F/	1	0.63	255	1.829	1	1	1	1&2	4.02	2153	228	1922	F	0.917	2822	0.68		C1 Str06
7	BTM10407	A/	1	0.89	253	1.702	1	1	1	1&2	4.02	2030	176	1781	F	0.917	2822	0.63	10 x 4 T	C2 Str07
		F/	3	0.89	253	1.702	1	1	1	1&2	4.02	2030	176	1781	F	0.917	2822	0.63		C2 Str07
8	BLG10101	A/	1	1.14	253	1.702	1	1	1	1&2	4.02	1909	173	1681	F	0.917	2822	0.6	10 x 4 T	D Stra01
		F/	3	1.14	253	1.702	1	1	1	1&2	4.02	1909	173	1681	F	0.917	2822	0.6		D Stra01
9	BLG10102	A/	1	1.51	254	1.727	1	1	1	TZONE		1793	209	1902	F	0.917	2822	0.67	10 x 4 T	D Stra02
		F/	2	1.51	254	1.727	1	1	1	TZONE		1793	209	1902	F	0.917	2822	0.67		D Stra02
10	BLG10103	A/	1	1.87	188	1.727	1	1	1	TZONE		1811	329	2033	F	0.917	2822	0.72	8 x 4 T	D Stra03
		F/	2	1.87	188	1.727	1	1	1	TZONE		1811	329	2033	F	0.917	2822	0.72		D Stra03
11	SHL10101	A/	1	2.39	201	1.829	1	1	1	F1&F2	5.83	1880	406	2171	F	0.954	2658	0.82	8 x 4 T	E Stra01
		F/	1	2.39	201	1.829	1	1	1	F1&F2	5.83	1880	406	2171	F	0.954	2658	0.82		E Stra01
12	SHL10102	A/	1	3	201	1.829	1	1	1	F1&F2	6.85	1796	467	2149	F	0.954	2658	0.81	8 x 4 T	E Stra02
		F/	1	3	201	1.829	1	1	1	F1&F2	6.85	1796	467	2149	F	0.954	2658	0.81		E Stra02
13	SHL10103	A/	1	3.61	201	1.829	1	1	1	F1&F2	8.19	1712	542	2142	F	0.954	2658	0.81	8 x 4 T	E Stra03
		F/	1	3.61	201	1.829	1	1	1	F1&F2	8.19	1712	542	2142	F	0.954	2658	0.81		E Stra03
14	SHL10204	A/	1	4.21	204	1.727	1	1	1	F1&F2	9.78	1612	538	2042	F	0.954	2658	0.77	8 x 4 T	F Stra04
		F/	2	4.21	204	1.727	1	1	1	F1&F2	9.78	1612	538	2042	F	0.954	2658	0.77		F Stra04
15	SHL10205	A/	1	4.78	205	1.829	1	0.75	1	F1&F2	11.29	1508	505	1913	F	0.954	2658	0.72	8 x 4 T	F Stra05
		F/	1	4.78	205	1.829	1	0.75	1	F1&F2	11.29	1508	505	1913	F	0.954	2658	0.72		F Stra05
16	SHL10306	A/	1	5.35	192	1.829	1	0.48	1	F1&F2	10.99	1401	337	1652	F	0.954	2658	0.62	8 x 4 T	G1 Str06
		F/	1	5.35	192	1.829	1	0.48	1	F1&F2	10.99	1401	337	1652	F	0.954	2658	0.62		G1 Str06
17	SHL10307	A/	1	5.93	192	1.829	1	0.32	1	F1&F2	9.95	1512	211	1637	F	0.954	2658	0.62	8 x 4 T	G1 Str07
		F/	1	5.93	192	1.829	1	0.32	1	F1&F2	9.95	1512	211	1637	F	0.954	2658	0.62		G1 Str07
18	SHL10508	A/	1	7.12	151	1.829	1	0.3	1	F1&F2	7.83	1747	194	1843	F	0.954	2658	0.69	7 x 4 T	H Stra08
		F/	1	7.12	151	1.829	1	0.3	1	F1&F2	7.83	1747	194	1843	F	0.954	2658	0.69		H Stra08
19	SHL10509	A/	1	7.72	151	1.829	1	0.3	1	F1&F2	6.75	1862	172	1933	F	0.954	2658	0.73	7 x 4 T	H Stra09
		F/	1	7.72	151	1.829	1	0.3	1	F1&F2	6.75	1862	172	1933	F	0.954	2658	0.73		H Stra09
20	SHL10510	A/	1	8.32	151	1.829	1	0.3	1	F1&F2	5.68	1978	157	2028	F	0.954	2658	0.76	7 x 4 T	H Stra10

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
		F/	1	8.32	151	1.829	1	0.3	1	F1&F2	5.68	1978	157	2028	F	0.954	2658	0.76		H Stra10
21	SHL10711	A/	1	9.61	151	1.829	1	0.3	1	TZONE		2127	41	2060	F	0.912	2846	0.72	7 x 4 T	I2 Str11
		F/	1	9.61	151	1.829	1	0.3	1	TZONE		2127	41	2060	F	0.912	2846	0.72		I2 Str11
22	SHL10812	A/	1	10.21	158	1.829	1	0.3	1	TZONE		2341	5	2228	F	0.887	2982	0.75	7 x 4 T	J Stra12
		F/	1	10.21	158	1.829	1	0.3	1	TZONE		2341	5	2228	F	0.887	2982	0.75		J Stra12
23	SHL10813	A/	1	10.8	158	1.829	1	0.3	1	1&2	0	2625	0	2494	F	0.881	3020	0.83	7 x 4 T	J Stra13
		F/	1	10.8	158	1.829	1	0.3	1	1&2	0	2625	0	2494	F	0.881	3020	0.83		J Stra13
24	DEC10101	A/	1	11.52	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9	8 x 4 T	No 1 D01
		F/	1	11.52	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9		No 1 D01
25	DEC10102	A/	1	11.56	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9	8 x 4 T	No 1 D02
		F/	1	11.56	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9		No 1 D02
26	DEC10103	A/	1	11.59	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9	8 x 4 T	No 1 D03
		F/	1	11.59	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9		No 1 D03
27	DEC10104	A/	1	11.62	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9	8 x 4 T	No 1 D04
		F/	1	11.62	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9		No 1 D04
28	DEC10105	A/	1	11.65	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9	8 x 4 T	No 1 D05
		F/	1	11.65	185	1.829	1	1	1	1&2	0	2864	0	2721	F	0.881	3020	0.9		No 1 D05
29	NTF10101	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1010	0	959	F	0.881	3020	0.32	5 x 4 T	No 3 D01
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1010	0	959	F	0.881	3020	0.32		No 3 D01
30	NTF10102	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1142	0	1085	F	0.881	3020	0.36	5 x 4 T	No 3 D02
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1142	0	1085	F	0.881	3020	0.36		No 3 D02
31	NTF10103	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1274	0	1210	F	0.881	3020	0.4	5 x 4 T	No 3 D03
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1274	0	1210	F	0.881	3020	0.4		No 3 D03
32	NTF10104	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1406	0	1336	F	0.881	3020	0.44	5 x 4 T	No 3 D04
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1406	0	1336	F	0.881	3020	0.44		No 3 D04
33	NTF10105	A/	1	6.55	63	1.829	1	1	1	F1&F2	0	1538	0	1462	F	0.881	3020	0.48	5 x 4 T	No 3 D05
		F/	1	6.55	63	1.829	1	1	1	F1&F2	0	1538	0	1462	F	0.881	3020	0.48		No 3 D05
34	SDK10101	A/	1	9.02	71	1.829	1	1	1	TZONE		1958	0	1860	F	0.937	2734	0.68	5 x 4 T	No 2 D01
		F/	1	9.02	71	1.829	1	1	1	TZONE		1958	0	1860	F	0.937	2734	0.68		No 2 D01

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm^2)			FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
												f_{RG}	f_{RL}	f_R						
35	SDK10102	A/	1	9.02	71	1.829	1	1	1	TZONE		1856	0	1763	F	0.937	2734	0.65	5 x 4 T	No 2 D02
		F/	1	9.02	71	1.829	1	1	1	TZONE		1856	0	1763	F	0.937	2734	0.65		No 2 D02
36	SDK10103	A/	1	9.02	71	1.829	1	1	1	TZONE		1754	0	1667	F	0.937	2734	0.61	5 x 4 T	No 2 D03
		F/	1	9.02	71	1.829	1	1	1	TZONE		1754	0	1667	F	0.937	2734	0.61		No 2 D03
37	SDK10104	A/	1	9.02	71	1.829	1	1	1	TZONE		1652	0	1570	F	0.937	2734	0.57	5 x 4 T	No 2 D04
		F/	1	9.02	71	1.829	1	1	1	TZONE		1652	0	1570	F	0.937	2734	0.57		No 2 D04
38	SDK10105	A/	1	9.02	71	1.829	1	1	1	TZONE		1551	0	1473	F	0.937	2734	0.54	5 x 4 T	No 2 D05
		F/	1	9.02	71	1.829	1	1	1	TZONE		1551	0	1473	F	0.937	2734	0.54		No 2 D05

Table D.4 SafeHull Phase A Fatigue Analysis of Class F Flat Bars for Ship D

15 MARCH 2001 15:19:21 PAGE: 1
ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with Class F Details, L = 117.66
LxBxDxd = 117.66x 15.24x 11.50x 4.94(m)
Hull-Girder Moment of Inertia Ivert. 108103.(cm2-m2) Ihoriz. 222700.(cm2-m2)
Neutral Axis Height 5.35(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 60.65m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 52115.(tf-m) MW(horiz.) 42070.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas (cm^2)		SCF	Stress Range (kg/cm^2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm^2) PS	fR/PS
						Head (m)	Force (tf)	As	Ac		fs	fL	fRi				
BLG10102	1	1	1.51	0.6	1.727	4.63	4.91	0	25	1.5	187	1902	1922	F	0.917	2822	0.68
		2	1.51	0.6	1.727	4.63	4.91	0	25	1	187	1902	1911	F	0.917	2822	0.68
[Weld Throat]			1.51	0.6	1.727	4.63	4.91	[Asw]=	0	1.25	187	0	*****	W	0.917	1790	NaN
BLG10103	1	1	1.87	0.634	1.727	5.11	5.74	0	18.6	1.5	293	2033	2080	F	0.917	2822	0.74
		2	1.87	0.634	1.727	5.11	5.74	0	18.6	1	293	2033	2054	F	0.917	2822	0.73
[Weld Throat]			1.87	0.634	1.727	5.11	5.74	[Asw]=	0	1.25	293	0	*****	W	0.917	1790	NaN
SHL10204	1	1	4.21	0.587	1.727	9.78	10.16	0	18.6	1.5	518	2042	2185	F	0.954	2658	0.82
		2	4.21	0.587	1.727	9.78	10.16	0	18.6	1	518	2042	2107	F	0.954	2658	0.79
[Weld Throat]			4.21	0.587	1.727	9.78	10.16	[Asw]=	0	1.25	518	0	*****	W	0.954	1684	NaN

APPENDIX E

FATIGUE ANALYSIS SUMMARY FOR SHIP E

Table E.1 SafeHull Phase A Fatigue Analysis of Class F2 Longitudinals for Ship E

Note: There are no flat bar stiffeners on this class

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with True LBP = 108.51 m
LxBxDxd = 105.25x 12.74x 8.74x 4.18(m)
Hull-Girder Moment of Inertia Ivert. 52395.(cm2-m2) Ihoriz. 87721.(cm2-m2)
Neutral Axis Height 4.55(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 59.00m from AP (0.530 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 32783.(tf-m) MW(horiz.) 24574.(tf-m)
******** "Net" Ship ******** Local Cf=0.95 Cw=0.75 Long Perm.

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
1	KPL10101	A/	1	0	106	1.524	1	1	1	1&2	4.01	2771	328	2502	F2	0.928	2441	1.03	2.5x5x8.5# T	FPK 01
		F/	1	0	106	1.524	1	1	1	1&2	4.01	2771	328	2502	F2	0.928	2441	1.03		FPK 01
2	KPL10202	A/	1	0.09	152	1.524	1	1	1	1&2	4.01	2698	236	2369	F2	0.928	2441	0.97	3x6x10.9# T	FPK 02
		F/	1	0.09	152	1.524	1	1	1	1&2	4.01	2698	236	2369	F2	0.928	2441	0.97		FPK 02
3	BTM10201	A/	1	0.19	2647	1.524	1	1	1	1&2	4.01	2209	14	1795	F2	0.928	2441	0.74	30x12x20#/20# T	A Stra01
		F/	1	0.19	2647	1.524	1	1	1	1&2	4.01	2209	14	1795	F2	0.928	2441	0.74		A Stra01
4	BTM10202	A/	1	0.33	146	1.524	1	1	1	1&2	4.01	2547	252	2260	F2	0.928	2441	0.93	3x6x10.9# T	A Stra02
		F/	1	0.33	146	1.524	1	1	1	1&2	4.01	2547	252	2260	F2	0.928	2441	0.93		A Stra02
5	BTM10203	A/	1	0.48	1250	1.524	1	1	1	1&2	4.01	2203	32	1804	F2	0.928	2441	0.74	21x9x17#/20# T	A Stra03
		F/	1	0.48	1250	1.524	1	1	1	1&2	4.01	2203	32	1804	F2	0.928	2441	0.74		A Stra03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
6	BTM10304	A/	1	0.66	146	1.524	1	1	1	1&2	4.01	2344	273	2113	F2	0.928	2441	0.87	3x6x10.9# T	B Stra04
		F/	1	0.66	146	1.524	1	1	1	1&2	4.01	2344	273	2113	F2	0.928	2441	0.87		B Stra04
7	BTM10305	A/	1	0.84	502	1.524	1	1	1	1&2	3.96	2144	73	1790	F2	0.928	2441	0.73	11x9 T	B Stra05
		F/	1	0.84	502	1.524	1	1	1	1&2	3.96	2144	73	1790	F2	0.928	2441	0.73		B Stra05
8	BTM10306	A/	1	1.02	146	1.524	1	1	1	1&2	3.77	2116	186	1859	F2	0.928	2441	0.76	3x6x10.9# T	B Stra06
		F/	1	1.02	146	1.524	1	1	1	1&2	3.77	2116	186	1859	F2	0.928	2441	0.76		B Stra06
9	BLG10101	A/	1	1.31	141	1.524	1	1	1	TZONE		2040	299	2223	F2	0.928	2441	0.91	3x6x10.9# T	BlgStr01
		F/	1	1.31	141	1.524	1	1	1	TZONE		2040	299	2223	F2	0.928	2441	0.91		BlgStr01
10	BLG10102	A/	1	1.74	99	1.524	1	1	1	TZONE		2143	495	2506	F2	0.928	2441	1.03	2.5x5x8.5# T	BlgStr02
		F/	1	1.74	99	1.524	1	1	1	TZONE		2143	495	2506	F2	0.928	2441	1.03		BlgStr02
11	BLG10103	A/	1	2.17	99	1.524	1	1	1	F1&F2	6.52	2146	785	2784	F2	0.928	2441	1.14	2.5x5x8.5# T	BlgStr03
		F/	1	2.17	99	1.524	1	1	1	F1&F2	6.52	2146	785	2784	F2	0.928	2441	1.14		BlgStr03
12	SHL10101	A/	1	3.03	102	1.524	1	1	1	F1&F2	8.37	2037	971	2857	F2	0.964	2302	1.24	2.5x5x8.5# T	DStrak01
		F/	1	3.03	102	1.524	1	1	1	F1&F2	8.37	2037	971	2857	F2	0.964	2302	1.24		DStrak01
13	SHL10102	A/	1	3.57	102	1.524	1	1	1	F1&F2	9.95	1933	816	2612	F2	0.964	2302	1.13	2.5x5x8.5# T	DStrak02
		F/	1	3.57	102	1.524	1	1	1	F1&F2	9.95	1933	816	2612	F2	0.964	2302	1.13		DStrak02
14	SHL10103	A/	1	4.12	102	1.524	1	0.7	1	F1&F2	11.53	1829	666	2370	F2	0.964	2302	1.03	2.5x5x8.5# T	DStrak03
		F/	1	4.12	102	1.524	1	0.7	1	F1&F2	11.53	1829	666	2370	F2	0.964	2302	1.03		DStrak03
15	SHL10204	A/	1	4.69	102	1.524	1	0.42	1	F1&F2	10.42	1770	363	2027	F2	0.964	2302	0.88	2.5x5x8.5# T	EStrak04
		F/	1	4.69	102	1.524	1	0.42	1	F1&F2	10.42	1770	363	2027	F2	0.964	2302	0.88		EStrak04
16	SHL10205	A/	1	5.26	102	1.524	1	0.3	1	F1&F2	8.94	1917	225	2034	F2	0.964	2302	0.88	2.5x5x8.5# T	EStrak05
		F/	1	5.26	102	1.524	1	0.3	1	F1&F2	8.94	1917	225	2034	F2	0.964	2302	0.88		EStrak05
17	SHL10206	A/	1	5.83	102	1.524	1	0.3	1	F1&F2	7.47	2063	188	2138	F2	0.964	2302	0.93	2.5x5x8.5# T	EStrak06
		F/	1	5.83	102	1.524	1	0.3	1	F1&F2	7.47	2063	188	2138	F2	0.964	2302	0.93		EStrak06
18	SHL10407	A/	1	6.97	102	1.524	1	0.3	1	TZONE		2083	95	2069	F2	0.941	2392	0.86	2.5x5x8.5# T	FStrak07
		F/	1	6.97	102	1.524	1	0.3	1	TZONE		2083	95	2069	F2	0.941	2392	0.86		FStrak07
19	SHL10408	A/	1	7.57	102	1.524	1	0.3	1	TZONE		2024	48	1968	F2	0.909	2517	0.78	2.5x5x8.5# T	FStrak08
		F/	1	7.57	102	1.524	1	0.3	1	TZONE		2024	48	1968	F2	0.909	2517	0.78		FStrak08
20	SHL10509	A/	1	8.27	108	1.524	1	0.3	1	1&2	0.51	2325	16	2224	F2	0.892	2592	0.86	2.5x5x8.5# T	GStrak09

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
		F/	1	8.27	108	1.524	1	0.3	1	1&2	0.51	2325	16	2224	F2	0.892	2592	0.86		GStrak09
21	DEC10101	A/	1	8.74	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93	2.5x5x8.5# T	Gunl 01
		F/	1	8.74	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93		Gunl 01
22	DEC10202	A/	1	8.76	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93	2.5x5x8.5# T	Dk1 02
		F/	1	8.76	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93		Dk1 02
23	DEC10203	A/	1	8.77	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93	2.5x5 x8.5# T	Dk1 03
		F/	1	8.77	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93		Dk1 03
24	DEC10304	A/	1	8.79	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93	2.5x5x8.5# T	Dk1 04
		F/	1	8.79	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93		Dk1 04
25	DEC10305	A/	1	8.82	251	1.524	1	1	1	1&2	0	2506	0	2381	F2	0.892	2592	0.92	3.5x7x13.7# T	Dk1 05
		F/	1	8.82	251	1.524	1	1	1	1&2	0	2506	0	2381	F2	0.892	2592	0.92		Dk1 05
26	DEC10306	A/	1	8.85	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93	2.5x5x8.5# T	Dk1 06
		F/	1	8.85	108	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93		Dk1 06
27	DEC10407	A/	1	8.87	101	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93	2.5x5x8.5# T	Dk1 07
		F/	1	8.87	101	1.524	1	1	1	1&2	0	2538	0	2411	F2	0.892	2592	0.93		Dk1 07
28	DEC10408	A/	1	8.89	175	1.524	1	1	1	1&2	0	2506	0	2381	F2	0.892	2592	0.92	3.5x7x13.7# T	Dk1 08
		F/	1	8.89	175	1.524	1	1	1	1&2	0	2506	0	2381	F2	0.892	2592	0.92		Dk1 08
29	DEC10409	A/	1	8.9	175	1.524	1	1	1	1&2	0	2506	0	2381	F2	0.892	2592	0.92	3.5x7x13.7# T	Dk1 09
		F/	1	8.9	175	1.524	1	1	1	1&2	0	2506	0	2381	F2	0.892	2592	0.92		Dk1 09
30	SDK10101	A/	1	6.42	58	1.524	1	1	1	F1&F2	0	2104	0	1999	F2	0.964	2302	0.87	1.75x4.5x5# T	Dk3 01
		F/	1	6.42	58	1.524	1	1	1	F1&F2	0	2104	0	1999	F2	0.964	2302	0.87		Dk3 01
31	SDK10102	A/	1	6.45	58	1.524	1	1	1	F1&F2	0	1936	0	1839	F2	0.964	2302	0.80	1.75x4.5x5# T	Dk3 02
		F/	1	6.45	58	1.524	1	1	1	F1&F2	0	1936	0	1839	F2	0.964	2302	0.80		Dk3 02
32	SDK10103	A/	1	6.48	58	1.524	1	1	1	F1&F2	0	1767	0	1679	F2	0.964	2302	0.73	1.75x4.5x5# T	Dk3 03
		F/	1	6.48	58	1.524	1	1	1	F1&F2	0	1767	0	1679	F2	0.964	2302	0.73		Dk3 03
33	SDK10104	A/	1	6.5	58	1.524	1	1	1	F1&F2	0	1598	0	1518	F2	0.964	2302	0.66	1.75x4.5x5# T	Dk3 04
		F/	1	6.5	58	1.524	1	1	1	F1&F2	0	1598	0	1518	F2	0.964	2302	0.66		Dk3 04
34	SDK10105	A/	1	6.53	168	1.524	1	1	1	F1&F2	0	1430	0	1358	F2	0.964	2302	0.59	3.5x7x13.7# T	Dk3 05
		F/	1	6.53	168	1.524	1	1	1	F1&F2	0	1430	0	1358	F2	0.964	2302	0.59		Dk3 05

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
35	SDK10106	A/	1	6.55	58	1.524	1	1	1	TZONE		1261	0	1198	F2	0.963	2303	0.52	1.75x4.5x5# T	Dk3 06
		F/	1	6.55	58	1.524	1	1	1	TZONE		1261	0	1198	F2	0.963	2303	0.52		Dk3 06
36	SDK10107	A/	1	6.58	168	1.524	1	1	1	TZONE		1096	0	1041	F2	0.962	2308	0.45	3.5x7x13.7# T	Dk3 07
		F/	1	6.58	168	1.524	1	1	1	TZONE		1096	0	1041	F2	0.962	2308	0.45		Dk3 07

Table E.2 SafeHull Phase A Fatigue Analysis of Class F Longitudinals for Ship E

Note: There are no flat bar stiffeners on this class

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ABS\SAFEHULL\CFATIGUE V6.11 (2000 Rules) -- Non Production (Special consideration required for L < 130m)
SHIP : with True LBP = 108.51 m, Class F Details
LxBxDxd = 105.25x 12.74x 8.74x 4.18(m)
Hull-Girder Moment of Inertia Ivert. 52395.(cm2-m2) Ihoriz. 87721.(cm2-m2)
Neutral Axis Height 4.55(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 59.00m from AP (0.530 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 32783.(tf-m) MW(horiz.) 24574.(tf-m)
******** "Net" Ship ******** Local Cf=0.95 Cw=0.75 Long Perm.

STF #	SafeHull STF ID	TOE	ID	Dist. from BL(m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
1	KPL10101	A/	1	0	106	1.524	1	1	1	1&2	4.01	2771	328	2502	F	0.928	2774	0.90	2.5x5x8.5# T	FPK 01
		F/	1	0	106	1.524	1	1	1	1&2	4.01	2771	328	2502	F	0.928	2774	0.90		FPK 01
2	KPL10202	A/	1	0.09	152	1.524	1	1	1	1&2	4.01	2698	236	2369	F	0.928	2774	0.85	3x6x10.9# T	FPK 02
		F/	1	0.09	152	1.524	1	1	1	1&2	4.01	2698	236	2369	F	0.928	2774	0.85		FPK 02
3	BTM10201	A/	1	0.19	2647	1.524	1	1	1	1&2	4.01	2209	14	1795	F	0.928	2774	0.65	30x12x20#/20# T	A Stra01
		F/	1	0.19	2647	1.524	1	1	1	1&2	4.01	2209	14	1795	F	0.928	2774	0.65		A Stra01
4	BTM10202	A/	1	0.33	146	1.524	1	1	1	1&2	4.01	2547	252	2260	F	0.928	2774	0.81	3x6x10.9# T	A Stra02
		F/	1	0.33	146	1.524	1	1	1	1&2	4.01	2547	252	2260	F	0.928	2774	0.81		A Stra02
5	BTM10203	A/	1	0.48	1250	1.524	1	1	1	1&2	4.01	2203	32	1804	F	0.928	2774	0.65	21x9x17#/20# T	A Stra03
		F/	1	0.48	1250	1.524	1	1	1	1&2	4.01	2203	32	1804	F	0.928	2774	0.65		A Stra03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL(m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
6	BTM10304	A/	1	0.66	146	1.524	1	1	1	1&2	4.01	2344	273	2113	F	0.928	2774	0.76	3x6x10.9# T	B Stra04
		F/	1	0.66	146	1.524	1	1	1	1&2	4.01	2344	273	2113	F	0.928	2774	0.76		B Stra04
7	BTM10305	A/	1	0.84	502	1.524	1	1	1	1&2	3.96	2144	73	1790	F	0.928	2774	0.65	11x9 T	B Stra05
		F/	1	0.84	502	1.524	1	1	1	1&2	3.96	2144	73	1790	F	0.928	2774	0.65		B Stra05
8	BTM10306	A/	1	1.02	146	1.524	1	1	1	1&2	3.77	2116	186	1859	F	0.928	2774	0.67	3x6x10.9# T	B Stra06
		F/	1	1.02	146	1.524	1	1	1	1&2	3.77	2116	186	1859	F	0.928	2774	0.67		B Stra06
9	BLG10101	A/	1	1.31	141	1.524	1	1	1	TZONE		2040	299	2223	F	0.928	2774	0.80	3x6x10.9# T	BlgStr01
		F/	1	1.31	141	1.524	1	1	1	TZONE		2040	299	2223	F	0.928	2774	0.80		BlgStr01
10	BLG10102	A/	1	1.74	99	1.524	1	1	1	TZONE		2143	495	2506	F	0.928	2774	0.90	2.5x5x8.5# T	BlgStr02
		F/	1	1.74	99	1.524	1	1	1	TZONE		2143	495	2506	F	0.928	2774	0.90		BlgStr02
11	BLG10103	A/	1	2.17	99	1.524	1	1	1	F1&F2	6.52	2146	785	2784	F	0.928	2774	1.00	2.5x5x8.5# T	BlgStr03
		F/	1	2.17	99	1.524	1	1	1	F1&F2	6.52	2146	785	2784	F	0.928	2774	1.00		BlgStr03
12	SHL10101	A/	1	3.03	102	1.524	1	1	1	F1&F2	8.37	2037	971	2857	F	0.964	2614	1.09	2.5x5x8.5# T	DStrak01
		F/	1	3.03	102	1.524	1	1	1	F1&F2	8.37	2037	971	2857	F	0.964	2614	1.09		DStrak01
13	SHL10102	A/	1	3.57	102	1.524	1	1	1	F1&F2	9.95	1933	816	2612	F	0.964	2614	1.00	2.5x5x8.5# T	DStrak02
		F/	1	3.57	102	1.524	1	1	1	F1&F2	9.95	1933	816	2612	F	0.964	2614	1.00		DStrak02
14	SHL10103	A/	1	4.12	102	1.524	1	0.7	1	F1&F2	11.53	1829	666	2370	F	0.964	2614	0.91	2.5x5x8.5# T	DStrak03
		F/	1	4.12	102	1.524	1	0.7	1	F1&F2	11.53	1829	666	2370	F	0.964	2614	0.91		DStrak03
15	SHL10204	A/	1	4.69	102	1.524	1	0.42	1	F1&F2	10.42	1770	363	2027	F	0.964	2614	0.78	2.5x5x8.5# T	EStrak04
		F/	1	4.69	102	1.524	1	0.42	1	F1&F2	10.42	1770	363	2027	F	0.964	2614	0.78		EStrak04
16	SHL10205	A/	1	5.26	102	1.524	1	0.3	1	F1&F2	8.94	1917	225	2034	F	0.964	2614	0.78	2.5x5x8.5# T	EStrak05
		F/	1	5.26	102	1.524	1	0.3	1	F1&F2	8.94	1917	225	2034	F	0.964	2614	0.78		EStrak05
17	SHL10206	A/	1	5.83	102	1.524	1	0.3	1	F1&F2	7.47	2063	188	2138	F	0.964	2614	0.82	2.5x5x8.5# T	EStrak06
		F/	1	5.83	102	1.524	1	0.3	1	F1&F2	7.47	2063	188	2138	F	0.964	2614	0.82		EStrak06
18	SHL10407	A/	1	6.97	102	1.524	1	0.3	1	TZONE		2083	95	2069	F	0.941	2717	0.76	2.5x5x8.5# T	FStrak07
		F/	1	6.97	102	1.524	1	0.3	1	TZONE		2083	95	2069	F	0.941	2717	0.76		FStrak07
19	SHL10408	A/	1	7.57	102	1.524	1	0.3	1	TZONE		2024	48	1968	F	0.909	2861	0.69	2.5x5x8.5# T	FStrak08
		F/	1	7.57	102	1.524	1	0.3	1	TZONE		2024	48	1968	F	0.909	2861	0.69		FStrak08
20	SHL10509	A/	1	8.27	108	1.524	1	0.3	1	1&2	0.51	2325	16	2224	F	0.892	2948	0.75	2.5x5x8.5# T	GStrak09
		F/	1	8.27	108	1.524	1	0.3	1	1&2	0.51	2325	16	2224	F	0.892	2948	0.75		GStrak09

STF #	SafeHull STF ID	TOE	ID	Dist. from BL(m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
21	DEC10101	A/	1	8.74	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82	2.5x5x8.5# T	Gunl 01
		F/	1	8.74	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82		Gunl 01
22	DEC10202	A/	1	8.76	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82	2.5x5x8.5# T	Dk1 02
		F/	1	8.76	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82		Dk1 02
23	DEC10203	A/	1	8.77	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82	2.5x5x8.5# T	Dk1 03
		F/	1	8.77	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82		Dk1 03
24	DEC10304	A/	1	8.79	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82	2.5x5x8.5# T	Dk1 04
		F/	1	8.79	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82		Dk1 04
25	DEC10305	A/	1	8.82	251	1.524	1	1	1	1&2	0	2506	0	2381	F	0.892	2948	0.81	3.5x7x13.7# T	Dk1 05
		F/	1	8.82	251	1.524	1	1	1	1&2	0	2506	0	2381	F	0.892	2948	0.81		Dk1 05
26	DEC10306	A/	1	8.85	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82	2.5x5x8.5# T	Dk1 06
		F/	1	8.85	108	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82		Dk1 06
27	DEC10407	A/	1	8.87	101	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82	2.5x5x8.5# T	Dk1 07
		F/	1	8.87	101	1.524	1	1	1	1&2	0	2538	0	2411	F	0.892	2948	0.82		Dk1 07
28	DEC10408	A/	1	8.89	175	1.524	1	1	1	1&2	0	2506	0	2381	F	0.892	2948	0.81	3.5x7x13.7# T	Dk1 08
		F/	1	8.89	175	1.524	1	1	1	1&2	0	2506	0	2381	F	0.892	2948	0.81		Dk1 08
29	DEC10409	A/	1	8.9	175	1.524	1	1	1	1&2	0	2506	0	2381	F	0.892	2948	0.81	3.5x7x13.7# T	Dk1 09
		F/	1	8.9	175	1.524	1	1	1	1&2	0	2506	0	2381	F	0.892	2948	0.81		Dk1 09
30	SDK10101	A/	1	6.42	58	1.524	1	1	1	F1&F2	0	2104	0	1999	F	0.964	2614	0.76	1.75x4.5x5# T	Dk3 01
		F/	1	6.42	58	1.524	1	1	1	F1&F2	0	2104	0	1999	F	0.964	2614	0.76		Dk3 01
31	SDK10102	A/	1	6.45	58	1.524	1	1	1	F1&F2	0	1936	0	1839	F	0.964	2614	0.70	1.75x4.5x5# T	Dk3 02
		F/	1	6.45	58	1.524	1	1	1	F1&F2	0	1936	0	1839	F	0.964	2614	0.70		Dk3 02
32	SDK10103	A/	1	6.48	58	1.524	1	1	1	F1&F2	0	1767	0	1679	F	0.964	2614	0.64	1.75x4.5x5# T	Dk3 03
		F/	1	6.48	58	1.524	1	1	1	F1&F2	0	1767	0	1679	F	0.964	2614	0.64		Dk3 03
33	SDK10104	A/	1	6.5	58	1.524	1	1	1	F1&F2	0	1598	0	1518	F	0.964	2614	0.58	1.75x4.5x5# T	Dk3 04
		F/	1	6.5	58	1.524	1	1	1	F1&F2	0	1598	0	1518	F	0.964	2614	0.58		Dk3 04
34	SDK10105	A/	1	6.53	168	1.524	1	1	1	F1&F2	0	1430	0	1358	F	0.964	2614	0.52	3.5x7x13.7# T	Dk3 05
		F/	1	6.53	168	1.524	1	1	1	F1&F2	0	1430	0	1358	F	0.964	2614	0.52		Dk3 05
35	SDK10106	A/	1	6.55	58	1.524	1	1	1	TZONE		1261	0	1198	F	0.963	2614	0.46	1.75x4.5x5# T	Dk3 06
		F/	1	6.55	58	1.524	1	1	1	TZONE		1261	0	1198	F	0.963	2614	0.46		Dk3 06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL(m)	SM (cm^3)	Unsup. Span (m)	Ct	Cy	LP#	LC#	Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS	USER DEFINED ID
36	SDK10107	A/	1	6.58	168	1.524	1	1	1	TZONE		1096	0	1041	F	0.962	2621	0.40	3.5x7x13.7# T	Dk3 07
		F/	1	6.58	168	1.524	1	1	1	TZONE		1096	0	1041	F	0.962	2621	0.40		Dk3 07

APPENDIX F

FATIGUE ANALYSIS SUMMARY FOR SHIP F

Table F.1 SafeHull Phase A Fatigue Analysis of Longitudinals for Ship F

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midship
LxBxDxd = 156.40x 16.76x 12.81x 5.50(m)
Hull-Girder Moment of Inertia Ivert. 283835.(cm2-m2) Ihoriz. 477734.(cm2-m2)
Neutral Axis Height 6.23(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 80.62m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 111311.(tf-m) MW(horiz.) 92024.(tf-m)

STF #	Stiffener	" TOE	ID	Dist. from BL(m)	SM (cm^3)	Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)			Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS
												f_{RG}	f_{RL}	f_R					
1	Bottom Long'l 1	A/	1	0	268	2.34	1	1	2	1&2	5.24	2324	471	2257	F2	0.889	2611	0.86	12 X 4 X 16# I/T
		F/	2	0	268	2.34	1	1	2	1&2	5.24	2324	471	2257	F2	0.889	2611	0.86	
2	Bottom Long'l 3	A/	1	0.19	265	2.34	1	1	2	1&2	5.21	2250	462	2189	F2	0.889	2611	0.84	12 X 4 X 16# I/T
		F/	2	0.19	265	2.34	1	1	2	1&2	5.21	2250	462	2189	F2	0.889	2611	0.84	
3	Bottom Long'l 5	A/	1	0.47	265	2.34	1	1	2	1&2	5.18	2140	464	2102	F2	0.889	2611	0.81	12 X 4 X 16# I/T
		F/	2	0.47	265	2.34	1	1	2	1&2	5.18	2140	464	2102	F2	0.889	2611	0.81	
4	Bottom Long'l 7	A/	2	0.84	262	2.34	1	1	2	1&2	5.13	1996	477	1997	F2	0.889	2611	0.76	12 X 4 X 16# I/T
		F/	1	0.84	262	2.34	1	1	2	1&2	5.13	1996	477	1997	F2	0.889	2611	0.76	
5	Bottom Long'l 9	A/	1	1.41	265	2.44	1	1	2	TZONE		1887	527	2293	F2	0.893	2590	0.89	12 X 4 X 16# I/T
		F/	1	1.41	265	2.44	1	1	2	TZONE		1887	527	2293	F2	0.893	2590	0.89	
6	Bottom Long'l 10	A/	1	1.83	236	2.44	1	1	2	TZONE		1789	624	2292	F2	0.906	2528	0.91	12 X 4 X 16# I/T
		F/	1	1.83	236	2.44	1	1	2	TZONE		1789	624	2292	F2	0.906	2528	0.91	
7	Bottom Long'l 11	A/	1	2.26	136	2.44	1	1	1	TZONE		1719	1342	2908	F2	0.918	2478	1.17	10 X 4 X 12# I/T
		F/	1	2.26	136	2.44	1	1	1	TZONE		1719	1342	2908	F2	0.918	2478	1.17	
8	Side Long'l 13	A/	1	3.2	171	2.44	1	1	1	F1&F2	7.53	1920	1112	2881	F2	0.928	2443	1.18	10 X 4 X 12# I/T

STF #	Stiffener	" TOE	ID	Dist. from BL(m)	SM (cm^3)	Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)			Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS
												f_{RG}	f_{RL}	f_R					
		F/	1	3.2	171	2.44	1	1	1	F1&F2	7.53	1920	1112	2881	F2	0.928	2443	1.18	
9	Side Long'l 14	A/	1	3.9	171	2.44	1	1	1	F1&F2	8.96	1860	1418	3114	F2	0.928	2443	1.27	10 X 4 X 12# I/T
		F/	1	3.9	171	2.44	1	1	1	F1&F2	8.96	1860	1418	3114	F2	0.928	2443	1.27	
10	Side Long'l 16	A/	1	5.35	169	2.44	1	0.73	1	F1&F2	12.9	1683	1484	3008	F2	0.928	2443	1.23	10 X 4 X 12# I/T
		F/	1	5.35	169	2.44	1	0.73	1	F1&F2	12.9	1683	1484	3008	F2	0.928	2443	1.23	
11	Side Long'l 17	A/	1	5.94	157	2.44	1	0.48	1	F1&F2	12.5	1609	925	2408	F2	0.928	2443	0.99	8 X 4 X 10 # I/T
		F/	1	5.94	157	2.44	1	0.48	1	F1&F2	12.5	1609	925	2408	F2	0.928	2443	0.99	
12	Side Long'l 18	A/	1	6.61	157	2.44	1	0.31	1	F1&F2	11.28	1629	595	2113	F2	0.928	2443	0.87	8 X 4 X 10 # I/T
		F/	1	6.61	157	2.44	1	0.31	1	F1&F2	11.28	1629	595	2113	F2	0.928	2443	0.87	
13	Side Long'l 21	A/	1	8	120	2.44	1	0.3	1	F1&F2	8.74	1852	573	2303	F2	0.928	2443	0.94	8 X 4 X 10# I/T
		F/	1	8	120	2.44	1	0.3	1	F1&F2	8.74	1852	573	2303	F2	0.928	2443	0.94	
14	Side Long'l 22	A/	1	8.69	120	2.44	1	0.3	1	F1&F2	7.5	1960	491	2329	F2	0.928	2443	0.95	8 X 4 X 10# I/T
		F/	1	8.69	120	2.44	1	0.3	1	F1&F2	7.5	1960	491	2329	F2	0.928	2443	0.95	
15	Side Long'l 23	A/	1	9.37	120	2.44	1	0.3	1	F1&F2	6.25	2069	410	2354	F2	0.928	2443	0.96	8 X 4 X 10# I/T
		F/	1	9.37	120	2.44	1	0.3	1	F1&F2	6.25	2069	410	2354	F2	0.928	2443	0.96	
16	Side Long'l 26	A/	1	10.75	98	2.44	1	0.3	1	TZONE		1983	144	2020	F2	0.882	2652	0.76	6 X 4 X 7.0# T
		F/	1	10.75	98	2.44	1	0.3	1	TZONE		1983	144	2020	F2	0.882	2652	0.76	
17	Side Long'l 27	A/	1	11.43	99	2.44	1	1	1	TZONE		2057	32	1985	F2	0.854	2805	0.71	6 X 4 X 7.0# T
		F/	1	11.43	99	2.44	1	1	1	TZONE		2057	32	1985	F2	0.854	2805	0.71	
18	Side Long'l 28	A/	1	12.11	99	2.44	1	1	1	1&2	0	2308	0	2193	F2	0.851	2827	0.78	6 X 4 X 7.0# T
		F/	1	12.11	99	2.44	1	1	1	1&2	0	2308	0	2193	F2	0.851	2827	0.78	
19	01 Lvl Long'l 12	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
20	01 Lvl Long'l 11	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
21	01 Lvl Long'l 10	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T

STF #	Stiffener	" TOE	ID	Dist. from BL(m)	SM (cm^3)	Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)			Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS
												f_{RG}	f_{RL}	f_R					
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
22	01 Lvl Long'l 9	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
23	01 Lvl Long'l 8	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
24	01 Lvl Long'l 7	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
25	01 Lvl Long'l 6	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
26	01 Lvl Long'l 5	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
27	01 Lvl Long'l 4	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
28	01 Lvl Long'l 3	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
29	01 Lvl Long'l 2	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
30	01 Lvl Long'l 1	A/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	6 X 4 X 7.0# T
		F/	1	12.8	99	2.44	1	1	1	1&2	0	2520	0	2394	F2	0.851	2827	0.85	
31	01 Lvl Long'l Cl	A/	1	12.8	1415	2.44	1	1	1	1&2	0	2400	0	2280	F2	0.851	2827	0.81	18 X 7-1/2 X 50# I/T
		F/	1	12.8	1415	2.44	1	1	1	1&2	0	2400	0	2280	F2	0.851	2827	0.81	
32	I.B. Long'l 1	A/	1	1.4	156	2.34	1	1	2	1&2	0.49	1992	75	1964	F2	0.889	2611	0.75	10 X 4 X 12# I/T
		F/	2	1.4	156	2.34	1	1	2	1&2	0.49	1992	75	1964	F2	0.889	2611	0.75	
33	I.B. Long'l 3	A/	1	1.65	135	2.34	1	1	2	1&2	0.45	1893	79	1874	F2	0.889	2611	0.72	10 X 4 X 12# I/T
		F/	2	1.65	135	2.34	1	1	2	1&2	0.45	1893	79	1874	F2	0.889	2611	0.72	
34	I.B. Long'l 5	A/	1	1.98	135	2.34	1	1	2	1&2	0.4	1764	71	1744	F2	0.889	2611	0.67	10 X 4 X 12# I/T
		F/	2	1.98	135	2.34	1	1	2	1&2	0.4	1764	71	1744	F2	0.889	2611	0.67	
35	I.B. Long'l 7	A/	1	2.39	135	2.34	1	1	2	1&2	0.34	1603	63	1583	F2	0.889	2611	0.61	10 X 4 X 12# I/T
		F/	2	2.39	135	2.34	1	1	2	1&2	0.34	1603	63	1583	F2	0.889	2611	0.61	
36	I.B. Long'l 9	A/	1	2.81	135	2.34	1	1	2	1&2	0.28	1439	36	1400	F2	0.889	2611	0.54	10 X 4 X 12# I/T
		F/	2	2.81	135	2.34	1	1	2	1&2	0.28	1439	36	1400	F2	0.889	2611	0.54	
37	1st Plat Long'l CL	A/	1	7.32	846	2.44	1	1	1	7&8	0	171	0	163	F2	0.889	2611	0.06	18x7.5x55# I-T

STF #	Stiffener	" TOE	ID	Dist. from BL(m)	SM (cm^3)	Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS
		F/	1	7.32	846	2.44	1	1	1	7&8	0	171	0	163	F2	0.889	2611	0.06	
38	1st Plat Long'l 1	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	295	0	280	F2	0.889	2611	0.11	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	295	0	280	F2	0.889	2611	0.11	
39	1st Plat Long'l 2	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	417	0	396	F2	0.889	2611	0.15	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	417	0	396	F2	0.889	2611	0.15	
40	1st Plat Long'l 3	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	541	0	514	F2	0.889	2611	0.2	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	541	0	514	F2	0.889	2611	0.2	
41	1st Plat Long'l 4	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	665	0	632	F2	0.889	2611	0.24	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	665	0	632	F2	0.889	2611	0.24	
42	1st Plat Long'l 5	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	789	0	750	F2	0.889	2611	0.29	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	789	0	750	F2	0.889	2611	0.29	
43	1st Plat Long'l 6	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	913	0	867	F2	0.889	2611	0.33	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	913	0	867	F2	0.889	2611	0.33	
44	1st Plat Long'l 7	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1037	0	985	F2	0.889	2611	0.38	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1037	0	985	F2	0.889	2611	0.38	
45	1st Plat Long'l 8	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1161	0	1103	F2	0.889	2611	0.42	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1161	0	1103	F2	0.889	2611	0.42	
46	1st Plat Long'l 9	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1288	0	1223	F2	0.889	2611	0.47	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1288	0	1223	F2	0.889	2611	0.47	
47	1st Plat Long'l 10	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1412	0	1341	F2	0.889	2611	0.51	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1412	0	1341	F2	0.889	2611	0.51	
48	1st Plat Long'l 11	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1536	0	1459	F2	0.889	2611	0.56	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1536	0	1459	F2	0.889	2611	0.56	
49	1st Plat Long'l 12	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1660	0	1577	F2	0.889	2611	0.6	5 X 4 X 6.0# T
		F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1660	0	1577	F2	0.889	2611	0.6	
50	2nd Plat Long'l CL	A/	1	4.57	998	2.44	1	1	1	7&8	0	260	0	247	F2	0.889	2611	0.09	18 X 7-1/2 X 50# I/T
		F/	1	4.57	998	2.44	1	1	1	7&8	0	260	0	247	F2	0.889	2611	0.09	
51	2nd Plat Long'l 1	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	380	0	361	F2	0.889	2611	0.14	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	380	0	361	F2	0.889	2611	0.14	
52	2nd Plat Long'l 2	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	500	0	475	F2	0.889	2611	0.18	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	500	0	475	F2	0.889	2611	0.18	
53	2nd Plat Long'l 3	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	620	0	589	F2	0.889	2611	0.23	8 X 4 X 10 # I/T

STF #	Stiffener	" TOE	ID	Dist. from BL(m)	SM (cm^3)	Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	620	0	589	F2	0.889	2611	0.23	
54	2nd Plat Long'l 4	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	740	0	703	F2	0.889	2611	0.27	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	740	0	703	F2	0.889	2611	0.27	
55	2nd Plat Long'l 5	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	859	0	816	F2	0.889	2611	0.31	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	859	0	816	F2	0.889	2611	0.31	
56	2nd Plat Long'l 6	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	979	0	930	F2	0.889	2611	0.36	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	979	0	930	F2	0.889	2611	0.36	
57	2nd Plat Long'l 7	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	1098	0	1043	F2	0.889	2611	0.4	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	1098	0	1043	F2	0.889	2611	0.4	
58	2nd Plat Long'l 8	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	1218	0	1157	F2	0.889	2611	0.44	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	1218	0	1157	F2	0.889	2611	0.44	
59	2nd Plat Long'l 9	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	1337	0	1271	F2	0.889	2611	0.49	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	1337	0	1271	F2	0.889	2611	0.49	
60	2nd Plat Long'l 10	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	1457	0	1384	F2	0.889	2611	0.53	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	1457	0	1384	F2	0.889	2611	0.53	
61	2nd Plat Long'l 11	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	1577	0	1498	F2	0.889	2611	0.57	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	1577	0	1498	F2	0.889	2611	0.57	
62	2nd Plat Long'l 12	A/	1	4.57	142	2.44	1	1	1	F1&F2	0	1697	0	1612	F2	0.889	2611	0.62	8 X 4 X 10 # I/T
		F/	1	4.57	142	2.44	1	1	1	F1&F2	0	1697	0	1612	F2	0.889	2611	0.62	
63	I.B. Girder 2	A/	1	0.8	62	2.44	1	1	1	1&2	0	2129	0	2023	F2	0.889	2611	0.77	5 X 4 X 6.0# T
		F/	1	0.8	62	2.44	1	1	1	1&2	0	2129	0	2023	F2	0.889	2611	0.77	
64	I.B. Girder 4	A/	1	1.06	62	2.44	1	1	1	1&2	0	2027	0	1926	F2	0.889	2611	0.74	5 X 4 X 6.0# T
		F/	1	1.06	62	2.44	1	1	1	1&2	0	2027	0	1926	F2	0.889	2611	0.74	
65	I.B. Girder 6	A/	1	1.38	62	2.44	1	1	1	TZONE		1873	0	1779	F2	0.889	2611	0.68	5 X 4 X 6.0# T
		F/	1	1.38	62	2.44	1	1	1	TZONE		1873	0	1779	F2	0.889	2611	0.68	
66	I.B. Girder 8	A/	1	1.86	54	2.44	1	1	1	TZONE		1713	0	1627	F2	0.889	2611	0.62	5 X 4 X 6.0# T
		F/	1	1.86	54	2.44	1	1	1	TZONE		1713	0	1627	F2	0.889	2611	0.62	
67	CVK	A/	1	0.69	149	2.44	1	1	1	1&2	0	2174	0	2066	F2	0.889	2611	0.79	8 X 4 X 10 # I/T
		F/	1	0.69	149	2.44	1	1	1	1&2	0	2174	0	2066	F2	0.889	2611	0.79	
68	Margin Plate	A/	1	2.85	136	2.34	1	1	2	1&2	0.28	1327	45	1303	F2	0.889	2611	0.5	10 X 4 X 12# I/T
		F/	2	2.85	136	2.34	1	1	2	1&2	0.28	1327	45	1303	F2	0.889	2611	0.5	
69	Main Dk Long'l 13	A/	1	10.06	70	2.44	1	1	1	TZONE		1951	0	1854	F2	0.909	2514	0.74	5 X 4 X 6.0# T

STF #	Stiffener	" TOE	ID	Dist. from BL(m)	SM (cm^3)	Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)			Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2) P_S	fR/PS	SCANTLINGS
												f_{RG}	f_{RL}	f_R					
		F/	1	10.06	70	2.44	1	1	1	TZONE		1951	0	1854	F2	0.909	2514	0.74	
70	Main Dk Long'l 12	A/	1	10.06	70	2.44	1	1	1	TZONE		1857	0	1764	F2	0.909	2514	0.7	5 X 4 X 6.0# T
		F/	1	10.06	70	2.44	1	1	1	TZONE		1857	0	1764	F2	0.909	2514	0.7	
71	Main Dk Long'l 11	A/	1	10.06	70	2.44	1	1	1	TZONE		1762	0	1674	F2	0.909	2514	0.67	5 X 4 X 6.0# T
		F/	1	10.06	70	2.44	1	1	1	TZONE		1762	0	1674	F2	0.909	2514	0.67	
72	Main Dk Long'l 10	A/	1	10.06	70	2.44	1	1	1	TZONE		1667	0	1584	F2	0.909	2514	0.63	5 X 4 X 6.0# T
		F/	1	10.06	70	2.44	1	1	1	TZONE		1667	0	1584	F2	0.909	2514	0.63	
73	Main Dk Long'l 9	A/	1	10.06	***	2.44	1	1	1	TZONE		1573	0	1494	F2	0.909	2514	0.59	Cross Deck at C.L.
		F/	1	10.06	***	2.44	1	1	1	TZONE		1573	0	1494	F2	0.909	2514	0.59	
74	Main Dk Long'l 8	A/	1	10.06	67	2.44	1	1	1	TZONE		1572	0	1493	F2	0.909	2514	0.59	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1572	0	1493	F2	0.909	2514	0.59	
75	Main Dk Long'l 7	A/	1	10.06	67	2.44	1	1	1	TZONE		1477	0	1403	F2	0.909	2514	0.56	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1477	0	1403	F2	0.909	2514	0.56	
76	Main Dk Long'l 6	A/	1	10.06	67	2.44	1	1	1	TZONE		1382	0	1313	F2	0.909	2514	0.52	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1382	0	1313	F2	0.909	2514	0.52	
77	Main Dk Long'l 5	A/	1	10.06	67	2.44	1	1	1	TZONE		1288	0	1224	F2	0.909	2514	0.49	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1288	0	1224	F2	0.909	2514	0.49	
78	Main Dk Long'l 4	A/	1	10.06	67	2.44	1	1	1	TZONE		1193	0	1134	F2	0.909	2514	0.45	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1193	0	1134	F2	0.909	2514	0.45	
79	Main Dk Long'l 3	A/	1	10.06	67	2.44	1	1	1	TZONE		1099	0	1044	F2	0.909	2514	0.42	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1099	0	1044	F2	0.909	2514	0.42	
80	Main Dk Long'l 2	A/	1	10.06	67	2.44	1	1	1	TZONE		1004	0	954	F2	0.909	2514	0.38	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		1004	0	954	F2	0.909	2514	0.38	
81	Main Dk Long'l 1	A/	1	10.06	67	2.44	1	1	1	TZONE		910	0	864	F2	0.909	2514	0.34	5 X 4 X 6.0# T
		F/	1	10.06	67	2.44	1	1	1	TZONE		910	0	864	F2	0.909	2514	0.34	
82	Main Dk Long'l Cl	A/	1	10.06	922	2.44	1	1	1	TZONE		815	0	774	F2	0.909	2514	0.31	18 X 7-1/2 X 50# I/T
		F/	1	10.06	922	2.44	1	1	1	TZONE		815	0	774	F2	0.909	2514	0.31	

Table F.2 Phase A Fatigue Analysis of Flat Bars for Ship F

Cf=0.95 Cw=0.75

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midship
LxBxDxd = 156.40x 16.76x 12.81x 5.50(m)
Hull-Girder Moment of Inertia Ivert. 283835.(cm2-m2) Ihoriz. 477734.(cm2-m2)
Neutral Axis Height 6.23(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 80.62m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 111311.(tf-m) MW(horiz.) 92024.(tf-m)

Cutout LABEL	ID	LOC	Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Range		Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Term Distr. Factor	Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm2)	Ac (cm2)		fs	fL	fRi				
BTM10101	1	1	0	0.688	2.34	5.24	8.64	0	31.1	1.5	264	2257	2292	F2	0.889	2611	0.88
		2	0	0.688	2.34	5.24	8.64	0	31.1	1	264	2257	2272	F2	0.889	2611	0.87
[Weld Throat]			0	0.688	2.34	5.24	8.64	[Asw]=	0	1.25	264	0	*****	W	0.889	1883	NaN
BTM10302	1	1	0.19	0.67	2.34	5.21	8.38	0	31.1	1.5	256	2189	2223	F2	0.889	2611	0.85
		2	0.19	0.67	2.34	5.21	8.38	0	31.1	1	256	2189	2204	F2	0.889	2611	0.84
[Weld Throat]			0.19	0.67	2.34	5.21	8.38	[Asw]=	0	1.25	256	0	*****	W	0.889	1883	NaN
BTM10503	1	1	0.47	0.678	2.34	5.18	8.42	0	31.1	1.5	257	2102	2137	F2	0.889	2611	0.82
		2	0.47	0.678	2.34	5.18	8.42	0	31.1	1	257	2102	2118	F2	0.889	2611	0.81
[Weld Throat]			0.47	0.678	2.34	5.18	8.42	[Asw]=	0	1.25	257	0	*****	W	0.889	1883	NaN
BTM10604	1	1	0.84	0.696	2.34	5.13	8.55	9.5	31.1	1.5	200	1997	2019	F2	0.889	2611	0.77
		2	0.84	0.696	2.34	5.13	8.55	9.5	31.1	1.25	200	1997	2013	F2	0.889	2611	0.77
[Weld Throat]			0.84	0.696	2.34	5.13	8.55	[Asw]=	8	1.25	200	0	297	W	0.889	1883	0.16

APPENDIX G

FATIGUE ANALYSIS SUMMARY FOR SHIP G

Table G.1 SafeHull Phase A Fatigue Analysis of Longitudinals for Ship G

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)

LxBxDxd = 156.40x 16.76x 12.81x 6.80(m)
Hull-Girder Moment of Inertia Ivert. 303713.(cm2-m2) Ihoriz. 517550.(cm2-m2)
Neutral Axis Height 6.45(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
Special Location at 80.62m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 111187.(tf-m) MW(horiz.) 91964.(tf-m)
"Net" Ship Cf=0.95 Cw=0.75

ST #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP#	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
1	Bottom Long'l 1	A/	1	0	268	2.34	1	1	2	1&2	5.23	2249	470	2196	F2	0.889	2611	0.84	12 X 4 X 16# I/T
		F/	2	0	268	2.34	1	1	2	1&2	5.23	2249	470	2196	F2	0.889	2611	0.84	
2	Bottom Long'l 3	A/	1	0.19	265	2.34	1	1	2	1&2	5.21	2179	461	2132	F2	0.889	2611	0.82	12 X 4 X 16# I/T
		F/	2	0.19	265	2.34	1	1	2	1&2	5.21	2179	461	2132	F2	0.889	2611	0.82	
3	Bottom Long'l 5	A/	1	0.47	265	2.34	1	1	2	1&2	5.17	2077	463	2051	F2	0.889	2611	0.79	12 X 4 X 16# I/T
		F/	2	0.47	265	2.34	1	1	2	1&2	5.17	2077	463	2051	F2	0.889	2611	0.79	
4	Bottom Long'l 7	A/	2	0.84	262	2.34	1	1	2	1&2	5.12	1942	476	1953	F2	0.889	2611	0.75	12 X 4 X 16# I/T
		F/	1	0.84	262	2.34	1	1	2	1&2	5.12	1942	476	1953	F2	0.889	2611	0.75	
5	Bottom Long'l 9	A/	2	1.41	264	2.34	1	1	2	TZONE		1834	491	2209	F2	0.893	2590	0.85	12 X 4 X 16# I/T
		F/	1	1.41	264	2.34	1	1	2	TZONE		1834	491	2209	F2	0.893	2590	0.85	
6	Bottom Long'l 10	A/	2	1.83	236	2.34	1	1	2	TZONE		1723	634	2240	F2	0.906	2528	0.89	12 X 4 X 16# I/T
		F/	1	1.83	236	2.34	1	1	2	TZONE		1723	634	2240	F2	0.906	2528	0.89	
7	Bottom Long'l 11	A/	2	2.26	136	2.34	1	1	1	TZONE		1631	1385	2865	F2	0.918	2478	1.16	10 X 4 X 12# I/T
		F/	1	2.26	136	2.34	1	1	1	TZONE		1631	1385	2865	F2	0.918	2478	1.16	
8	Side Long'l 13	A/	1	3.2	171	2.34	1	1	1	F1&F2	7.86	1808	1072	2736	F2	0.928	2443	1.12	10 X 4 X 12# I/T

ST #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP#	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
		F/	2	3.2	171	2.34	1	1	1	F1&F2	7.86	1808	1072	2736	F2	0.928	2443	1.12	
9	Side Long'l 14	A/	1	3.9	171	2.34	1	1	1	F1&F2	8.48	1752	1238	2840	F2	0.928	2443	1.16	10 X 4 X 12# I/T
		F/	2	3.9	171	2.34	1	1	1	F1&F2	8.48	1752	1238	2840	F2	0.928	2443	1.16	
10	Side Long'l 16	A/	1	5.35	169	2.34	1	1	1	F1&F2	10.58	1586	1532	2962	F2	0.928	2443	1.21	10 X 4 X 12# I/T
		F/	2	5.35	169	2.34	1	1	1	F1&F2	10.58	1586	1532	2962	F2	0.928	2443	1.21	
11	Side Long'l 17	A/	1	5.94	156	2.34	1	1	1	F1&F2	11.69	1517	1655	3013	F2	0.928	2443	1.23	8 X 4 X 10 # I/T
		F/	2	5.94	156	2.34	1	1	1	F1&F2	11.69	1517	1655	3013	F2	0.928	2443	1.23	
12	Side Long'l 18	A/	1	6.61	156	2.34	1	0.73	1	F1&F2	12.95	1472	1473	2798	F2	0.928	2443	1.15	8 X 4 X 10 # I/T
		F/	2	6.61	156	2.34	1	0.73	1	F1&F2	12.95	1472	1473	2798	F2	0.928	2443	1.15	
13	Side Long'l 21	A/	2	8	119	2.34	1	0.34	1	F1&F2	10.64	1679	732	2291	F2	0.928	2443	0.94	8 X 4 X 10# I/T
		F/	1	8	119	2.34	1	0.34	1	F1&F2	10.64	1679	732	2291	F2	0.928	2443	0.94	
14	Side Long'l 22	A/	2	8.69	119	2.34	1	0.3	1	F1&F2	9.12	1781	551	2215	F2	0.928	2443	0.91	8 X 4 X 10# I/T
		F/	1	8.69	119	2.34	1	0.3	1	F1&F2	9.12	1781	551	2215	F2	0.928	2443	0.91	
15	Side Long'l 23	A/	2	9.37	119	2.34	1	0.3	1	F1&F2	7.6	1882	459	2224	F2	0.928	2443	0.91	8 X 4 X 10# I/T
		F/	1	9.37	119	2.34	1	0.3	1	F1&F2	7.6	1882	459	2224	F2	0.928	2443	0.91	
16	Side Long'l 26	A/	2	10.75	98	2.34	1	0.3	1	TZONE		1784	214	1898	F2	0.882	2652	0.72	6 X 4 X 7.0# T
		F/	1	10.75	98	2.34	1	0.3	1	TZONE		1784	214	1898	F2	0.882	2652	0.72	
17	Side Long'l 27	A/	2	11.43	101	2.34	1	1	1	TZONE		1843	278	2014	F2	0.854	2805	0.72	6 X 4 X 7.0# T
		F/	1	11.43	101	2.34	1	1	1	TZONE		1843	278	2014	F2	0.854	2805	0.72	
18	Side Long'l 28	A/	2	12.11	101	2.34	1	1	1	1&2	0.39	2076	92	2059	F2	0.851	2827	0.73	6 X 4 X 7.0# T
		F/	1	12.11	101	2.34	1	1	1	1&2	0.39	2076	92	2059	F2	0.851	2827	0.73	
19	01 Lvl Long'l 12	A/	1	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
20	01 Lvl Long'l 11	A/	1	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
21	01 Lvl Long'l 10	A/	1	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	101	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
22	01 Lvl Long'l 9	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T

ST #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP#	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2)			Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
												f_{RG}	f_{RL}	f_R					
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
23	01 Lvl Long'l 8	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
24	01 Lvl Long'l 7	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
25	01 Lvl Long'l 6	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
26	01 Lvl Long'l 5	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
27	01 Lvl Long'l 4	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
28	01 Lvl Long'l 3	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
29	01 Lvl Long'l 2	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
30	01 Lvl Long'l 1	A/	1	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	6 X 4 X 7.0# T
		F/	2	12.8	99	2.34	1	1	1	1&2	0	2273	0	2159	F2	0.851	2827	0.76	
31	01 Lvl Long'l Cl	A/	1	12.8	1408	2.34	1	1	1	1&2	0	2161	0	2053	F2	0.851	2827	0.73	18 X 7-1/2 X 50# I/T
		F/	2	12.8	1408	2.34	1	1	1	1&2	0	2161	0	2053	F2	0.851	2827	0.73	
32	I.B. Long'l 1	A/	1	1.4	156	2.34	1	1	2	1&2	0.48	1938	75	1912	F2	0.889	2611	0.73	10 X 4 X 12# I/T
		F/	2	1.4	156	2.34	1	1	2	1&2	0.48	1938	75	1912	F2	0.889	2611	0.73	
33	I.B. Long'l 3	A/	1	1.65	135	2.34	1	1	2	1&2	0.45	1847	78	1829	F2	0.889	2611	0.70	10 X 4 X 12# I/T
		F/	2	1.65	135	2.34	1	1	2	1&2	0.45	1847	78	1829	F2	0.889	2611	0.70	
34	I.B. Long'l 5	A/	1	1.98	135	2.34	1	1	2	1&2	0.4	1726	71	1707	F2	0.889	2611	0.65	10 X 4 X 12# I/T
		F/	2	1.98	135	2.34	1	1	2	1&2	0.4	1726	71	1707	F2	0.889	2611	0.65	
35	I.B. Long'l 7	A/	1	2.39	135	2.34	1	1	2	1&2	0.34	1576	63	1557	F2	0.889	2611	0.60	10 X 4 X 12# I/T
		F/	2	2.39	135	2.34	1	1	2	1&2	0.34	1576	63	1557	F2	0.889	2611	0.60	
36	I.B. Long'l 9	A/	1	2.81	135	2.34	1	1	2	1&2	0.28	1422	36	1385	F2	0.889	2611	0.53	10 X 4 X 12# I/T
		F/	2	2.81	135	2.34	1	1	2	1&2	0.28	1422	36	1385	F2	0.889	2611	0.53	
37	IB Margin Plate	A/	1	2.85	135	2.34	1	1	2	F1&F2	0.43	1743	71	1723	F2	0.889	2611	0.66	10 X 4 X 12# I/T
		F/	2	2.85	135	2.34	1	1	2	F1&F2	0.43	1743	71	1723	F2	0.889	2611	0.66	
38	1st Plat Long'l Cl	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	240	0	228	F2	0.889	2611	0.09	5 X 4 X 6.0# T

S T #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP#	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	240	0	228	F2	0.889	2611	0.09	
39	1st Plat Long'l 1	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	469	0	446	F2	0.889	2611	0.17	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	469	0	446	F2	0.889	2611	0.17	
40	1st Plat Long'l 2	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	584	0	554	F2	0.889	2611	0.21	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	584	0	554	F2	0.889	2611	0.21	
41	1st Plat Long'l 3	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	698	0	663	F2	0.889	2611	0.25	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	698	0	663	F2	0.889	2611	0.25	
42	1st Plat Long'l 4	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	813	0	772	F2	0.889	2611	0.30	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	813	0	772	F2	0.889	2611	0.30	
43	1st Plat Long'l 5	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	927	0	881	F2	0.889	2611	0.34	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	927	0	881	F2	0.889	2611	0.34	
44	1st Plat Long'l 6	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	1156	0	1098	F2	0.889	2611	0.42	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	1156	0	1098	F2	0.889	2611	0.42	
45	1st Plat Long'l 7	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	1270	0	1207	F2	0.889	2611	0.46	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	1270	0	1207	F2	0.889	2611	0.46	
46	1st Plat Long'l 8	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	1385	0	1315	F2	0.889	2611	0.50	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	1385	0	1315	F2	0.889	2611	0.50	
47	1st Plat Long'l 9	A/	1	7.32	52	2.34	1	1	1	F1&F2	0	1499	0	1424	F2	0.889	2611	0.55	5 X 4 X 6.0# T
		F/	2	7.32	52	2.34	1	1	1	F1&F2	0	1499	0	1424	F2	0.889	2611	0.55	
48	2nd Plat Long'l Cl	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	384	0	365	F2	0.889	2611	0.14	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	384	0	365	F2	0.889	2611	0.14	
49	2nd Plat Long'l 1	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	495	0	470	F2	0.889	2611	0.18	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	495	0	470	F2	0.889	2611	0.18	
50	2nd Plat Long'l 2	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	606	0	575	F2	0.889	2611	0.22	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	606	0	575	F2	0.889	2611	0.22	
51	2nd Plat Long'l 3	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	716	0	680	F2	0.889	2611	0.26	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	716	0	680	F2	0.889	2611	0.26	
52	2nd Plat Long'l 4	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	827	0	785	F2	0.889	2611	0.30	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	827	0	785	F2	0.889	2611	0.30	
53	2nd Plat Long'l 5	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	937	0	890	F2	0.889	2611	0.34	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	937	0	890	F2	0.889	2611	0.34	
54	2nd Plat Long'l 6	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	1158	0	1100	F2	0.889	2611	0.42	8 X 4 X 10 # I/T

ST#	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP#	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2)			Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
												f_{RG}	f_{RL}	f_R					
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	1158	0	1100	F2	0.889	2611	0.42	
55	2nd Plat Long'l 7	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	1268	0	1205	F2	0.889	2611	0.46	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	1268	0	1205	F2	0.889	2611	0.46	
56	2nd Plat Long'l 8	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	1379	0	1310	F2	0.889	2611	0.50	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	1379	0	1310	F2	0.889	2611	0.50	
57	2nd Plat Long'l 9	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	1489	0	1415	F2	0.889	2611	0.54	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	1489	0	1415	F2	0.889	2611	0.54	
58	2nd Plat Long'l 10	A/	1	4.57	141	2.34	1	1	1	F1&F2	0	1600	0	1520	F2	0.889	2611	0.58	8 X 4 X 10 # I/T
		F/	2	4.57	141	2.34	1	1	1	F1&F2	0	1600	0	1520	F2	0.889	2611	0.58	
59	I.B. Girder 2	A/	1	0.8	62	2.44	1	1	1	1&2	0	2067	0	1963	F2	0.889	2611	0.75	5 X 4 X 6.0# T
		F/	1	0.8	62	2.44	1	1	1	1&2	0	2067	0	1963	F2	0.889	2611	0.75	
60	I.B. Girder 4	A/	1	1.06	62	2.44	1	1	1	1&2	0	1972	0	1873	F2	0.889	2611	0.72	5 X 4 X 6.0# T
		F/	1	1.06	62	2.44	1	1	1	1&2	0	1972	0	1873	F2	0.889	2611	0.72	
61	I.B. Girder 6	A/	1	1.38	62	2.44	1	1	1	TZONE		1823	0	1732	F2	0.889	2611	0.66	5 X 4 X 6.0# T
		F/	1	1.38	62	2.44	1	1	1	TZONE		1823	0	1732	F2	0.889	2611	0.66	
62	I.B. Girder 8	A/	1	1.86	54	2.44	1	1	1	TZONE		1652	0	1569	F2	0.889	2611	0.60	5 X 4 X 6.0# T
		F/	1	1.86	54	2.44	1	1	1	TZONE		1652	0	1569	F2	0.889	2611	0.60	
63	CVK	A/	1	0.69	149	2.44	1	1	1	1&2	0	2109	0	2003	F2	0.889	2611	0.77	8 X 4 X 10 # I/T
		F/	1	0.69	149	2.44	1	1	1	1&2	0	2109	0	2003	F2	0.889	2611	0.77	
64	Main Dk Long'l 12	A/	1	10.06	70	2.34	1	1	1	TZONE		1766	0	1678	F2	0.909	2514	0.67	5 X 4 X 6.0# T
		F/	2	10.06	70	2.34	1	1	1	TZONE		1766	0	1678	F2	0.909	2514	0.67	
65	Main Dk Long'l 11	A/	1	10.06	70	2.34	1	1	1	TZONE		1679	0	1595	F2	0.909	2514	0.63	5 X 4 X 6.0# T
		F/	2	10.06	70	2.34	1	1	1	TZONE		1679	0	1595	F2	0.909	2514	0.63	
66	Main Dk Long'l 10	A/	1	10.06	70	2.34	1	1	1	TZONE		1591	0	1512	F2	0.909	2514	0.60	5 X 4 X 6.0# T
		F/	2	10.06	70	2.34	1	1	1	TZONE		1591	0	1512	F2	0.909	2514	0.60	
67	Main Dk Long'l 9	A/	1	10.06	*****	2.34	1	1	1	TZONE		1504	0	1429	F2	0.909	2514	0.57	Cross Deck at C.L.
		F/	2	10.06	*****	2.34	1	1	1	TZONE		1504	0	1429	F2	0.909	2514	0.57	
68	Main Dk Long'l 8	A/	1	10.06	67	2.34	1	1	1	TZONE		1417	0	1346	F2	0.909	2514	0.54	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		1417	0	1346	F2	0.909	2514	0.54	
69	Main Dk Long'l 7	A/	1	10.06	67	2.34	1	1	1	TZONE		1330	0	1263	F2	0.909	2514	0.50	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		1330	0	1263	F2	0.909	2514	0.50	
70	Main Dk Long'l 6	A/	1	10.06	67	2.34	1	1	1	TZONE		1242	0	1180	F2	0.909	2514	0.47	5 X 4 X 6.0# T

ST#	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm3)	Span (m)	C_t	C_y	LP#	Load Case #	Local Load Rng (m)	Stress Range (kg/cm2) f_{RG}	f_{RL}	f_R	Fatigue Class	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio f_R/PS	SCANTLINGS
		F/	2	10.06	67	2.34	1	1	1	TZONE		1242	0	1180	F2	0.909	2514	0.47	
71	Main Dk Long'l 5	A/	1	10.06	67	2.34	1	1	1	TZONE		1155	0	1097	F2	0.909	2514	0.44	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		1155	0	1097	F2	0.909	2514	0.44	
72	Main Dk Long'l 4	A/	1	10.06	67	2.34	1	1	1	TZONE		1068	0	1015	F2	0.909	2514	0.40	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		1068	0	1015	F2	0.909	2514	0.40	
73	Main Dk Long'l 3	A/	1	10.06	67	2.34	1	1	1	TZONE		981	0	932	F2	0.909	2514	0.37	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		981	0	932	F2	0.909	2514	0.37	
74	Main Dk Long'l 2	A/	1	10.06	67	2.34	1	1	1	TZONE		893	0	849	F2	0.909	2514	0.34	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		893	0	849	F2	0.909	2514	0.34	
75	Main Dk Long'l 1	A/	1	10.06	67	2.34	1	1	1	TZONE		806	0	766	F2	0.909	2514	0.30	5 X 4 X 6.0# T
		F/	2	10.06	67	2.34	1	1	1	TZONE		806	0	766	F2	0.909	2514	0.30	
76	Main Dk Long'l Cl	A/	1	10.06	901	2.34	1	1	1	TZONE		719	0	683	F2	0.909	2514	0.27	18 X 7-1/2 X 50# I/T
		F/	2	10.06	901	2.34	1	1	1	TZONE		719	0	683	F2	0.909	2514	0.27	

Table G.2 Phase A Fatigue Analysis of Flat Bars for Ship G

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)

LxBxDxd = 156.40x 16.76x 12.81x 6.80(m)
Hull-Girder Moment of Inertia Ivert. 303713.(cm2-m2) Ihoriz. 517550.(cm2-m2)
Neutral Axis Height 6.45(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 80.62m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 111187.(tf-m) MW(horiz.) 91964.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout			Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas A_s (cm^2)	A_c	SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	f_R/PS
						Head (m)	Force (tf)										
LABEL	ID	LOC									f_s	f_L	f_{Ri}				
BTM10604	2	1	0.84	0.696	2.34	5.12	8.54	7.1	51.8	1.5	138	1953	1964	F2	0.889	2611	0.75
		2	0.84	0.696	2.34	5.12	8.54	7.1	51.8	1.25	138	1953	1961	F2	0.889	2611	0.75
[Weld Throat]			0.84	0.696	2.34	5.12	8.54	[Asw]=	4.5	1.25	138	0	273	W	0.889	1883	0.14
SHL10101	2	1	1.41	0.685	2.34	5.39	8.86	9.5	51.8	1.5	137	2209	2219	F2	0.893	2590	0.86
		2	1.41	0.685	2.34	5.39	8.86	9.5	51.8	1.25	137	2209	2216	F2	0.893	2590	0.86
[Weld Throat]			1.41	0.685	2.34	5.39	8.86	[Asw]=	6	1.25	137	0	272	W	0.893	1868	0.15
SHL10102	2	1	1.83	0.653	2.34	6.52	10.22	9.5	51.8	1.5	158	2240	2252	F2	0.906	2528	0.89
		2	1.83	0.653	2.34	6.52	10.22	9.5	51.8	1.25	158	2240	2248	F2	0.906	2528	0.89
[Weld			1.83	0.653	2.34	6.52	10.22	[Asw]=	6	1.25	158	0	314	W	0.906	1824	0.17

Cutout			Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas A_s (cm^2)	A_c	SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	f_R/PS
						Head (m)	Force (tf)										
LABEL	ID	LOC									f_s	f_L	f_{Ri}				
Throat]																	
SHL10103	2	1	2.26	0.665	2.34	8.06	12.85	9.5	41.8	1.5	238	2865	2887	F2	0.918	2478	1.16
		2	2.26	0.665	2.34	8.06	12.85	9.5	41.8	1.25	238	2865	2880	F2	0.918	2478	1.16
[Weld Throat]			2.26	0.665	2.34	8.06	12.85	[Asw]=	6	1.25	238	0	471	W	0.918	1786	0.26
SHL10404	2	1	3.2	0.663	2.34	7.86	12.51	0	41.8	1.5	284	2736	2769	F2	0.928	2443	1.13
		2	3.2	0.663	2.34	7.86	12.51	0	41.8	1	284	2736	2751	F2	0.928	2443	1.13
[Weld Throat]			3.2	0.663	2.34	7.86	12.51	[Asw]=	0	1.25	284	0	*****	W	0.928	1760	NaN
SHL10505	2	1	3.9	0.71	2.34	8.48	14.44	0	41.8	1.5	328	2840	2883	F2	0.928	2443	1.18
		2	3.9	0.71	2.34	8.48	14.44	0	41.8	1	328	2840	2859	F2	0.928	2443	1.17
[Weld Throat]			3.9	0.71	2.34	8.48	14.44	[Asw]=	0	1.25	328	0	*****	W	0.928	1760	NaN
SHL10706	2	1	5.35	0.697	2.34	10.58	17.69	0	41.8	1.5	402	2962	3023	F2	0.928	2443	1.24
		2	5.35	0.697	2.34	10.58	17.69	0	41.8	1	402	2962	2989	F2	0.928	2443	1.22
[Weld Throat]			5.35	0.697	2.34	10.58	17.69	[Asw]=	0	1.25	402	0	*****	W	0.928	1760	NaN
SHL10807	2	1	5.94	0.631	2.34	11.69	17.7	0	32.3	1.5	521	3013	3113	F2	0.928	2443	1.27
		2	5.94	0.631	2.34	11.69	17.7	0	32.3	1	521	3013	3058	F2	0.928	2443	1.25
[Weld Throat]			5.94	0.631	2.34	11.69	17.7	[Asw]=	0	1.25	521	0	*****	W	0.928	1760	NaN
SHL10908	1	1	6.61	0.69	2.34	12.95	21.44	0	27.4	1.5	546	2798	2915	F2	0.928	2443	1.19
		2	6.61	0.69	2.34	12.95	21.44	0	27.4	1	546	2798	2851	F2	0.928	2443	1.17
[Weld Throat]			6.61	0.69	2.34	12.95	21.44	[Asw]=	0	1.25	546	0	*****	W	0.928	1760	NaN
SHL11009	1	1	8	0.685	2.34	10.64	17.48	9.5	27.5	1.5	153	2291	2302	F2	0.928	2443	0.94
		2	8	0.685	2.34	10.64	17.48	9.5	27.5	1.25	153	2291	2299	F2	0.928	2443	0.94
[Weld Throat]			8	0.685	2.34	10.64	17.48	[Asw]=	6	1.25	153	0	303	W	0.928	1760	0.17

Cutout			Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas A_s (cm^2)	A_c	SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	f_R/PS
						Head (m)	Force (tf)										
LABEL	ID	LOC									f_s	f_L	f_{Ri}				
SHL11010	1	1	8.69	0.685	2.34	9.12	14.98	9.5	27.5	1.5	115	2215	2222	F2	0.928	2443	0.91
		2	8.69	0.685	2.34	9.12	14.98	9.5	27.5	1.25	115	2215	2220	F2	0.928	2443	0.91
[Weld Throat]			8.69	0.685	2.34	9.12	14.98	[Asw]=	6	1.25	115	0	228	W	0.928	1760	0.13
SHL11011	1	1	9.37	0.685	2.34	7.6	12.49	9.5	27.5	1.5	96	2224	2229	F2	0.928	2443	0.91
		2	9.37	0.685	2.34	7.6	12.49	9.5	27.5	1.25	96	2224	2228	F2	0.928	2443	0.91
[Weld Throat]			9.37	0.685	2.34	7.6	12.49	[Asw]=	6	1.25	96	0	190	W	0.928	1760	0.11
SHL11212	1	1	10.75	0.685	2.34	2.9	4.76	9.5	18	1.5	49	1898	1900	F2	0.882	2652	0.72
		2	10.75	0.685	2.34	2.9	4.76	9.5	18	1.25	49	1898	1899	F2	0.882	2652	0.72
[Weld Throat]			10.75	0.685	2.34	2.9	4.76	[Asw]=	6	1.25	49	0	98	W	0.882	1911	0.05
SHS10101	1	1	11.43	0.685	2.34	1.17	1.92	4.7	11.9	1.5	110	2014	2021	F2	0.854	2805	0.72
		2	11.43	0.685	2.34	1.17	1.92	4.7	11.9	1.25	110	2014	2019	F2	0.854	2805	0.72
[Weld Throat]			11.43	0.685	2.34	1.17	1.92	[Asw]=	4.5	1.25	110	0	144	W	0.854	2018	0.07
SHS10102	1	1	12.11	0.685	2.34	0.39	0.64	4.7	11.9	1.5	36	2059	2060	F2	0.851	2827	0.73
		2	12.11	0.685	2.34	0.39	0.64	4.7	11.9	1.25	36	2059	2060	F2	0.851	2827	0.73
[Weld Throat]			12.11	0.685	2.34	0.39	0.64	[Asw]=	4.5	1.25	36	0	48	W	0.851	2033	0.02

Table G-3 Comparison of SafeHull Phase A and Phase B Analyses for Ship G

									PHASE A ANALYSIS									PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
1	Bottom Long'l 1	A/	1	0	268	2.3	1&2	0.85	5.23	2249	470	2196	F2	0.889	2611	0.84	960	1155	0.44
		F/	2	0	268	2.3	1&2	0.85	5.23	2249	470	2196	F2	0.889	2611	0.84		1155	0.44
2	Bottom Long'l 3	A/	1	0.19	265	2.3	1&2	0.85	5.21	2179	461	2132	F2	0.889	2611	0.82	1123	1279	0.49
		F/	2	0.19	265	2.3	1&2	0.85	5.21	2179	461	2132	F2	0.889	2611	0.82		1279	0.49
3	Bottom Long'l 5	A/	1	0.47	265	2.3	1&2	0.85	5.17	2077	463	2051	F2	0.889	2611	0.79	1225	1363	0.52
		F/	2	0.47	265	2.3	1&2	0.85	5.17	2077	463	2051	F2	0.889	2611	0.79		1363	0.52
4	Bottom Long'l 7	A/	2	0.84	262	2.3	1&2	0.85	5.12	1942	476	1953	F2	0.889	2611	0.75	1323	1453	0.56
		F/	1	0.84	262	2.3	1&2	0.85	5.12	1942	476	1953	F2	0.889	2611	0.75		1453	0.56
5	Bottom Long'l 9	A/	2	1.41	264	2.3	TZONE	1.00		1834	491	2209	F2	0.893	2590	0.85	1212	1618	0.62
		F/	1	1.41	264	2.3	TZONE	1.00		1834	491	2209	F2	0.893	2590	0.85		1618	0.62
6	Bottom Long'l 10	A/	2	1.83	236	2.3	TZONE	1.00		1723	634	2240	F2	0.906	2528	0.89	1103	1651	0.65
		F/	1	1.83	236	2.3	TZONE	1.00		1723	634	2240	F2	0.906	2528	0.89		1651	0.65
7	Bottom Long'l 11	A/	2	2.26	136	2.3	TZONE	1.00		1631	1385	2865	F2	0.918	2478	1.16	1103	2363	0.95
		F/	1	2.26	136	2.3	TZONE	1.00		1631	1385	2865	F2	0.918	2478	1.16		2363	0.95
8	Side Long'l 13	A/	1	3.2	171	2.3	F1&F2	1.00	7.86	1808	1072	2736	F2	0.928	2443	1.12	1082	2046	0.84
		F/	2	3.2	171	2.3	F1&F2	1.00	7.86	1808	1072	2736	F2	0.928	2443	1.12		2046	0.84
9	Side Long'l 14	A/	1	3.9	171	2.3	F1&F2	1.00	8.48	1752	1238	2840	F2	0.928	2443	1.16	1104	2225	0.91
		F/	2	3.9	171	2.3	F1&F2	1.00	8.48	1752	1238	2840	F2	0.928	2443	1.16		2225	0.91
10	Side Long'l 16	A/	1	5.35	169	2.3	F1&F2	1.00	10.6	1586	1532	2962	F2	0.928	2443	1.21	1209	2604	1.07
		F/	2	5.35	169	2.3	F1&F2	1.00	10.6	1586	1532	2962	F2	0.928	2443	1.21		2604	1.07
11	Side Long'l 17	A/	1	5.94	156	2.3	F1&F2	1.00	11.7	1517	1655	3013	F2	0.928	2443	1.23	1191	2703	1.11
		F/	2	5.94	156	2.3	F1&F2	1.00	11.7	1517	1655	3013	F2	0.928	2443	1.23		2703	1.11

									PHASE A ANALYSIS								PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
12	Side Long'l 18	A/	1	6.61	156	2.3	F1&F2	1.00	13	1472	1473	2798	F2	0.928	2443	1.15	1185	2525	1.03
		F/	2	6.61	156	2.3	F1&F2	1.00	13	1472	1473	2798	F2	0.928	2443	1.15		2525	1.03
13	Side Long'l 21	A/	2	8	119	2.3	F1&F2	1.00	10.6	1679	732	2291	F2	0.928	2443	0.94	1195	1831	0.75
		F/	1	8	119	2.3	F1&F2	1.00	10.6	1679	732	2291	F2	0.928	2443	0.94		1831	0.75
14	Side Long'l 22	A/	2	8.69	119	2.3	F1&F2	1.00	9.12	1781	551	2215	F2	0.928	2443	0.91	1195	1658	0.68
		F/	1	8.69	119	2.3	F1&F2	1.00	9.12	1781	551	2215	F2	0.928	2443	0.91		1658	0.68
15	Side Long'l 23	A/	2	9.37	119	2.3	F1&F2	1.00	7.6	1882	459	2224	F2	0.928	2443	0.91	1289	1661	0.68
		F/	1	9.37	119	2.3	F1&F2	1.00	7.6	1882	459	2224	F2	0.928	2443	0.91		1661	0.68
16	Side Long'l 26	A/	2	10.75	98	2.3	TZONE	1.00		1784	214	1898	F2	0.882	2652	0.72	1795	1908	0.72
		F/	1	10.75	98	2.3	TZONE	1.00		1784	214	1898	F2	0.882	2652	0.72		1908	0.72
17	Side Long'l 27	A/	2	11.43	101	2.3	TZONE	1.00		1843	278	2014	F2	0.854	2805	0.72	2201	2354	0.84
		F/	1	11.43	101	2.3	TZONE	1.00		1843	278	2014	F2	0.854	2805	0.72		2354	0.84
18	Side Long'l 28	A/	2	12.11	101	2.3	1&2	1.00	0.39	2076	92	2059	F2	0.851	2827	0.73	2201	2178	0.77
		F/	1	12.11	101	2.3	1&2	1.00	0.39	2076	92	2059	F2	0.851	2827	0.73		2178	0.77
19	01 Lvl Long'l 12	A/	1	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2580	2451	0.87
		F/	2	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2451	0.87
20	01 Lvl Long'l 11	A/	1	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2545	2417	0.86
		F/	2	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2417	0.86
21	01 Lvl Long'l 10	A/	1	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2535	2408	0.85
		F/	2	12.8	101	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2408	0.85
22	01 Lvl Long'l 9	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2526	2399	0.85
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2399	0.85
23	01 Lvl Long'l 8	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2523	2397	0.85
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2397	0.85
24	01 Lvl Long'l 7	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2521	2394	0.85
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2394	0.85

									PHASE A ANALYSIS								PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
25	01 Lvl Long'l 6	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2518	2392	0.85
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2392	0.85
26	01 Lvl Long'l 5	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2515	2389	0.85
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2389	0.85
27	01 Lvl Long'l 4	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2513	2387	0.84
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2387	0.84
28	01 Lvl Long'l 3	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2510	2384	0.84
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2384	0.84
29	01 Lvl Long'l 2	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2507	2381	0.84
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2381	0.84
30	01 Lvl Long'l 1	A/	1	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76	2504	2378	0.84
		F/	2	12.8	99	2.3	1&2	1.00	0	2273	0	2159	F2	0.851	2827	0.76		2378	0.84
31	01 Lvl Long'l Cl	A/	1	12.8	1408	2.3	1&2	1.00	0	2161	0	2053	F2	0.851	2827	0.73	2502	2377	0.84
		F/	2	12.8	1408	2.3	1&2	1.00	0	2161	0	2053	F2	0.851	2827	0.73		2377	0.84
32	I.B. Long'l 1	A/	1	1.4	156	2.3	1&2	1.00	0.48	1938	75	1912	F2	0.889	2611	0.73	209	270	0.10
		F/	2	1.4	156	2.3	1&2	1.00	0.48	1938	75	1912	F2	0.889	2611	0.73		270	0.10
33	I.B. Long'l 3	A/	1	1.65	135	2.3	1&2	1.00	0.45	1847	78	1829	F2	0.889	2611	0.70	541	588	0.23
		F/	2	1.65	135	2.3	1&2	1.00	0.45	1847	78	1829	F2	0.889	2611	0.70		588	0.23
34	I.B. Long'l 5	A/	1	1.98	135	2.3	1&2	1.00	0.4	1726	71	1707	F2	0.889	2611	0.65	666	700	0.27
		F/	2	1.98	135	2.3	1&2	1.00	0.4	1726	71	1707	F2	0.889	2611	0.65		700	0.27
35	I.B. Long'l 7	A/	1	2.39	135	2.3	1&2	1.00	0.34	1576	63	1557	F2	0.889	2611	0.60	688	713	0.27
		F/	2	2.39	135	2.3	1&2	1.00	0.34	1576	63	1557	F2	0.889	2611	0.60		713	0.27
36	I.B. Long'l 9	A/	1	2.81	135	2.3	1&2	1.00	0.28	1422	36	1385	F2	0.889	2611	0.53	901	890	0.34
		F/	2	2.81	135	2.3	1&2	1.00	0.28	1422	36	1385	F2	0.889	2611	0.53		890	0.34

									PHASE A ANALYSIS								PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
37	IB Margin Plate	A/	1	2.85	135	2.3	F1&F2	1.00	0.43	1743	71	1723	F2	0.889	2611	0.66	1050	1065	0.41
		F/	2	2.85	135	2.3	F1&F2	1.00	0.43	1743	71	1723	F2	0.889	2611	0.66		1065	0.41
38	1st Plat Long'l Cl	A/	1	7.32	52	2.3	F1&F2	1.00	0	240	0	228	F2	0.889	2611	0.09	501	476	0.18
		F/	2	7.32	52	2.3	F1&F2	1.00	0	240	0	228	F2	0.889	2611	0.09		476	0.18
39	1st Plat Long'l 1	A/	1	7.32	52	2.3	F1&F2	1.00	0	469	0	446	F2	0.889	2611	0.17	503	478	0.18
		F/	2	7.32	52	2.3	F1&F2	1.00	0	469	0	446	F2	0.889	2611	0.17		478	0.18
40	1st Plat Long'l 2	A/	1	7.32	52	2.3	F1&F2	1.00	0	584	0	554	F2	0.889	2611	0.21	505.6	480	0.18
		F/	2	7.32	52	2.3	F1&F2	1.00	0	584	0	554	F2	0.889	2611	0.21		480	0.18
41	1st Plat Long'l 3	A/	1	7.32	52	2.3	F1&F2	1.00	0	698	0	663	F2	0.889	2611	0.25	509.7	484	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	698	0	663	F2	0.889	2611	0.25		484	0.19
42	1st Plat Long'l 4	A/	1	7.32	52	2.3	F1&F2	1.00	0	813	0	772	F2	0.889	2611	0.30	513.8	488	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	813	0	772	F2	0.889	2611	0.30		488	0.19
43	1st Plat Long'l 5	A/	1	7.32	52	2.3	F1&F2	1.00	0	927	0	881	F2	0.889	2611	0.34	517.9	492	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	927	0	881	F2	0.889	2611	0.34		492	0.19
44	1st Plat Long'l 6	A/	1	7.32	52	2.3	F1&F2	1.00	0	1156	0	1098	F2	0.889	2611	0.42	522	496	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	1156	0	1098	F2	0.889	2611	0.42		496	0.19
45	1st Plat Long'l 7	A/	1	7.32	52	2.3	F1&F2	1.00	0	1270	0	1207	F2	0.889	2611	0.46	526.1	500	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	1270	0	1207	F2	0.889	2611	0.46		500	0.19
46	1st Plat Long'l 8	A/	1	7.32	52	2.3	F1&F2	1.00	0	1385	0	1315	F2	0.889	2611	0.50	530	503	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	1385	0	1315	F2	0.889	2611	0.50		503	0.19
47	1st Plat Long'l 9	A/	1	7.32	52	2.3	F1&F2	1.00	0	1499	0	1424	F2	0.889	2611	0.55	532	505	0.19
		F/	2	7.32	52	2.3	F1&F2	1.00	0	1499	0	1424	F2	0.889	2611	0.55		505	0.19
48	2nd Plat Long'l Cl	A/	1	4.57	141	2.3	F1&F2	1.00	0	384	0	365	F2	0.889	2611	0.14	407	387	0.15
		F/	2	4.57	141	2.3	F1&F2	1.00	0	384	0	365	F2	0.889	2611	0.14		387	0.15
49	2nd Plat Long'l 1	A/	1	4.57	141	2.3	F1&F2	1.00	0	495	0	470	F2	0.889	2611	0.18	430.2	409	0.16
		F/	2	4.57	141	2.3	F1&F2	1.00	0	495	0	470	F2	0.889	2611	0.18		409	0.16

									PHASE A ANALYSIS									PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
50	2nd Plat Long'l 2	A/	1	4.57	141	2.3	F1&F2	1.00	0	606	0	575	F2	0.889	2611	0.22	459.4	436	0.17
		F/	2	4.57	141	2.3	F1&F2	1.00	0	606	0	575	F2	0.889	2611	0.22		436	0.17
51	2nd Plat Long'l 3	A/	1	4.57	141	2.3	F1&F2	1.00	0	716	0	680	F2	0.889	2611	0.26	484.5	460	0.18
		F/	2	4.57	141	2.3	F1&F2	1.00	0	716	0	680	F2	0.889	2611	0.26		460	0.18
52	2nd Plat Long'l 4	A/	1	4.57	141	2.3	F1&F2	1.00	0	827	0	785	F2	0.889	2611	0.30	509.7	484	0.19
		F/	2	4.57	141	2.3	F1&F2	1.00	0	827	0	785	F2	0.889	2611	0.30		484	0.19
53	2nd Plat Long'l 5	A/	1	4.57	141	2.3	F1&F2	1.00	0	937	0	890	F2	0.889	2611	0.34	535	508	0.19
		F/	2	4.57	141	2.3	F1&F2	1.00	0	937	0	890	F2	0.889	2611	0.34		508	0.19
54	2nd Plat Long'l 6	A/	1	4.57	141	2.3	F1&F2	1.00	0	1158	0	1100	F2	0.889	2611	0.42	560.1	532	0.20
		F/	2	4.57	141	2.3	F1&F2	1.00	0	1158	0	1100	F2	0.889	2611	0.42		532	0.20
55	2nd Plat Long'l 7	A/	1	4.57	141	2.3	F1&F2	1.00	0	1268	0	1205	F2	0.889	2611	0.46	615.7	585	0.22
		F/	2	4.57	141	2.3	F1&F2	1.00	0	1268	0	1205	F2	0.889	2611	0.46		585	0.22
56	2nd Plat Long'l 8	A/	1	4.57	141	2.3	F1&F2	1.00	0	1379	0	1310	F2	0.889	2611	0.50	702.6	667	0.26
		F/	2	4.57	141	2.3	F1&F2	1.00	0	1379	0	1310	F2	0.889	2611	0.50		667	0.26
57	2nd Plat Long'l 9	A/	1	4.57	141	2.3	F1&F2	1.00	0	1489	0	1415	F2	0.889	2611	0.54	783	744	0.28
		F/	2	4.57	141	2.3	F1&F2	1.00	0	1489	0	1415	F2	0.889	2611	0.54		744	0.28
58	2nd Plat Lg'l 10	A/	1	4.57	141	2.3	F1&F2	1.00	0	1600	0	1520	F2	0.889	2611	0.58	863.2	820	0.31
		F/	2	4.57	141	2.3	F1&F2	1.00	0	1600	0	1520	F2	0.889	2611	0.58		820	0.31
59	I.B. Girder 2	A/	1	0.8	62	2.4	1&2	1.00	0	2067	0	1963	F2	0.889	2611	0.75	786	746	0.29
		F/	1	0.8	62	2.4	1&2	1.00	0	2067	0	1963	F2	0.889	2611	0.75		746	0.29
60	I.B. Girder 4	A/	1	1.06	62	2.4	1&2	1.00	0	1972	0	1873	F2	0.889	2611	0.72	943	896	0.34
		F/	1	1.06	62	2.4	1&2	1.00	0	1972	0	1873	F2	0.889	2611	0.72		896	0.34
61	I.B. Girder 6	A/	1	1.38	62	2.4	TZONE	1.00		1823	0	1732	F2	0.889	2611	0.66	1018	967	0.37
		F/	1	1.38	62	2.4	TZONE	1.00		1823	0	1732	F2	0.889	2611	0.66		967	0.37
62	I.B. Girder 8	A/	1	1.86	54	2.4	TZONE	1.00		1652	0	1569	F2	0.889	2611	0.60	982	933	0.36
		F/	1	1.86	54	2.4	TZONE	1.00		1652	0	1569	F2	0.889	2611	0.60		933	0.36

									PHASE A ANALYSIS								PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
63	CVK	A/	1	0.69	149	2.4	1&2	1.00	0	2109	0	2003	F2	0.889	2611	0.77	500	475	0.18
		F/	1	0.69	149	2.4	1&2	1.00	0	2109	0	2003	F2	0.889	2611	0.77		475	0.18
64	Mn Dk Long'l 12	A/	1	10.06	70	2.3	TZONE	1.00		1766	0	1678	F2	0.909	2514	0.67	1503	1429	0.57
		F/	2	10.06	70	2.3	TZONE	1.00		1766	0	1678	F2	0.909	2514	0.67		1429	0.57
65	Mn Dk Long'l 11	A/	1	10.06	70	2.3	TZONE	1.00		1679	0	1595	F2	0.909	2514	0.63	1500	1425	0.57
		F/	2	10.06	70	2.3	TZONE	1.00		1679	0	1595	F2	0.909	2514	0.63		1425	0.57
66	Mn Dk Long'l 10	A/	1	10.06	70	2.3	TZONE	1.00		1591	0	1512	F2	0.909	2514	0.60	1496	1422	0.57
		F/	2	10.06	70	2.3	TZONE	1.00		1591	0	1512	F2	0.909	2514	0.60		1422	0.57
67	Mn Dk Long'l 9	A/	1	10.06	****	2.3	TZONE	1.00		1504	0	1429	F2	0.909	2514	0.57	1493	1419	0.56
		F/	2	10.06	****	2.3	TZONE	1.00		1504	0	1429	F2	0.909	2514	0.57		1419	0.56
68	Mn Dk Long'l 8	A/	1	10.06	67	2.3	TZONE	1.00		1417	0	1346	F2	0.909	2514	0.54	1489	1415	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		1417	0	1346	F2	0.909	2514	0.54		1415	0.56
69	Mn Dk Long'l 7	A/	1	10.06	67	2.3	TZONE	1.00		1330	0	1263	F2	0.909	2514	0.50	1486	1411	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		1330	0	1263	F2	0.909	2514	0.50		1411	0.56
70	Mn Dk Long'l 6	A/	1	10.06	67	2.3	TZONE	1.00		1242	0	1180	F2	0.909	2514	0.47	1483	1409	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		1242	0	1180	F2	0.909	2514	0.47		1409	0.56
71	Mn Dk Long'l 5	A/	1	10.06	67	2.3	TZONE	1.00		1155	0	1097	F2	0.909	2514	0.44	1480	1405	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		1155	0	1097	F2	0.909	2514	0.44		1405	0.56
72	Mn Dk Long'l 4	A/	1	10.06	67	2.3	TZONE	1.00		1068	0	1015	F2	0.909	2514	0.40	1476	1403	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		1068	0	1015	F2	0.909	2514	0.40		1403	0.56
73	Mn Dk Long'l 3	A/	1	10.06	67	2.3	TZONE	1.00		981	0	932	F2	0.909	2514	0.37	1473	1399	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		981	0	932	F2	0.909	2514	0.37		1399	0.56
74	Mn Dk Long'l 2	A/	1	10.06	67	2.3	TZONE	1.00		893	0	849	F2	0.909	2514	0.34	1470	1397	0.56
		F/	2	10.06	67	2.3	TZONE	1.00		893	0	849	F2	0.909	2514	0.34		1397	0.56
75	Mn Dk Long'l 1	A/	1	10.06	67	2.3	TZONE	1.00		806	0	766	F2	0.909	2514	0.30	1466	1394	0.55
		F/	2	10.06	67	2.3	TZONE	1.00		806	0	766	F2	0.909	2514	0.30		1394	0.55

									PHASE A ANALYSIS								PHASE B ANALYSIS		
STF #	Stiffener	TOE	ID	Dist. from BL (m)	SM (cm^3)	Unsup Span (m)	Load Case #	C_m	Local Load Rng	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)	Ratio of Stress	Global Stress Range	Com-bined Stress Range	Ratio of Stress
									(m)	f_{RG}	f_{RL}	f_R			P_S	f_R/PS	f_{RG}	f_R	f_R/PS
76	Mn Dk Long'l Cl	A/	1	10.06	901	2.3	TZONE	1.00		719	0	683	F2	0.909	2514	0.27	1463	1390	0.55
		F/	2	10.06	901	2.3	TZONE	1.00		719	0	683	F2	0.909	2514	0.27		1390	0.55

Table G.4 Phase B Analysis of Fatigue of Flat Bars for Ship G

Cutout LABEL ID LOC	FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	Phase A Analysis SCF	Phase A Stress Range (kg/cm2) fs	Phase A Stress Range (kg/cm2) fL	Phase A Stress Range (kg/cm2) fRi	Phase A fR/PS	Phase B Stress Range (kg/cm2) fs	Phase B Stress Range (kg/cm2) fL	Phase B Stress Range (kg/cm2) fRi	Phase B fR/PS
BTM10604 2 1	F2	0.889	2611	1.5	138	1953	1964	0.75	138	1453	1468	0.56
2	F2	0.889	2611	1.25	138	1953	1961	0.75	138	1453	1463	0.56
[Weld Throat]	W	0.889	1883	1.25	138	0	273	0.14	138	0	173	0.09
SHL10101 2 1	F2	0.893	2590	1.5	137	2209	2219	0.86	137	1618	1631	0.63
2	F2	0.893	2590	1.25	137	2209	2216	0.86	137	1618	1627	0.63
[Weld Throat]	W	0.893	1868	1.25	137	0	272	0.15	137	0	171	0.09
SHL10102 2 1	F2	0.906	2528	1.5	158	2240	2252	0.89	158	1651	1668	0.66
2	F2	0.906	2528	1.25	158	2240	2248	0.89	158	1651	1663	0.66
[Weld Throat]	W	0.906	1824	1.25	158	0	314	0.17	158	0	198	0.11
SHL10103 2 1	F2	0.918	2478	1.5	238	2865	2887	1.16	238	2363	2390	0.96
2	F2	0.918	2478	1.25	238	2865	2880	1.16	238	2363	2382	0.96
[Weld Throat]	W	0.918	1786	1.25	238	0	471	0.26	238	0	298	0.17
SHL10404 2 1	F2	0.928	2443	1.5	284	2736	2769	1.13	284	2046	2090	0.86
2	F2	0.928	2443	1	284	2736	2751	1.13	284	2046	2066	0.85
[Weld Throat]	W	0.928	1760	1.25	284	0	*****	NaN	284	0	*****	NaN
SHL10505 2 1	F2	0.928	2443	1.5	328	2840	2883	1.18	328	2225	2278	0.93
2	F2	0.928	2443	1	328	2840	2859	1.17	328	2225	2249	0.92
[Weld Throat]	W	0.928	1760	1.25	328	0	*****	NaN	328	0	*****	NaN
SHL10706 2 1	F2	0.928	2443	1.5	402	2962	3023	1.24	402	2604	2673	1.09
2	F2	0.928	2443	1	402	2962	2989	1.22	402	2604	2635	1.08
[Weld Throat]	W	0.928	1760	1.25	402	0	*****	NaN	402	0	*****	NaN
SHL10807 2 1	F2	0.928	2443	1.5	521	3013	3113	1.27	521	2703	2814	1.15
2	F2	0.928	2443	1	521	3013	3058	1.25	521	2703	2753	1.13
[Weld Throat]	W	0.928	1760	1.25	521	0	*****	NaN	521	0	*****	NaN
SHL10908 1 1	F2	0.928	2443	1.5	546	2798	2915	1.19	546	2525	2655	1.09
2	F2	0.928	2443	1	546	2798	2851	1.17	546	2525	2584	1.06

[Weld Throat]	W	0.928	1760	1.25	546	0	*****	NaN	546	0	*****	NaN
SHL11009 1 1	F2	0.928	2443	1.5	153	2291	2302	0.94	153	1831	1845	0.76
2	F2	0.928	2443	1.25	153	2291	2299	0.94	153	1831	1841	0.75
[Weld Throat]	W	0.928	1760	1.25	153	0	303	0.17	153	0	191	0.11
SHL11010 1 1	F2	0.928	2443	1.5	115	2215	2222	0.91	115	1658	1667	0.68
2	F2	0.928	2443	1.25	115	2215	2220	0.91	115	1658	1665	0.68
[Weld Throat]	W	0.928	1760	1.25	115	0	228	0.13	115	0	144	0.08
SHL11011 1 1	F2	0.928	2443	1.5	96	2224	2229	0.91	96	1661	1667	0.68
2	F2	0.928	2443	1.25	96	2224	2228	0.91	96	1661	1665	0.68
[Weld Throat]	W	0.928	1760	1.25	96	0	190	0.11	96	0	120	0.07
SHL11212 1 1	F2	0.882	2652	1.5	49	1898	1900	0.72	49	1908	1910	0.72
2	F2	0.882	2652	1.25	49	1898	1899	0.72	49	1908	1909	0.72
[Weld Throat]	W	0.882	1911	1.25	49	0	98	0.05	49	0	61	0.03
SHS10101 1 1	F2	0.854	2805	1.5	110	2014	2021	0.72	110	2354	2360	0.84
2	F2	0.854	2805	1.25	110	2014	2019	0.72	110	2354	2358	0.84
[Weld Throat]	W	0.854	2018	1.25	110	0	144	0.07	110	0	138	0.07
SHS10102 1 1	F2	0.851	2827	1.5	36	2059	2060	0.73	36	2178	2178	0.77
2	F2	0.851	2827	1.25	36	2059	2060	0.73	36	2178	2178	0.77
[Weld Throat]	W	0.851	2033	1.25	36	0	48	0.02	36	0	45	0.02

APPENDIX H

FATIGUE ANALYSIS SUMMARY FOR SHIP H

Table H.1 SafeHull Phase A Fatigue Analysis of Longitudinals for Ship H

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midships
LxBxDxd = 156.40x 16.76x 12.81x 6.65(m)
Hull-Girder Moment of Inertia Ivert. 262097.(cm2-m2) Ihoriz. 332646.(cm2-m2)
Neutral Axis Height 6.04(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 80.62m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 108994.(tf-m) MW(horiz.) 90355.(tf-m)

"Net" Ship Cf=0.95 Cw=0.75

ST #	Stiffener	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm cm3	Unsup. Span (m)	Ct	Cy	LP#	LC#	Loca Load Range (m)	Stress Range (kg/cm2)			FAT. CLASS	Long Term Distr Factor	Perm.Stress (kg/cm2)		SCANTLINGS	USER DEFINED ID
													f_{RG}	f_{RL}	f_R			P_S	fR/PS		
1	Bottom Long'l 1	BTM10101	A/	1	0	271	2.34	1	1	2	1&2	5.16	2384	459	2296	F2	0.889	2611	0.88	12 X 4 X 16# I/T	A1 01
			F/	2	0	271	2.34	1	1	2	1&2	5.16	2384	459	2296	F2	0.889	2611	0.88		A1 01
2	Bottom Long'l 3	BTM10302	A/	1	0.19	266	2.44	1	1	2	1&2	5.13	2305	493	2260	F2	0.889	2611	0.87	12 X 4 X 16# I/T	B1 02
			F/	1	0.19	266	2.44	1	1	2	1&2	5.13	2305	493	2260	F2	0.889	2611	0.87		B1 02
3	Bottom Long'l 5	BTM10503	A/	1	0.47	265	2.34	1	1	2	1&2	5.1	2189	457	2136	F2	0.889	2611	0.82	12 X 4 X 16# I/T	B3 03
			F/	2	0.47	265	2.34	1	1	2	1&2	5.1	2189	457	2136	F2	0.889	2611	0.82		B3 03
4	Bottom Long'l 7	BTM10604	A/	1	0.84	262	2.34	1	1	2	1&2	5.05	2036	470	2024	F2	0.889	2611	0.78	12 X 4 X 16# I/T	C1 04
			F/	2	0.84	262	2.34	1	1	2	1&2	5.05	2036	470	2024	F2	0.889	2611	0.78		C1 04
5	Bottom Long'l 9	SHL10101	A/	1	1.41	260	2.34	1	1	2	TZONE		1963	491	2331	F2	0.893	2590	0.9	12 X 4 X 16# I/T	D1 01
			F/	2	1.41	260	2.34	1	1	2	TZONE		1963	491	2331	F2	0.893	2590	0.9		D1 01
6	Bottom Long'l 10	SHL10102	A/	1	1.83	233	2.44	1	1	2	TZONE		2016	686	2567	F2	0.906	2528	1.02	12 X 4 X 16# I/T	D1 02
			F/	1	1.83	233	2.44	1	1	2	TZONE		2016	686	2567	F2	0.906	2528	1.02		D1 02
7	Bottom Long'l 11	SHL10103	A/	1	2.26	233	2.44	1	1	1	TZONE		2230	788	2866	F2	0.918	2478	1.16	12 X 4 X 16# I/T	D1 03
			F/	1	2.26	233	2.44	1	1	1	TZONE		2230	788	2866	F2	0.918	2478	1.16		D1 03
8	Side Long'l 13	SHL10404	A/	1	3.2	237	2.44	1	1	1	F1&F2	7.72	2495	822	3151	F2	0.928	2443	1.29	12 X 4 X 14# I/T	S14 04
			F/	1	3.2	237	2.44	1	1	1	F1&F2	7.72	2495	822	3151	F2	0.928	2443	1.29		S14 04

ST #	Stiffener	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm cm3	Unsup. Span (m)	Ct	Cy	LP#	LC#	Loca Load Range (m)	Stress Range (kg/cm2)			FAT. CLASS	Long Term Distr Factor	Perm.Stress (kg/cm2)		SCANTLINGS	USER DEFINED ID
													f_{RG}	f_{RL}	f_R			P_S	fR/PS		
9	Side Long'l 14	SHL10505	A/	1	3.9	237	2.44	1	1	1	F1&F2	8.36	2449	954	3233	F2	0.928	2443	1.32	12 X 4 X 14# I/T	2ND_PL05
			F/	1	3.9	237	2.44	1	1	1	F1&F2	8.36	2449	954	3233	F2	0.928	2443	1.32		2ND_PL05
10	Side Long'l 16	SHL10706	A/	1	5.35	169	2.44	1	1	1	F1&F2	10.62	2293	1668	3763	F2	0.928	2443	1.54	10 X 4 X 12# I/T	S17 06
			F/	1	5.35	169	2.44	1	1	1	F1&F2	10.62	2293	1668	3763	F2	0.928	2443	1.54		S17 06
11	Side Long'l 17	SHL10807	A/	1	5.94	157	2.44	1	1	1	F1&F2	11.76	2221	1804	3824	F2	0.928	2443	1.57	8 X 4 X 10 # I/T	S18 07
			F/	1	5.94	157	2.44	1	1	1	F1&F2	11.76	2221	1804	3824	F2	0.928	2443	1.57		S18 07
12	Side Long'l 18	SHL10908	A/	1	6.61	157	2.44	1	0.67	1	F1&F2	13.05	2309	1471	3591	F2	0.928	2443	1.47	8 X 4 X 10 # I/T	1ST_PL08
			F/	1	6.61	157	2.44	1	0.67	1	F1&F2	13.05	2309	1471	3591	F2	0.928	2443	1.47		1ST_PL08
13	Side Long'l 21	SHL11009	A/	1	8	119	2.44	1	0.31	1	F1&F2	10.24	2546	705	3088	F2	0.928	2443	1.26	8 X 4 X 10# I/T	G2 09
			F/	1	8	119	2.44	1	0.31	1	F1&F2	10.24	2546	705	3088	F2	0.928	2443	1.26		G2 09
14	Side Long'l 22	SHL11010	A/	1	8.69	119	2.44	1	0.3	1	F1&F2	8.78	2661	580	3079	F2	0.928	2443	1.26	8 X 4 X 10# I/T	G2 10
			F/	1	8.69	119	2.44	1	0.3	1	F1&F2	8.78	2661	580	3079	F2	0.928	2443	1.26		G2 10
15	Side Long'l 23	SHL11011	A/	1	9.37	119	2.44	1	0.3	1	F1&F2	7.32	2777	484	3097	F2	0.928	2443	1.27	8 X 4 X 10# I/T	G2 11
			F/	1	9.37	119	2.44	1	0.3	1	F1&F2	7.32	2777	484	3097	F2	0.928	2443	1.27		G2 11
16	Side Long'l 26	SHL11212	A/	1	10.75	159	2.44	1	0.3	1	TZONE		2383	133	2390	F2	0.882	2652	0.9	8 X 4 X 10 # I/T	H2 12
			F/	1	10.75	159	2.44	1	0.3	1	TZONE		2383	133	2390	F2	0.882	2652	0.9		H2 12
17	Side Long'l 27	SHS10101	A/	1	11.43	101	2.44	1	1	1	TZONE		2287	246	2407	F2	0.854	2805	0.86	5.96x4.3x.141/.231 T	J 01
			F/	1	11.43	101	2.44	1	1	1	TZONE		2287	246	2407	F2	0.854	2805	0.86		J 01
18	Side Long'l 28	SHS10102	A/	1	12.11	101	2.44	1	1	1	1&2	0.16	2528	42	2441	F2	0.851	2827	0.86	5.96x4.3x.141/.231 T	J 02
			F/	1	12.11	101	2.44	1	1	1	1&2	0.16	2528	42	2441	F2	0.851	2827	0.86		J 02
19	01 Lvl Long'l 12	DEC10101	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_01
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_01
20	01 Lvl Long'l 11	DEC10102	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_02
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_02
21	01 Lvl Long'l 10	DEC10103	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_03
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_03
22	01 Lvl Long'l 9	DEC10104	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_04
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_04
23	01 Lvl Long'l 8	DEC10205	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_05
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_05
24	01 Lvl Long'l 7	DEC10206	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_06
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_06

ST #	Stiffener	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm cm3	Unsup. Span (m)	Ct	Cy	LP#	LC#	Loca Load Range (m)	Stress Range (kg/cm2)			FAT. CLASS	Long Term Distr Factor	Perm.Stress (kg/cm2)		SCANTLINGS	USER DEFINED ID
													f_{RG}	f_{RL}	f_R			P_S	fR/PS		
25	01 Lvl Long'l 6	DEC10207	A/	1	12.8	102	2.315	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_07
			F/	3	12.8	102	2.315	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_07
26	01 Lvl Long'l 5	DEC10208	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_08
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_08
27	01 Lvl Long'l 4	DEC10209	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_09
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_09
28	01 Lvl Long'l 3	DEC10210	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_10
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_10
29	01 Lvl Long'l 2	DEC10211	A/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_11
			F/	1	12.8	102	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_11
30	01 Lvl Long'l 1	DEC10412	A/	1	12.8	101	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92	5.96x4.3x.141/.231 T	01LVL_12
			F/	1	12.8	101	2.44	1	1	1	1&2	0	2750	0	2612	F2	0.851	2827	0.92		01LVL_12
31	01 Lvl Long'l Cl	DEC10413	A/	1	12.8	1390	2.44	1	1	1	1&2	0	2625	0	2494	F2	0.851	2827	0.88	18 X 7-1/2 X 50# I/T	01LVL_13
			F/	1	12.8	1390	2.44	1	1	1	1&2	0	2625	0	2494	F2	0.851	2827	0.88		01LVL_13
32	I.B. Long'l 1	INB10301	A/	1	1.4	154	2.34	1	1	2	1&2	0.47	2032	75	2001	F2	0.889	2611	0.77	10 X 4 X 12# I/T	Long2 01
			F/	2	1.4	154	2.34	1	1	2	1&2	0.47	2032	75	2001	F2	0.889	2611	0.77		Long2 01
33	I.B. Long'l 3	INB10502	A/	1	1.65	133	2.34	1	1	2	1&2	0.44	1927	78	1905	F2	0.889	2611	0.73	10 X 4 X 12# I/T	Long4 02
			F/	2	1.65	133	2.34	1	1	2	1&2	0.44	1927	78	1905	F2	0.889	2611	0.73		Long4 02
34	I.B. Long'l 5	INB10703	A/	1	1.98	133	2.34	1	1	2	1&2	0.4	1790	71	1768	F2	0.889	2611	0.68	10 X 4 X 12# I/T	Long6 03
			F/	2	1.98	133	2.34	1	1	2	1&2	0.4	1790	71	1768	F2	0.889	2611	0.68		Long6 03
35	I.B. Long'l 7	INB10904	A/	1	2.39	133	2.34	1	1	2	1&2	0.34	1620	63	1599	F2	0.889	2611	0.61	10 X 4 X 12# I/T	Long8 04
			F/	2	2.39	133	2.34	1	1	2	1&2	0.34	1620	63	1599	F2	0.889	2611	0.61		Long8 04
36	I.B. Long'l 9	INB11105	A/	1	2.81	134	2.44	1	1	2	1&2	0.28	1445	39	1410	F2	0.889	2611	0.54	10 X 4 X 12# I/T	Long1005
			F/	1	2.81	134	2.44	1	1	2	1&2	0.28	1445	39	1410	F2	0.889	2611	0.54		Long1005
37	1st Plat Long'l 1	WTF10101	A/	1	7.32	828	2.44	1	1	1	F1&F2	0	385	0	366	F2	0.889	2611	0.14	18 X 7-1/2 X 50# I/T	
			F/	1	7.32	828	2.44	1	1	1	F1&F2	0	385	0	366	F2	0.889	2611	0.14		
38	1st Plat Long'l 2	WTF10202	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	735	0	698	F2	0.889	2611	0.27	5 X 4 X 6.0# T	
			F/	1	7.32	52	2.44	1	1	1	F1&F2	0	735	0	698	F2	0.889	2611	0.27		
39	1st Plat Long'l 3	WTF10203	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	910	0	864	F2	0.889	2611	0.33	5 X 4 X 6.0# T	
			F/	1	7.32	52	2.44	1	1	1	F1&F2	0	910	0	864	F2	0.889	2611	0.33		
40	1st Plat Long'l 4	WTF10204	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1085	0	1031	F2	0.889	2611	0.39	5 X 4 X 6.0# T	
			F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1085	0	1031	F2	0.889	2611	0.39		
41	1st Plat Long'l 5	WTF10205	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1260	0	1197	F2	0.889	2611	0.46	5 X 4 X 6.0# T	
			F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1260	0	1197	F2	0.889	2611	0.46		
42	1st Plat Long'l 6	WTF10206	A/	1	7.32	52	2.44	1	1	1	F1&F2	0	1435	0	1363	F2	0.889	2611	0.52	5 X 4 X 6.0# T	
			F/	1	7.32	52	2.44	1	1	1	F1&F2	0	1435	0	1363	F2	0.889	2611	0.52		

ST #	Stiffener	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm cm3	Unsup. Span (m)	Ct	Cy	LP#	LC#	Loca Load Range (m)	Stress Range (kg/cm2)			FAT. CLASS	Long Term Distr Factor	Perm.Stress (kg/cm2)		SCANTLINGS	USER DEFINED ID
													f_{RG}	f_{RL}	f_R			P_S	fR/PS		
43	1st Plat Long'l 7	WTF10307	A/	1	7.32	54	2.44	1	1	1	F1&F2	0	1785	0	1695	F2	0.889	2611	0.65	4.94x4.2x.125/.22T	1st_Pl07
			F/	1	7.32	54	2.44	1	1	1	F1&F2	0	1785	0	1695	F2	0.889	2611	0.65		1st_Pl07
44	1st Plat Long'l 8	WTF10308	A/	1	7.32	54	2.44	1	1	1	F1&F2	0	1960	0	1862	F2	0.889	2611	0.71	4.94x4.2x.125/.22T	1st_Pl08
			F/	1	7.32	54	2.44	1	1	1	F1&F2	0	1960	0	1862	F2	0.889	2611	0.71		1st_Pl08
45	1st Plat Long'l 9	WTF10309	A/	1	7.32	54	2.44	1	1	1	F1&F2	0	2134	0	2028	F2	0.889	2611	0.78	4.94x4.2x.125/.22T	1st_Pl09
			F/	1	7.32	54	2.44	1	1	1	F1&F2	0	2134	0	2028	F2	0.889	2611	0.78		1st_Pl09
46	1st Plat Long'l 10	WTF10310	A/	1	7.32	54	2.44	1	1	1	F1&F2	0	2309	0	2194	F2	0.889	2611	0.84	4.94x4.2x.125/.22T	1st_Pl10
			F/	1	7.32	54	2.44	1	1	1	F1&F2	0	2309	0	2194	F2	0.889	2611	0.84		1st_Pl10
47	2nd Plat Long'l 1	NTF10101	A/	1	4.57	852	2.44	1	1	1	F1&F2	0	412	0	391	F2	0.889	2611	0.15	18 X 7-1/2 X 50# I/T	2nd Pl01
			F/	1	4.57	852	2.44	1	1	1	F1&F2	0	412	0	391	F2	0.889	2611	0.15		2nd Pl01
48	2nd Plat Long'l 2	NTF10102	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	581	0	552	F2	0.889	2611	0.21	8 X 4 X 10 # I/T	2nd Pl02
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	581	0	552	F2	0.889	2611	0.21		2nd Pl02
49	2nd Plat Long'l 3	NTF10103	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	750	0	712	F2	0.889	2611	0.27	8 X 4 X 10 # I/T	2nd Pl03
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	750	0	712	F2	0.889	2611	0.27		2nd Pl03
50	2nd Plat Long'l 4	NTF10104	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	919	0	873	F2	0.889	2611	0.33	8 X 4 X 10 # I/T	2nd Pl04
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	919	0	873	F2	0.889	2611	0.33		2nd Pl04
51	2nd Plat Long'l 5	NTF10105	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	1088	0	1033	F2	0.889	2611	0.4	8 X 4 X 10 # I/T	2nd Pl05
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	1088	0	1033	F2	0.889	2611	0.4		2nd Pl05
52	2nd Plat Long'l 6	NTF10106	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	1257	0	1194	F2	0.889	2611	0.46	8 X 4 X 10 # I/T	2nd Pl06
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	1257	0	1194	F2	0.889	2611	0.46		2nd Pl06
53	2nd Plat Long'l 7	NTF10207	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	1594	0	1514	F2	0.889	2611	0.58	8 X 4 X 10 # I/T	2ndPla07
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	1594	0	1514	F2	0.889	2611	0.58		2ndPla07
54	2nd Plat Long'l 8	NTF10208	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	1763	0	1675	F2	0.889	2611	0.64	8 X 4 X 10 # I/T	2ndPla08
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	1763	0	1675	F2	0.889	2611	0.64		2ndPla08
55	2nd Plat Long'l 9	NTF10209	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	1932	0	1835	F2	0.889	2611	0.7	8 X 4 X 10 # I/T	2ndPla09
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	1932	0	1835	F2	0.889	2611	0.7		2ndPla09
56	2nd Plat Long'l 10	NTF10210	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	2101	0	1996	F2	0.889	2611	0.76	8 X 4 X 10 # I/T	2ndPla10
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	2101	0	1996	F2	0.889	2611	0.76		2ndPla10
57	2nd Plat Long'l CL	NTF10211	A/	1	4.57	138	2.44	1	1	1	F1&F2	0	2270	0	2156	F2	0.889	2611	0.83	8 X 4 X 10 # I/T	2ndPla11
			F/	1	4.57	138	2.44	1	1	1	F1&F2	0	2270	0	2156	F2	0.889	2611	0.83		2ndPla11
58	I.B. Girder 2	NBG10101	A/	1	0.8	61	2.44	1	1	1	1&2	0	2178	0	2069	F2	0.889	2611	0.79	5 X 4 X 6.0# T	G2 01
			F/	1	0.8	61	2.44	1	1	1	1&2	0	2178	0	2069	F2	0.889	2611	0.79		G2 01
59	I.B. Girder 4	NBG20201	A/	1	1.06	61	2.44	1	1	1	1&2	0	2069	0	1966	F2	0.889	2611	0.75	5 X 4 X 6.0# T	G3 01
			F/	1	1.06	61	2.44	1	1	1	1&2	0	2069	0	1966	F2	0.889	2611	0.75		G3 01

ST #	Stiffener	SafeHull STF ID	TOE	ID	Dist. from BL (m)	sm cm3	Unsup. Span (m)	Ct	Cy	LP#	LC#	Loca Load Range (m)	Stress Range (kg/cm2)			FAT. CLASS	Long Term Distr Factor	Perm.Stress (kg/cm2)		SCANTLINGS	USER DEFINED ID
													f_{RG}	f_{RL}	f_R			P_S	fR/PS		
60	I.B. Girder 6	NBG30301	A/	1	1.38	61	2.44	1	1	1	TZONE		1931	0	1834	F2	0.889	2611	0.7	5 X 4 X 6.0# T	G4 01
			F/	1	1.38	61	2.44	1	1	1	TZONE		1931	0	1834	F2	0.889	2611	0.7		G4 01
61	I.B. Girder 8	NBG40401	A/	1	1.86	53	2.44	1	1	1	TZONE		1920	0	1824	F2	0.889	2611	0.7	5 X 4 X 6.0# T	G5 01
			F/	1	1.86	53	2.44	1	1	1	TZONE		1920	0	1824	F2	0.889	2611	0.7		G5 01
62	CVK	BGR10101	A/	1	0.69	147	2.44	1	1	1	1&2	0	2225	0	2114	F2	0.889	2611	0.81	8 X 4 X 10 # I/T	CVK 01
			F/	1	0.69	147	2.44	1	1	1	1&2	0	2225	0	2114	F2	0.889	2611	0.81		CVK 01
63	Margin Plate	BGR20201	A/	1	2.85	55	2.44	1	1	2	1&2	0.28	1326	121	1375	F2	0.889	2611	0.53	5 X 4 X 6.0# T	Margin01
			F/	1	2.85	55	2.44	1	1	2	1&2	0.28	1326	121	1375	F2	0.889	2611	0.53		Margin01
64	Mn Dk Lg'l 12	SDK10101	A/	1	10.06	72	2.44	1	1	1	TZONE		2538	0	2411	F2	0.909	2514	0.96	4.94x4.2x.125/.22T	Main_D01
			F/	1	10.06	72	2.44	1	1	1	TZONE		2538	0	2411	F2	0.909	2514	0.96		Main_D01
65	Mn Dk Lg'l 11	SDK10102	A/	1	10.06	72	2.44	1	1	1	TZONE		2412	0	2291	F2	0.909	2514	0.91	4.94x4.2x.125/.22T	Main_D02
			F/	1	10.06	72	2.44	1	1	1	TZONE		2412	0	2291	F2	0.909	2514	0.91		Main_D02
66	Mn Dk Lg'l 10	SDK10203	A/	1	10.06	71	2.44	1	1	1	TZONE		2286	0	2172	F2	0.909	2514	0.86	4.94x4.2x.125/.22T	Main_D03
			F/	1	10.06	71	2.44	1	1	1	TZONE		2286	0	2172	F2	0.909	2514	0.86		Main_D03
67	Mn Dk Long'l 9	SDK10204	A/	1	10.06	71	2.44	1	1	1	TZONE		2160	0	2052	F2	0.909	2514	0.82	4.94x4.2x.125/.22T	Main_D04
			F/	1	10.06	71	2.44	1	1	1	TZONE		2160	0	2052	F2	0.909	2514	0.82		Main_D04
68	Mn Dk Long'l 8	SDK10305	A/	1	10.06	71	2.44	1	1	1	TZONE		2034	0	1932	F2	0.909	2514	0.77	4.94x4.2x.125/.22T	Main_D05
			F/	1	10.06	71	2.44	1	1	1	TZONE		2034	0	1932	F2	0.909	2514	0.77		Main_D05
69	Mn Dk Long'l 7	SDK10306	A/	1	10.06	71	2.44	1	1	1	TZONE		1897	0	1802	F2	0.909	2514	0.72	4.94x4.2x.125/.22T	Main_D06
			F/	1	10.06	71	2.44	1	1	1	TZONE		1897	0	1802	F2	0.909	2514	0.72		Main_D06
70	Mn Dk Long'l 6	SDK10307	A/	1	10.06	71	2.315	1	1	1	TZONE		1760	0	1672	F2	0.909	2514	0.67	4.94x4.2x.125/.22T	Main_D07
			F/	3	10.06	71	2.315	1	1	1	TZONE		1760	0	1672	F2	0.909	2514	0.67		Main_D07
71	Mn Dk Long'l 5	SDK10308	A/	1	10.06	71	2.44	1	1	1	TZONE		1624	0	1542	F2	0.909	2514	0.61	4.94x4.2x.125/.22T	Main_D08
			F/	1	10.06	71	2.44	1	1	1	TZONE		1624	0	1542	F2	0.909	2514	0.61		Main_D08
72	Mn Dk Long'l 4	SDK10309	A/	1	10.06	71	2.44	1	1	1	TZONE		1487	0	1413	F2	0.909	2514	0.56	4.94x4.2x.125/.22T	Main_D09
			F/	1	10.06	71	2.44	1	1	1	TZONE		1487	0	1413	F2	0.909	2514	0.56		Main_D09
73	Mn Dk Long'l 3	SDK10310	A/	1	10.06	71	2.44	1	1	1	TZONE		1350	0	1283	F2	0.909	2514	0.51	4.94x4.2x.125/.22T	Main_D10
			F/	1	10.06	71	2.44	1	1	1	TZONE		1350	0	1283	F2	0.909	2514	0.51		Main_D10
74	Mn Dk Long'l 2	SDK10411	A/	1	10.06	71	2.44	1	1	1	TZONE		1193	0	1133	F2	0.909	2514	0.45	4.94x4.2x.125/.22T	Main_D11
			F/	1	10.06	71	2.44	1	1	1	TZONE		1193	0	1133	F2	0.909	2514	0.45		Main_D11
75	Mn Dk Long'l 1	SDK10512	A/	1	10.06	71	2.44	1	1	1	TZONE		1050	0	997	F2	0.909	2514	0.4	4.94x4.2x.125/.22T	MDInef12
			F/	1	10.06	71	2.44	1	1	1	TZONE		1050	0	997	F2	0.909	2514	0.4		MDInef12
76	Main Dk Lg'l Cl	SDK10613	A/	1	10.06	848	2.44	1	1	1	TZONE		908	0	862	F2	0.909	2514	0.34	18 X 7-1/2 X 50# I/T	Main_D13
			F/	1	10.06	848	2.44	1	1	1	TZONE		908	0	862	F2	0.909	2514	0.34		Main_D13

Table H.2 Phase A Fatigue Analysis of Flat Bars for Ship H

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)

LxBxDxd = 156.40x 16.76x 12.81x 6.80(m)
Hull-Girder Moment of Inertia Ivert. 303713.(cm2-m2) Ihoriz. 517550.(cm2-m2)
Neutral Axis Height 6.45(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 80.62m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 111187.(tf-m) MW(horiz.) 91964.(tf-m)
******** "Net" Ship ******** Cf=0.95 Cw=0.75

Cutout			Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas A_s (cm^2)	A_c	SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	f_R/PS
LABEL	ID	LOC				Head (m)	Force (tf)				f_s	f_L	f_{Ri}				
BTM10101	2	1	0	0.688	2.34	5.16	8.51	0	60.5	1.5	134	2296	2305	F2	0.889	2611	0.88
		2	0	0.688	2.34	5.16	8.51	0	60.5	1	134	2296	2300	F2	0.889	2611	0.88
[Weld Throat]			0	0.688	2.34	5.16	8.51	[Asw]=	0	1.25	134	0	*****	W	0.889	1883	NaN
BTM10503	2	1	0.47	0.678	2.34	5.1	8.29	0	60.5	1.5	130	2136	2145	F2	0.889	2611	0.82
		2	0.47	0.678	2.34	5.1	8.29	0	60.5	1	130	2136	2140	F2	0.889	2611	0.82
[Weld Throat]			0.47	0.678	2.34	5.1	8.29	[Asw]=	0	1.25	130	0	*****	W	0.889	1883	NaN
BTM10604	2	1	0.84	0.696	2.34	5.05	8.43	0	60.5	1.5	132	2024	2034	F2	0.889	2611	0.78
		2	0.84	0.696	2.34	5.05	8.43	0	60.5	1	132	2024	2028	F2	0.889	2611	0.78
[Weld Throat]			0.84	0.696	2.34	5.05	8.43	[Asw]=	0	1.25	132	0	*****	W	0.889	1883	NaN
DEC10207	2	1	12.8	0.66	2.315	0	0	0	17.4	1.5	0	2612	2612	F2	0.851	2827	0.92
		2	12.8	0.66	2.315	0	0	0	17.4	1	0	2612	2612	F2	0.851	2827	0.92
[Weld Throat]			12.8	0.66	2.315	0	0	[Asw]=	0	1.25	0	0	*****	W	0.851	2033	NaN

Cutout			Dist. from BL (m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas A_s (cm^2)	A_c	SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	f_R/PS
LABEL	ID	LOC				Head (m)	Force (tf)				f_s	f_L	f_{Ri}				
INB10301	1	1	1.4	0.691	2.34	0.47	0.79	0	43.2	1.5	17	2001	2001	F2	0.889	2611	0.77
		2	1.4	0.691	2.34	0.47	0.79	0	43.2	1	17	2001	2001	F2	0.889	2611	0.77
[Weld Throat]			1.4	0.691	2.34	0.47	0.79	[Asw]=	0	1.25	17	0	*****	W	0.889	1883	NaN
INB10502	1	1	1.65	0.675	2.34	0.44	0.71	0	43.2	1.5	16	1905	1906	F2	0.889	2611	0.73
		2	1.65	0.675	2.34	0.44	0.71	0	43.2	1	16	1905	1905	F2	0.889	2611	0.73
[Weld Throat]			1.65	0.675	2.34	0.44	0.71	[Asw]=	0	1.25	16	0	*****	W	0.889	1883	NaN
INB10703	1	1	1.98	0.682	2.34	0.4	0.65	0	43.2	1.5	14	1768	1768	F2	0.889	2611	0.68
		2	1.98	0.682	2.34	0.4	0.65	0	43.2	1	14	1768	1768	F2	0.889	2611	0.68
[Weld Throat]			1.98	0.682	2.34	0.4	0.65	[Asw]=	0	1.25	14	0	*****	W	0.889	1883	NaN
INB10904	1	1	2.39	0.708	2.34	0.34	0.58	0	43.2	1.5	13	1599	1599	F2	0.889	2611	0.61
		2	2.39	0.708	2.34	0.34	0.58	0	43.2	1	13	1599	1599	F2	0.889	2611	0.61
[Weld Throat]			2.39	0.708	2.34	0.34	0.58	[Asw]=	0	1.25	13	0	*****	W	0.889	1883	NaN
SDK10307	2	1	10.06	0.66	2.315	0	0	0	13.8	1.5	0	1672	1672	F2	0.909	2514	0.67
		2	10.06	0.66	2.315	0	0	0	13.8	1	0	1672	1672	F2	0.909	2514	0.67
[Weld Throat]			10.06	0.66	2.315	0	0	[Asw]=	0	1.25	0	0	*****	W	0.909	1813	NaN

APPENDIX I

FATIGUE ANALYSIS SUMMARY FOR SHIP I

Table I.1 Phase A Fatigue Analysis of Longitudinals for Ship I

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midship
LxBxDxd = 194.00x 29.50x 21.60x 7.00(m)
Hull-Girder Moment of Inertia Ivert. 2449110.(cm2-m2) Ihoriz. 3991371.(cm2-m2)
Neutral Axis Height 9.06(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 100.00m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 286082.(tf-m) MW(horiz.) 208664.(tf-m)
******** "Net" Ship ******** Local Cf=0.95 Cw=0.75 Long Perm.

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
1	BTM10801	A/	1	0.08	522	2.42	1	1	1	1&2	3.95	1023	178	969	F2	0.867	2737	0.35	WT 265x33	IB Bhd01
		F/	3	0.08	522	2.42	1	1	1	1&2	3.95	1023	178	969	F2	0.867	2737	0.35		IB Bhd01
2	BTM10802	A/	1	0.16	522	2.42	1	1	1	1&2	3.95	1013	178	962	F2	0.867	2737	0.35	WT 265x33	IB Bhd02
		F/	3	0.16	522	2.42	1	1	1	1&2	3.95	1013	178	962	F2	0.867	2737	0.35		IB Bhd02
3	BTM10803	A/	1	0.24	522	2.42	1	1	1	1&2	3.94	1004	180	956	F2	0.867	2737	0.35	WT 265x33	IB Bhd03
		F/	3	0.24	522	2.42	1	1	1	1&2	3.94	1004	180	956	F2	0.867	2737	0.35		IB Bhd03
4	BLG10101	A/	1	0.67	317	2.3	1	1	1	1&2	3.92	960	293	1011	F2	0.867	2737	0.37	WT 205x23	Bilge 01
		F/	5	0.67	317	2.3	1	1	1	1&2	3.92	960	293	1011	F2	0.867	2737	0.37		Bilge 01
5	BLG10102	A/	1	1.28	317	2.3	1	1	1	1&2	3.89	888	304	963	F2	0.867	2737	0.35	WT 205x23	Bilge 02
		F/	5	1.28	317	2.3	1	1	1	1&2	3.89	888	304	963	F2	0.867	2737	0.35		Bilge 02
6	BLG10103	A/	1	1.88	318	2.5	1	1	1	1&2	3.86	817	355	946	F2	0.867	2737	0.35	WT 205x23	Bilge 03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	1.88	318	2.5	1	1	1	1&2	3.86	817	355	946	F2	0.867	2737	0.35		Bilge 03
7	BLG10104	A/	1	2.49	318	2.5	1	1	2	TZONE		789	391	1121	F2	0.867	2737	0.41	WT 205x23	Bilge 04
		F/	1	2.49	318	2.5	1	1	2	TZONE		789	391	1121	F2	0.867	2737	0.41		Bilge 04
8	SHL10101	A/	1	3.17	326	2.5	1	1	2	TZONE		834	433	1204	F2	0.885	2632	0.46	WT 205x23	Blg-3P01
		F/	1	3.17	326	2.5	1	1	2	TZONE		834	433	1204	F2	0.885	2632	0.46		Blg-3P01
9	SHL10102	A/	1	3.9	326	2.5	1	1	2	TZONE		866	529	1325	F2	0.899	2556	0.52	WT 205x23	Blg-3P02
		F/	1	3.9	326	2.5	1	1	2	TZONE		866	529	1325	F2	0.899	2556	0.52		Blg-3P02
10	SHL10203	A/	1	5.41	260	2.5	1	1	2	F1&F2	7.73	919	976	1800	F2	0.907	2524	0.71	WT 205x19.5	3P-2P 03
		F/	1	5.41	260	2.5	1	1	2	F1&F2	7.73	919	976	1800	F2	0.907	2524	0.71		3P-2P 03
11	SHL10204	A/	1	6.21	260	2.5	1	1	2	F1&F2	9.05	889	1143	1930	F2	0.907	2524	0.76	WT 205x19.5	3P-2P 04
		F/	1	6.21	260	2.5	1	1	2	F1&F2	9.05	889	1143	1930	F2	0.907	2524	0.76		3P-2P 04
12	SHL10205	A/	1	7.02	260	2.5	1	0.65	2	F1&F2	10.31	858	844	1617	F2	0.907	2524	0.64	WT 205x19.5	3P-2P 05
		F/	1	7.02	260	2.5	1	0.65	2	F1&F2	10.31	858	844	1617	F2	0.907	2524	0.64		3P-2P 05
13	SHL10206	A/	1	7.83	260	2.5	1	0.42	2	F1&F2	9.47	828	501	1263	F2	0.907	2524	0.5	WT 205x19.5	3P-2P 06
		F/	1	7.83	260	2.5	1	0.42	2	F1&F2	9.47	828	501	1263	F2	0.907	2524	0.5		3P-2P 06
14	SHL10307	A/	1	8.41	199	2.5	1	0.31	2	F1&F2	8.85	807	348	1097	F2	0.907	2524	0.43	WT 180x16.5	2P-1P 07
		F/	1	8.41	199	2.5	1	0.31	2	F1&F2	8.85	807	348	1097	F2	0.907	2524	0.43		2P-1P 07
15	SHL10308	A/	1	9.02	199	2.5	1	0.3	2	F1&F2	8.21	784	307	1037	F2	0.907	2524	0.41	WT 180x16.5	2P-1P 08
		F/	1	9.02	199	2.5	1	0.3	2	F1&F2	8.21	784	307	1037	F2	0.907	2524	0.41		2P-1P 08
16	SHL10309	A/	1	9.63	180	2.5	1	0.3	2	F1&F2	7.57	814	313	1071	F2	0.907	2524	0.42	WT 180x16.5	2P-1P 09
		F/	1	9.63	180	2.5	1	0.3	2	F1&F2	7.57	814	313	1071	F2	0.907	2524	0.42		2P-1P 09
17	SHL10310	A/	1	10.25	180	2.5	1	0.3	2	F1&F2	6.92	848	273	1065	F2	0.907	2524	0.42	WT 180x16.5	2P-1P 10
		F/	1	10.25	180	2.5	1	0.3	2	F1&F2	6.92	848	273	1065	F2	0.907	2524	0.42		2P-1P 10
18	SHL10411	A/	1	11.51	153	2.5	1	0.3	1	F1&F2	5.32	920	303	1162	F2	0.907	2524	0.46	WT 155x14	1P-3D 11
		F/	1	11.51	153	2.5	1	0.3	1	F1&F2	5.32	920	303	1162	F2	0.907	2524	0.46		1P-3D 11
19	SHL10412	A/	1	12.23	153	2.5	1	0.3	1	F1&F2	4.6	960	262	1161	F2	0.907	2524	0.46	WT 155x14	1P-3D 12
		F/	1	12.23	153	2.5	1	0.3	1	F1&F2	4.6	960	262	1161	F2	0.907	2524	0.46		1P-3D 12
20	SHL10413	A/	1	12.94	153	2.5	1	0.3	1	F1&F2	3.89	1000	212	1152	F2	0.907	2524	0.46	WT 155x14	1P-3D 13
		F/	1	12.94	153	2.5	1	0.3	1	F1&F2	3.89	1000	212	1152	F2	0.907	2524	0.46		1P-3D 13

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
21	SHL10514	A/	1	14.27	153	2.5	1	0.3	1	F1&F2	2.56	1063	136	1138	F2	0.907	2524	0.45	WT 155x14	3D-2D 14
		F/	1	14.27	153	2.5	1	0.3	1	F1&F2	2.56	1063	136	1138	F2	0.907	2524	0.45		3D-2D 14
22	SHL10515	A/	1	14.93	153	2.5	1	0.3	1	F1&F2	1.9	1088	100	1129	F2	0.907	2524	0.45	WT 155x14	3D-2D 15
		F/	1	14.93	153	2.5	1	0.3	1	F1&F2	1.9	1088	100	1129	F2	0.907	2524	0.45		3D-2D 15
23	SHL10516	A/	1	15.6	153	2.5	1	0.3	1	F1&F2	1.23	1114	62	1117	F2	0.907	2524	0.44	WT 155x14	3D-2D 16
		F/	1	15.6	153	2.5	1	0.3	1	F1&F2	1.23	1114	62	1117	F2	0.907	2524	0.44		3D-2D 16
24	SHL10617	A/	1	16.91	205	2.5	1	0.3	1	TZONE		1110	0	1054	F2	0.889	2611	0.4	WT 180x16.5	2D-She17
		F/	1	16.91	205	2.5	1	0.3	1	TZONE		1110	0	1054	F2	0.889	2611	0.4		2D-She17
25	SHL10618	A/	1	17.63	205	2.5	1	0.3	1	TZONE		1108	0	1053	F2	0.871	2711	0.39	WT 180x16.5	2D-She18
		F/	1	17.63	205	2.5	1	0.3	1	TZONE		1108	0	1053	F2	0.871	2711	0.39		2D-She18
26	SHL10619	A/	1	18.34	205	2.5	1	0.3	1	TZONE		1132	0	1075	F2	0.854	2810	0.38	WT 180x16.5	2D-She19
		F/	1	18.34	205	2.5	1	0.3	1	TZONE		1132	0	1075	F2	0.854	2810	0.38		2D-She19
27	SHS10201	A/	1	19.67	280	2.5	1	1	1	1&2	0	1243	0	1181	F2	0.826	2962	0.4	WT 205x19.5	MD-01 01
		F/	1	19.67	280	2.5	1	1	1	1&2	0	1243	0	1181	F2	0.826	2962	0.4		MD-01 01
28	SHS10202	A/	1	20.34	280	2.5	1	1	1	1&2	0	1322	0	1256	F2	0.826	2962	0.42	WT 205x19.5	MD-01 02
		F/	1	20.34	280	2.5	1	1	1	1&2	0	1322	0	1256	F2	0.826	2962	0.42		MD-01 02
29	SHS10203	A/	1	21.01	280	2.5	1	1	1	1&2	0	1400	0	1330	F2	0.826	2962	0.45	WT 205x19.5	MD-01 03
		F/	1	21.01	280	2.5	1	1	1	1&2	0	1400	0	1330	F2	0.826	2962	0.45		MD-01 03
30	DEC10101	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String01
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String01
31	DEC10102	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String02
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String02
32	DEC10103	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String03
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String03
33	DEC10104	A/	1	21.6	279	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String04
		F/	3	21.6	279	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String04
34	DEC10105	A/	1	21.6	279	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String05
		F/	3	21.6	279	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String05
35	DEC10106	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String06
36	DEC10107	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String07
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String07
37	DEC10108	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	String08
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		String08
38	DEC10209	A/	1	21.6	279	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Lvl09
		F/	3	21.6	279	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Lvl09
39	DEC10310	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef10
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef10
40	DEC10311	A/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef11
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef11
41	DEC10412	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb12
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb12
42	DEC10413	A/	1	21.6	267	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb13
		F/	3	21.6	267	2.42	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb13
43	DEC10414	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb14
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb14
44	DEC10415	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb15
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb15
45	DEC10416	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb16
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb16
46	DEC10417	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb17
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb17
47	DEC10418	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01 Inb18
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01 Inb18
48	DEC10519	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef19
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef19
49	DEC10520	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef20
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef20

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		fR	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
50	DEC10521	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef21
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef21
51	DEC10522	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef22
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef22
52	DEC10523	A/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46	WT 205x19.5	01Inef23
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1446	0	1374	F2	0.826	2962	0.46		01Inef23
53	WTF31501	A/	1	13.6	78	2.5	1	1	1	F1&F2	0	804	0	764	F2	0.826	2962	0.26	WT 155x10.5	3DInef01
		F/	1	13.6	78	2.5	1	1	1	F1&F2	0	804	0	764	F2	0.826	2962	0.26		3DInef01
54	WTF31502	A/	1	13.6	78	2.5	1	1	1	F1&F2	0	835	0	794	F2	0.826	2962	0.27	WT 155x10.5	3DInef02
		F/	1	13.6	78	2.5	1	1	1	F1&F2	0	835	0	794	F2	0.826	2962	0.27		3DInef02
55	WTF31503	A/	1	13.6	78	2.5	1	1	1	F1&F2	0	867	0	823	F2	0.826	2962	0.28	WT 155x10.5	3DInef03
		F/	1	13.6	78	2.5	1	1	1	F1&F2	0	867	0	823	F2	0.826	2962	0.28		3DInef03
56	WTF31604	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	898	0	853	F2	0.826	2962	0.29	WT 155x10.5	3DOtbd04
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	898	0	853	F2	0.826	2962	0.29		3DOtbd04
57	WTF31605	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	930	0	883	F2	0.826	2962	0.3	WT 155x10.5	3DOtbd05
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	930	0	883	F2	0.826	2962	0.3		3DOtbd05
58	WTF31606	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	961	0	913	F2	0.826	2962	0.31	WT 155x10.5	3DOtbd06
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	961	0	913	F2	0.826	2962	0.31		3DOtbd06
59	WTF31607	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	992	0	943	F2	0.826	2962	0.32	WT 155x10.5	3DOtbd07
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	992	0	943	F2	0.826	2962	0.32		3DOtbd07
60	WTF31608	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	1024	0	973	F2	0.826	2962	0.33	WT 155x10.5	3DOtbd08
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	1024	0	973	F2	0.826	2962	0.33		3DOtbd08
61	WTF41701	A/	1	15.2	2433	2.5	1	1	1	7&8	0	288	0	273	F2	0.826	2962	0.09	W/T 549x184	2DInef01
		F/	1	15.2	2433	2.5	1	1	1	7&8	0	288	0	273	F2	0.826	2962	0.09		2DInef01
62	WTF41702	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	319	0	303	F2	0.826	2962	0.1	WT 180x16.5	2DInef02
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	319	0	303	F2	0.826	2962	0.1		2DInef02
63	WTF41703	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	351	0	333	F2	0.826	2962	0.11	WT 180x16.5	2DInef03
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	351	0	333	F2	0.826	2962	0.11		2DInef03
64	WTF41704	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	382	0	363	F2	0.826	2962	0.12	WT 180x16.5	2DInef04

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	382	0	363	F2	0.826	2962	0.12		2DInef04
65	WTF41705	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	413	0	393	F2	0.826	2962	0.13	WT 180x16.5	2DInef05
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	413	0	393	F2	0.826	2962	0.13		2DInef05
66	WTF41706	A/	1	15.2	176	2.4	1	1	1	F1&F2	0	445	0	423	F2	0.826	2962	0.14	WT 180x16.5	2DInef06
		F/	4	15.2	176	2.4	1	1	1	F1&F2	0	445	0	423	F2	0.826	2962	0.14		2DInef06
67	WTF41807	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	476	0	452	F2	0.826	2962	0.15	WT 180x16.5	2DInef07
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	476	0	452	F2	0.826	2962	0.15		2DInef07
68	WTF41808	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	508	0	482	F2	0.826	2962	0.16	WT 180x16.5	2DInef08
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	508	0	482	F2	0.826	2962	0.16		2DInef08
69	WTF41809	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	539	0	512	F2	0.826	2962	0.17	WT 180x16.5	2DInef09
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	539	0	512	F2	0.826	2962	0.17		2DInef09
70	WTF41810	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	570	0	542	F2	0.826	2962	0.18	WT 180x16.5	2DInef10
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	570	0	542	F2	0.826	2962	0.18		2DInef10
71	WTF41811	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	602	0	572	F2	0.826	2962	0.19	WT 180x16.5	2DInef11
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	602	0	572	F2	0.826	2962	0.19		2DInef11
72	WTF41812	A/	1	15.2	176	2.4	1	1	1	F1&F2	0	633	0	601	F2	0.826	2962	0.2	WT 180x16.5	2DInef12
		F/	4	15.2	176	2.4	1	1	1	F1&F2	0	633	0	601	F2	0.826	2962	0.2		2DInef12
73	WTF41913	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	659	0	626	F2	0.826	2962	0.21	WT 180x16.5	2DInbd13
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	659	0	626	F2	0.826	2962	0.21		2DInbd13
74	WTF41914	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	691	0	656	F2	0.826	2962	0.22	WT 180x16.5	2DInbd14
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	691	0	656	F2	0.826	2962	0.22		2DInbd14
75	WTF41915	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	722	0	686	F2	0.826	2962	0.23	WT 180x16.5	2DInbd15
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	722	0	686	F2	0.826	2962	0.23		2DInbd15
76	WTF41916	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	753	0	716	F2	0.826	2962	0.24	WT 180x16.5	2DInbd16
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	753	0	716	F2	0.826	2962	0.24		2DInbd16
77	WTF52101	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	863	0	820	F2	0.826	2962	0.28	WT 155x10.5	2DInne01
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	863	0	820	F2	0.826	2962	0.28		2DInne01
78	WTF52102	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	895	0	850	F2	0.826	2962	0.29	WT 155x10.5	2DInne02
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	895	0	850	F2	0.826	2962	0.29		2DInne02

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
79	WTF52203	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	926	0	880	F2	0.826	2962	0.3	WT 155x10.5	2DOtbd03
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	926	0	880	F2	0.826	2962	0.3		2DOtbd03
80	WTF52204	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	957	0	909	F2	0.826	2962	0.31	WT 155x10.5	2DOtbd04
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	957	0	909	F2	0.826	2962	0.31		2DOtbd04
81	WTF52205	A/	1	16.2	79	2.42	1	1	1	F1&F2	0	989	0	939	F2	0.826	2962	0.32	WT 155x10.5	2DOtbd05
		F/	3	16.2	79	2.42	1	1	1	F1&F2	0	989	0	939	F2	0.826	2962	0.32		2DOtbd05
82	WTF52206	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1020	0	969	F2	0.826	2962	0.33	WT 155x10.5	2DOtbd06
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1020	0	969	F2	0.826	2962	0.33		2DOtbd06
83	WTF52207	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1051	0	999	F2	0.826	2962	0.34	WT 155x10.5	2DOtbd07
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1051	0	999	F2	0.826	2962	0.34		2DOtbd07
84	WTF52208	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1083	0	1029	F2	0.826	2962	0.35	WT 155x10.5	2DOtbd08
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1083	0	1029	F2	0.826	2962	0.35		2DOtbd08
85	WTF52209	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1114	0	1059	F2	0.826	2962	0.36	WT 155x10.5	2DOtbd09
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1114	0	1059	F2	0.826	2962	0.36		2DOtbd09
86	INS10101	A/	1	0.6	341	2.5	1	1	1	1&2	0.52	991	36	976	F2	0.867	2737	0.36	WT 205x23	IBS-IB01
		F/	1	0.6	341	2.5	1	1	1	1&2	0.52	991	36	976	F2	0.867	2737	0.36		IBS-IB01
87	INS10202	A/	1	1.88	326	2.5	1	1	1	1&2	0.49	841	41	838	F2	0.867	2737	0.31	WT 205x23	IbIB-302
		F/	1	1.88	326	2.5	1	1	1	1&2	0.49	841	41	838	F2	0.867	2737	0.31		IbIB-302
88	INS10203	A/	1	2.56	326	2.5	1	1	2	TZONE		771	37	767	F2	0.874	2696	0.28	WT 205x23	IbIB-303
		F/	1	2.56	326	2.5	1	1	2	TZONE		771	37	767	F2	0.874	2696	0.28		IbIB-303
89	INS10204	A/	1	3.24	326	2.5	1	1	2	TZONE		731	32	725	F2	0.887	2625	0.28	WT 205x23	IbIB-304
		F/	1	3.24	326	2.5	1	1	2	TZONE		731	32	725	F2	0.887	2625	0.28		IbIB-304
90	INS10205	A/	1	3.92	326	2.5	1	1	1	TZONE		721	30	714	F2	0.899	2554	0.28	WT 205x23	IbIB-305
		F/	1	3.92	326	2.5	1	1	1	TZONE		721	30	714	F2	0.899	2554	0.28		IbIB-305
91	INS10406	A/	1	5.24	260	2.5	1	1	1	F1&F2	0.44	686	44	693	F2	0.907	2524	0.27	WT 205x19.5	Ib3P2P06
		F/	1	5.24	260	2.5	1	1	1	F1&F2	0.44	686	44	693	F2	0.907	2524	0.27		Ib3P2P06
92	INS10507	A/	1	5.88	255	2.5	1	1	1	F1&F2	0.48	656	48	669	F2	0.907	2524	0.27	WT 205x19.5	Ib3P2P07
		F/	1	5.88	255	2.5	1	1	1	F1&F2	0.48	656	48	669	F2	0.907	2524	0.27		Ib3P2P07
93	INS10608	A/	1	6.52	255	2.5	1	1	1	F1&F2	0.52	626	52	645	F2	0.907	2524	0.26	WT 205x19.5	Ib3P2P08

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	6.52	255	2.5	1	1	1	F1&F2	0.52	626	52	645	F2	0.907	2524	0.26		Ib3P2P08
94	INS10609	A/	1	7.16	255	2.5	1	1	1	F1&F2	0.56	596	56	620	F2	0.907	2524	0.25	WT 205x19.5	Ib3P2P09
		F/	1	7.16	255	2.5	1	1	1	F1&F2	0.56	596	56	620	F2	0.907	2524	0.25		Ib3P2P09
95	INS10710	A/	1	8.4	191	2.5	1	1	1	F1&F2	0.63	537	79	586	F2	0.907	2524	0.23	WT 180x16.5	Ib2P1P10
		F/	1	8.4	191	2.5	1	1	1	F1&F2	0.63	537	79	586	F2	0.907	2524	0.23		Ib2P1P10
96	INS10811	A/	1	9	191	2.5	1	1	1	F1&F2	0.67	509	84	563	F2	0.907	2524	0.22	WT 180x16.5	Ib2P1P11
		F/	1	9	191	2.5	1	1	1	F1&F2	0.67	509	84	563	F2	0.907	2524	0.22		Ib2P1P11
97	INS10912	A/	1	9.6	173	2.5	1	1	1	F1&F2	0.7	532	98	598	F2	0.907	2524	0.24	WT 180x16.5	Ib2P1P12
		F/	1	9.6	173	2.5	1	1	1	F1&F2	0.7	532	98	598	F2	0.907	2524	0.24		Ib2P1P12
98	INS10913	A/	1	10.2	173	2.5	1	1	1	F1&F2	0.74	560	103	629	F2	0.907	2524	0.25	WT 180x16.5	Ib2P1P13
		F/	1	10.2	173	2.5	1	1	1	F1&F2	0.74	560	103	629	F2	0.907	2524	0.25		Ib2P1P13
99	INS11014	A/	1	11.36	98	2.5	1	1	1	F1&F2	0	613	0	582	F2	0.907	2524	0.23	WT 155x10.5	Ib1P3D14
		F/	1	11.36	98	2.5	1	1	1	F1&F2	0	613	0	582	F2	0.907	2524	0.23		Ib1P3D14
100	INS11015	A/	1	11.92	98	2.5	1	1	1	F1&F2	0	639	0	607	F2	0.907	2524	0.24	WT 155x10.5	Ib1P3D15
		F/	1	11.92	98	2.5	1	1	1	F1&F2	0	639	0	607	F2	0.907	2524	0.24		Ib1P3D15
101	INS11116	A/	1	12.48	98	2.5	1	1	1	F1&F2	0	665	0	632	F2	0.907	2524	0.25	WT 155x10.5	Ib1P3D16
		F/	1	12.48	98	2.5	1	1	1	F1&F2	0	665	0	632	F2	0.907	2524	0.25		Ib1P3D16
102	INS11117	A/	1	13.04	98	2.5	1	1	1	F1&F2	0	692	0	657	F2	0.907	2524	0.26	WT 155x10.5	Ib1P3D17
		F/	1	13.04	98	2.5	1	1	1	F1&F2	0	692	0	657	F2	0.907	2524	0.26		Ib1P3D17
103	INS11218	A/	1	14.14	98	2.5	1	1	1	F1&F2	0	743	0	706	F2	0.907	2524	0.28	WT 155x10.5	IB3D2D18
		F/	1	14.14	98	2.5	1	1	1	F1&F2	0	743	0	706	F2	0.907	2524	0.28		IB3D2D18
104	INS11219	A/	1	14.67	98	2.5	1	1	1	F1&F2	0	768	0	730	F2	0.907	2524	0.29	WT 155x10.5	IB3D2D19
		F/	1	14.67	98	2.5	1	1	1	F1&F2	0	768	0	730	F2	0.907	2524	0.29		IB3D2D19
105	INS11320	A/	1	15.7	98	2.5	1	1	1	F1&F2	0	816	0	775	F2	0.907	2524	0.31	WT 155x10.5	Ib2D2D20
		F/	1	15.7	98	2.5	1	1	1	F1&F2	0	816	0	775	F2	0.907	2524	0.31		Ib2D2D20
106	INS11421	A/	1	16.76	98	2.5	1	1	1	TZONE		872	0	829	F2	0.893	2590	0.32	WT 155x10.5	Ib2DMD21
		F/	1	16.76	98	2.5	1	1	1	TZONE		872	0	829	F2	0.893	2590	0.32		Ib2DMD21
107	INS11422	A/	1	17.32	98	2.5	1	1	1	TZONE		918	0	872	F2	0.879	2668	0.33	WT 155x10.5	Ib2DMD22
		F/	1	17.32	98	2.5	1	1	1	TZONE		918	0	872	F2	0.879	2668	0.33		Ib2DMD22

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
108	INS11423	A/	1	17.88	98	2.5	1	1	1	TZONE		978	0	929	F2	0.865	2746	0.34	WT 155x10.5	Ib2DMD23
		F/	1	17.88	98	2.5	1	1	1	TZONE		978	0	929	F2	0.865	2746	0.34		Ib2DMD23
109	INS11424	A/	1	18.44	98	2.5	1	1	1	TZONE		1052	0	999	F2	0.851	2823	0.35	WT 155x10.5	Ib2DMD24
		F/	1	18.44	98	2.5	1	1	1	TZONE		1052	0	999	F2	0.851	2823	0.35		Ib2DMD24
110	INS21601	A/	1	19.67	281	2.5	1	1	1	1&2	0	1243	0	1181	F2	0.826	2962	0.4	WT 205x19.5	IbMD0101
		F/	1	19.67	281	2.5	1	1	1	1&2	0	1243	0	1181	F2	0.826	2962	0.4		IbMD0101
111	INS21602	A/	1	20.32	281	2.5	1	1	1	1&2	0	1319	0	1253	F2	0.826	2962	0.42	WT 205x19.5	IbMD0102
		F/	1	20.32	281	2.5	1	1	1	1&2	0	1319	0	1253	F2	0.826	2962	0.42		IbMD0102
112	INS21703	A/	1	20.95	281	2.5	1	1	1	1&2	0	1393	0	1324	F2	0.826	2962	0.45	WT 205x19.5	IbMD0103
		F/	1	20.95	281	2.5	1	1	1	1&2	0	1393	0	1324	F2	0.826	2962	0.45		IbMD0103
113	INS31801	A/	1	1.2	345	2.5	1	1	1	1&2	0	921	0	875	F2	0.867	2737	0.32	WT 205x23	Ob Bhd01
		F/	1	1.2	345	2.5	1	1	1	1&2	0	921	0	875	F2	0.867	2737	0.32		Ob Bhd01
114	INS31902	A/	1	1.88	337	2.5	1	1	1	1&2	0	841	0	799	F2	0.867	2737	0.29	WT 205x23	Ob Bhd02
		F/	1	1.88	337	2.5	1	1	1	1&2	0	841	0	799	F2	0.867	2737	0.29		Ob Bhd02
115	INS31903	A/	1	2.56	337	2.5	1	1	1	TZONE		795	11	766	F2	0.874	2696	0.28	WT 205x23	Ob Bhd03
		F/	1	2.56	337	2.5	1	1	1	TZONE		795	11	766	F2	0.874	2696	0.28		Ob Bhd03
116	INS31904	A/	1	3.24	337	2.5	1	1	1	TZONE		796	31	786	F2	0.887	2625	0.3	WT 205x23	Ob Bhd04
		F/	1	3.24	337	2.5	1	1	1	TZONE		796	31	786	F2	0.887	2625	0.3		Ob Bhd04
117	INS31905	A/	1	3.92	337	2.5	1	1	1	TZONE		828	50	834	F2	0.899	2554	0.33	WT 205x23	Ob Bhd05
		F/	1	3.92	337	2.5	1	1	1	TZONE		828	50	834	F2	0.899	2554	0.33		Ob Bhd05
118	INS32006	A/	1	5.24	264	2.5	1	1	1	F1&F2	0.74	817	72	845	F2	0.907	2524	0.33	WT 205x19.5	OB3P2P06
		F/	1	5.24	264	2.5	1	1	1	F1&F2	0.74	817	72	845	F2	0.907	2524	0.33		OB3P2P06
119	INS32007	A/	1	5.88	264	2.5	1	1	1	F1&F2	0.73	787	71	815	F2	0.907	2524	0.32	WT 205x19.5	OB3P2P07
		F/	1	5.88	264	2.5	1	1	1	F1&F2	0.73	787	71	815	F2	0.907	2524	0.32		OB3P2P07
120	INS32008	A/	1	6.52	264	2.5	1	1	1	F1&F2	0.72	757	70	786	F2	0.907	2524	0.31	WT 205x19.5	OB3P2P08
		F/	1	6.52	264	2.5	1	1	1	F1&F2	0.72	757	70	786	F2	0.907	2524	0.31		OB3P2P08
121	INS32009	A/	1	7.16	264	2.5	1	1	1	F1&F2	0.72	727	70	757	F2	0.907	2524	0.3	WT 205x19.5	OB3P2P09
		F/	1	7.16	264	2.5	1	1	1	F1&F2	0.72	727	70	757	F2	0.907	2524	0.3		OB3P2P09
122	INS32110	A/	1	8.4	199	2.5	1	1	1	F1&F2	0.7	668	84	714	F2	0.907	2524	0.28	WT 180x16.5	OB2P1P10

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	8.4	199	2.5	1	1	1	F1&F2	0.7	668	84	714	F2	0.907	2524	0.28		OB2P1P10
123	INS32111	A/	1	9	199	2.5	1	1	1	F1&F2	0.69	640	83	687	F2	0.907	2524	0.27	WT 180x16.5	OB2P1P11
		F/	1	9	199	2.5	1	1	1	F1&F2	0.69	640	83	687	F2	0.907	2524	0.27		OB2P1P11
124	INS32112	A/	1	9.6	180	2.5	1	1	1	F1&F2	0.68	662	91	715	F2	0.907	2524	0.28	WT 180x16.5	OB2P1P12
		F/	1	9.6	180	2.5	1	1	1	F1&F2	0.68	662	91	715	F2	0.907	2524	0.28		OB2P1P12
125	INS32113	A/	1	10.2	180	2.5	1	1	1	F1&F2	0.67	690	89	741	F2	0.907	2524	0.29	WT 180x16.5	OB2P1P13
		F/	1	10.2	180	2.5	1	1	1	F1&F2	0.67	690	89	741	F2	0.907	2524	0.29		OB2P1P13
126	SDK10101	A/	1	19	104	2.5	1	1	1	TZONE		1172	0	1113	F2	0.837	2901	0.38	WT 155x10.5	MD Otb01
		F/	1	19	104	2.5	1	1	1	TZONE		1172	0	1113	F2	0.837	2901	0.38		MD Otb01
127	SDK10102	A/	1	19	104	2.5	1	1	1	TZONE		1167	0	1109	F2	0.837	2901	0.38	WT 155x10.5	MD Otb02
		F/	1	19	104	2.5	1	1	1	TZONE		1167	0	1109	F2	0.837	2901	0.38		MD Otb02
128	SDK10203	A/	1	19	102	2.5	1	1	1	TZONE		1163	0	1105	F2	0.837	2901	0.38	WT 155x10.5	MD Otb03
		F/	1	19	102	2.5	1	1	1	TZONE		1163	0	1105	F2	0.837	2901	0.38		MD Otb03
129	SDK10204	A/	1	19	102	2.42	1	1	1	TZONE		1159	0	1101	F2	0.837	2901	0.38	WT 155x10.5	MD Otb04
		F/	3	19	102	2.42	1	1	1	TZONE		1159	0	1101	F2	0.837	2901	0.38		MD Otb04
130	SDK10205	A/	1	19	102	2.5	1	1	1	TZONE		1154	0	1096	F2	0.837	2901	0.38	WT 155x10.5	MD Otb05
		F/	1	19	102	2.5	1	1	1	TZONE		1154	0	1096	F2	0.837	2901	0.38		MD Otb05
131	SDK10206	A/	1	19	102	2.5	1	1	1	TZONE		1150	0	1092	F2	0.837	2901	0.38	WT 155x10.5	MD Otb06
		F/	1	19	102	2.5	1	1	1	TZONE		1150	0	1092	F2	0.837	2901	0.38		MD Otb06
132	SDK10207	A/	1	19	102	2.5	1	1	1	TZONE		1145	0	1088	F2	0.837	2901	0.37	WT 155x10.5	MD Otb07
		F/	1	19	102	2.5	1	1	1	TZONE		1145	0	1088	F2	0.837	2901	0.37		MD Otb07
133	SDK10208	A/	1	19	102	2.5	1	1	1	TZONE		1140	0	1083	F2	0.837	2901	0.37	WT 155x10.5	MD Otb08
		F/	1	19	102	2.5	1	1	1	TZONE		1140	0	1083	F2	0.837	2901	0.37		MD Otb08
134	SDK10309	A/	1	19	102	2.42	1	1	1	TZONE		1134	0	1077	F2	0.837	2901	0.37	WT 155x10.5	MD Inb09
		F/	3	19	102	2.42	1	1	1	TZONE		1134	0	1077	F2	0.837	2901	0.37		MD Inb09
135	SDK10310	A/	1	19	102	2.5	1	1	1	TZONE		1130	0	1073	F2	0.837	2901	0.37	WT 155x10.5	MD Inb10
		F/	1	19	102	2.5	1	1	1	TZONE		1130	0	1073	F2	0.837	2901	0.37		MD Inb10
136	SDK10311	A/	1	19	102	2.5	1	1	1	TZONE		1125	0	1069	F2	0.837	2901	0.37	WT 155x10.5	MD Inb11
		F/	1	19	102	2.5	1	1	1	TZONE		1125	0	1069	F2	0.837	2901	0.37		MD Inb11

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup. Span (m)	Ct	Cy	LP #	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG. CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
137	SDK10312	A/	1	19	102	2.5	1	1	1	TZONE		1121	0	1065	F2	0.837	2901	0.37	WT 155x10.5	MD Inb12
		F/	1	19	102	2.5	1	1	1	TZONE		1121	0	1065	F2	0.837	2901	0.37		MD Inb12
138	SDK10313	A/	1	19	102	2.42	1	1	1	TZONE		1117	0	1061	F2	0.837	2901	0.37	WT 155x10.5	MD Inb13
		F/	3	19	102	2.42	1	1	1	TZONE		1117	0	1061	F2	0.837	2901	0.37		MD Inb13
139	SDK10314	A/	1	19	102	2.5	1	1	1	TZONE		1113	0	1057	F2	0.837	2901	0.36	WT 155x10.5	MD Inb14
		F/	1	19	102	2.5	1	1	1	TZONE		1113	0	1057	F2	0.837	2901	0.36		MD Inb14
140	SDK10315	A/	1	19	102	2.5	1	1	1	TZONE		1108	0	1053	F2	0.837	2901	0.36	WT 155x10.5	MD Inb15
		F/	1	19	102	2.5	1	1	1	TZONE		1108	0	1053	F2	0.837	2901	0.36		MD Inb15
141	SDK10316	A/	1	19	102	2.5	1	1	1	TZONE		1104	0	1049	F2	0.837	2901	0.36	WT 155x10.5	MD Inb16
		F/	1	19	102	2.5	1	1	1	TZONE		1104	0	1049	F2	0.837	2901	0.36		MD Inb16
142	SDK10317	A/	1	19	102	2.5	1	1	1	TZONE		1100	0	1045	F2	0.837	2901	0.36	WT 155x10.5	MD Inb17
		F/	1	19	102	2.5	1	1	1	TZONE		1100	0	1045	F2	0.837	2901	0.36		MD Inb17
143	SDK10418	A/	1	19	102	2.5	1	1	1	TZONE		1096	0	1041	F2	0.837	2901	0.36	WT 155x10.5	MD Inn18
		F/	1	19	102	2.5	1	1	1	TZONE		1096	0	1041	F2	0.837	2901	0.36		MD Inn18
144	SDK10519	A/	1	19	102	2.42	1	1	1	TZONE		1091	0	1037	F2	0.837	2901	0.36	WT 155x10.5	MD Inb19
		F/	3	19	102	2.42	1	1	1	TZONE		1091	0	1037	F2	0.837	2901	0.36		MD Inb19
145	SDK10520	A/	1	19	102	2.5	1	1	1	TZONE		1087	0	1033	F2	0.837	2901	0.36	WT 155x10.5	MD Inb20
		F/	1	19	102	2.5	1	1	1	TZONE		1087	0	1033	F2	0.837	2901	0.36		MD Inb20
146	SDK10521	A/	1	19	102	2.5	1	1	1	TZONE		1083	0	1029	F2	0.837	2901	0.35	WT 155x10.5	MD Inb21
		F/	1	19	102	2.5	1	1	1	TZONE		1083	0	1029	F2	0.837	2901	0.35		MD Inb21
147	SDK10522	A/	1	19	102	2.5	1	1	1	TZONE		1079	0	1025	F2	0.837	2901	0.35	WT 155x10.5	MD Inb22
		F/	1	19	102	2.5	1	1	1	TZONE		1079	0	1025	F2	0.837	2901	0.35		MD Inb22
148	SDK10523	A/	1	19	102	2.5	1	1	1	TZONE		1074	0	1021	F2	0.837	2901	0.35	WT 155x10.5	MD Inb23
		F/	1	19	102	2.5	1	1	1	TZONE		1074	0	1021	F2	0.837	2901	0.35		MD Inb23
149	SDK10524	A/	1	19	1914	2.5	1	1	1	TZONE		1070	0	1016	F2	0.837	2901	0.35	W/T 424x165	MD Inb24
		F/	1	19	1914	2.5	1	1	1	TZONE		1070	0	1016	F2	0.837	2901	0.35		MD Inb24

Table I.2 Phase A Fatigue Analysis of Flat Bars for Ship I

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midship
LxBxDxd = 194.00x 29.50x 21.60x 7.00(m)
Hull-Girder Moment of Inertia Ivert. 2449110.(cm2-m2) Ihoriz. 3991371.(cm2-m2)
Neutral Axis Height 9.06(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 100.00m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 286082.(tf-m) MW(horiz.) 208664.(tf-m)

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2)	Ac (cm^2)		fs	fL	fRi				
BTM10801	1	1	0.08	0.625	2.42	3.95	6.13	0	90.9	1.5	64	966	971	F2	0.867	2737	0.35
		2	0.08	0.625	2.42	3.95	6.13	0	90.9	1	64	966	969	F2	0.867	2737	0.35
[Weld Throat]			0.08	0.625	2.42	3.95	6.13	[Asw]=	0	1.25	64	0	*****	W	0.867	1970	NaN
BTM10802	1	1	0.16	0.625	2.42	3.95	6.12	0	90.9	1.5	64	959	964	F2	0.867	2737	0.35
		2	0.16	0.625	2.42	3.95	6.12	0	90.9	1	64	959	961	F2	0.867	2737	0.35
[Weld Throat]			0.16	0.625	2.42	3.95	6.12	[Asw]=	0	1.25	64	0	*****	W	0.867	1970	NaN
BTM10803	1	1	0.24	0.635	2.42	3.94	6.21	0	90.9	1.5	65	954	959	F2	0.867	2737	0.35
		2	0.24	0.635	2.42	3.94	6.21	0	90.9	1	65	954	956	F2	0.867	2737	0.35
[Weld Throat]			0.24	0.635	2.42	3.94	6.21	[Asw]=	0	1.25	65	0	*****	W	0.867	1970	NaN
BLG10101	1	1	0.67	0.698	2.3	3.92	6.45	0	48.4	1.5	127	1009	1027	F2	0.867	2737	0.38
		2	0.67	0.698	2.3	3.92	6.45	0	48.4	1	127	1009	1017	F2	0.867	2737	0.37
[Weld Throat]			0.67	0.698	2.3	3.92	6.45	[Asw]=	0	1.25	127	0	*****	W	0.867	1970	NaN
BLG10102	1	1	1.28	0.73	2.3	3.89	6.69	0	48.4	1.5	131	960	980	F2	0.867	2737	0.36

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
		2	1.28	0.73	2.3	3.89	6.69	0	48.4	1	131	960	969	F2	0.867	2737	0.35
[Weld Throat]			1.28	0.73	2.3	3.89	6.69	[Asw]=	0	1.25	131	0	*****	W	0.867	1970	NaN
DEC10104	2	1	21.6	0.557	2.42	0	0	0	12.2	1.5	0	1375	1375	F2	0.826	2962	0.46
		2	21.6	0.557	2.42	0	0	0	12.2	1	0	1375	1375	F2	0.826	2962	0.46
[Weld Throat]			21.6	0.557	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10105	2	1	21.6	0.557	2.42	0	0	0	12.2	1.5	0	1375	1375	F2	0.826	2962	0.46
		2	21.6	0.557	2.42	0	0	0	12.2	1	0	1375	1375	F2	0.826	2962	0.46
[Weld Throat]			21.6	0.557	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10209	2	1	21.6	0.565	2.42	0	0	0	23.3	1.5	0	1370	1370	F2	0.826	2962	0.46
		2	21.6	0.565	2.42	0	0	0	23.3	1	0	1370	1370	F2	0.826	2962	0.46
[Weld Throat]			21.6	0.565	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10414	2	1	21.6	0.6	2.42	0	0	0	23.3	1.5	0	1370	1370	F2	0.826	2962	0.46
		2	21.6	0.6	2.42	0	0	0	23.3	1	0	1370	1370	F2	0.826	2962	0.46
[Weld Throat]			21.6	0.6	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10519	2	1	21.6	0.61	2.42	0	0	0	23.3	1.5	0	1370	1370	F2	0.826	2962	0.46
		2	21.6	0.61	2.42	0	0	0	23.3	1	0	1370	1370	F2	0.826	2962	0.46
[Weld Throat]			21.6	0.61	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
SDK10204	2	1	19	0.64	2.42	0	0	0	18.4	1.5	0	1098	1098	F2	0.837	2901	0.38
		2	19	0.64	2.42	0	0	0	18.4	1	0	1098	1098	F2	0.837	2901	0.38
[Weld Throat]			19	0.64	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.837	2084	NaN
SDK10314	2	1	19	0.6	2.42	0	0	0	16.2	1.5	0	1054	1054	F2	0.837	2901	0.36
		2	19	0.6	2.42	0	0	0	16.2	1	0	1054	1054	F2	0.837	2901	0.36
[Weld Throat]			19	0.6	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.837	2084	NaN
SDK10519	2	1	19	0.6	2.42	0	0	0	16.2	1.5	0	1034	1034	F2	0.837	2901	0.36
		2	19	0.6	2.42	0	0	0	16.2	1	0	1034	1034	F2	0.837	2901	0.36
[Weld Throat]			19	0.6	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.837	2084	NaN

Table I.3 Phase A Fatigue Analysis of Class F Longitudinals for Ship I

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midship
LxBxDxd = 194.00x 29.50x 21.60x 7.00(m)
Hull-Girder Moment of Inertia Ivert. 2449110.(cm2-m2) Ihoriz. 3991371.(cm2-m2)
Neutral Axis Height 9.06(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 100.00m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 286082.(tf-m) MW(horiz.) 208664.(tf-m)

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
1	BTM10801	A/	1	0.08	522	2.42	1	1	1	1&2	4	1019	178	966	F	0.867	3111	0.31	WT 265x33	IB Bhd01
		F/	3	0.08	522	2.42	1	1	1	1&2	4	1019	178	966	F	0.867	3111	0.31		IB Bhd01
2	BTM10802	A/	1	0.16	522	2.42	1	1	1	1&2	4	1010	178	959	F	0.867	3111	0.31	WT 265x33	IB Bhd02
		F/	3	0.16	522	2.42	1	1	1	1&2	4	1010	178	959	F	0.867	3111	0.31		IB Bhd02
3	BTM10803	A/	1	0.24	522	2.42	1	1	1	1&2	3.9	1001	180	954	F	0.867	3111	0.31	WT 265x33	IB Bhd03
		F/	3	0.24	522	2.42	1	1	1	1&2	3.9	1001	180	954	F	0.867	3111	0.31		IB Bhd03
4	BLG10101	A/	1	0.67	317	2.3	1	1	1	1&2	3.9	956	293	1009	F	0.867	3111	0.32	WT 205x23	Bilge 01
		F/	5	0.67	317	2.3	1	1	1	1&2	3.9	956	293	1009	F	0.867	3111	0.32		Bilge 01
5	BLG10102	A/	1	1.28	317	2.3	1	1	1	1&2	3.9	885	304	960	F	0.867	3111	0.31	WT 205x23	Bilge 02
		F/	5	1.28	317	2.3	1	1	1	1&2	3.9	885	304	960	F	0.867	3111	0.31		Bilge 02
6	BLG10103	A/	1	1.88	318	2.5	1	1	1	1&2	3.9	814	355	944	F	0.867	3111	0.3	WT 205x23	Bilge 03
		F/	1	1.88	318	2.5	1	1	1	1&2	3.9	814	355	944	F	0.867	3111	0.3		Bilge 03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
7	BLG10104	A/	1	2.49	318	2.5	1	1	2	TZONE		787	391	1119	F	0.867	3111	0.36	WT 205x23	Bilge 04
		F/	1	2.49	318	2.5	1	1	2	TZONE		787	391	1119	F	0.867	3111	0.36		Bilge 04
8	SHL10101	A/	1	3.17	326	2.5	1	1	2	TZONE		832	433	1202	F	0.885	2993	0.4	WT 205x23	Blg-3P01
		F/	1	3.17	326	2.5	1	1	2	TZONE		832	433	1202	F	0.885	2993	0.4		Blg-3P01
9	SHL10102	A/	1	3.9	326	2.5	1	1	2	TZONE		864	529	1323	F	0.899	2907	0.46	WT 205x23	Blg-3P02
		F/	1	3.9	326	2.5	1	1	2	TZONE		864	529	1323	F	0.899	2907	0.46		Blg-3P02
10	SHL10203	A/	1	5.41	260	2.5	1	1	2	F1&F2	7.7	918	976	1799	F	0.907	2870	0.63	WT 205x19.5	3P-2P 03
		F/	1	5.41	260	2.5	1	1	2	F1&F2	7.7	918	976	1799	F	0.907	2870	0.63		3P-2P 03
11	SHL10204	A/	1	6.21	260	2.5	1	1	2	F1&F2	9.1	888	1143	1929	F	0.907	2870	0.67	WT 205x19.5	3P-2P 04
		F/	1	6.21	260	2.5	1	1	2	F1&F2	9.1	888	1143	1929	F	0.907	2870	0.67		3P-2P 04
12	SHL10205	A/	1	7.02	260	2.5	1	0.65	2	F1&F2	10	857	844	1616	F	0.907	2870	0.56	WT 205x19.5	3P-2P 05
		F/	1	7.02	260	2.5	1	0.65	2	F1&F2	10	857	844	1616	F	0.907	2870	0.56		3P-2P 05
13	SHL10206	A/	1	7.83	260	2.5	1	0.42	2	F1&F2	9.5	827	501	1262	F	0.907	2870	0.44	WT 205x19.5	3P-2P 06
		F/	1	7.83	260	2.5	1	0.42	2	F1&F2	9.5	827	501	1262	F	0.907	2870	0.44		3P-2P 06
14	SHL10307	A/	1	8.41	199	2.5	1	0.31	2	F1&F2	8.9	806	348	1096	F	0.907	2870	0.38	WT 180x16.5	2P-1P 07
		F/	1	8.41	199	2.5	1	0.31	2	F1&F2	8.9	806	348	1096	F	0.907	2870	0.38		2P-1P 07
15	SHL10308	A/	1	9.02	199	2.5	1	0.3	2	F1&F2	8.2	783	307	1036	F	0.907	2870	0.36	WT 180x16.5	2P-1P 08
		F/	1	9.02	199	2.5	1	0.3	2	F1&F2	8.2	783	307	1036	F	0.907	2870	0.36		2P-1P 08
16	SHL10309	A/	1	9.63	180	2.5	1	0.3	2	F1&F2	7.6	814	313	1071	F	0.907	2870	0.37	WT 180x16.5	2P-1P 09
		F/	1	9.63	180	2.5	1	0.3	2	F1&F2	7.6	814	313	1071	F	0.907	2870	0.37		2P-1P 09
17	SHL10310	A/	1	10.25	180	2.5	1	0.3	2	F1&F2	6.9	848	273	1065	F	0.907	2870	0.37	WT 180x16.5	2P-1P 10
		F/	1	10.25	180	2.5	1	0.3	2	F1&F2	6.9	848	273	1065	F	0.907	2870	0.37		2P-1P 10
18	SHL10411	A/	1	11.51	153	2.5	1	0.3	1	F1&F2	5.3	919	303	1161	F	0.907	2870	0.4	WT 155x14	1P-3D 11
		F/	1	11.51	153	2.5	1	0.3	1	F1&F2	5.3	919	303	1161	F	0.907	2870	0.4		1P-3D 11
19	SHL10412	A/	1	12.23	153	2.5	1	0.3	1	F1&F2	4.6	959	262	1160	F	0.907	2870	0.4	WT 155x14	1P-3D 12
		F/	1	12.23	153	2.5	1	0.3	1	F1&F2	4.6	959	262	1160	F	0.907	2870	0.4		1P-3D 12
20	SHL10413	A/	1	12.94	153	2.5	1	0.3	1	F1&F2	3.9	999	212	1151	F	0.907	2870	0.4	WT 155x14	1P-3D 13
		F/	1	12.94	153	2.5	1	0.3	1	F1&F2	3.9	999	212	1151	F	0.907	2870	0.4		1P-3D 13
21	SHL10514	A/	1	14.27	153	2.5	1	0.3	1	F1&F2	2.6	1061	136	1137	F	0.907	2870	0.4	WT 155x14	3D-2D 14

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	14.27	153	2.5	1	0.3	1	F1&F2	2.6	1061	136	1137	F	0.907	2870	0.4		3D-2D 14
22	SHL10515	A/	1	14.93	153	2.5	1	0.3	1	F1&F2	1.9	1087	100	1128	F	0.907	2870	0.39	WT 155x14	3D-2D 15
		F/	1	14.93	153	2.5	1	0.3	1	F1&F2	1.9	1087	100	1128	F	0.907	2870	0.39		3D-2D 15
23	SHL10516	A/	1	15.6	153	2.5	1	0.3	1	F1&F2	1.2	1113	62	1116	F	0.907	2870	0.39	WT 155x14	3D-2D 16
		F/	1	15.6	153	2.5	1	0.3	1	F1&F2	1.2	1113	62	1116	F	0.907	2870	0.39		3D-2D 16
24	SHL10617	A/	1	16.91	185	2.5	1	0.3	1	TZONE		1109	0	1053	F	0.889	2969	0.35	WT 155x16.5	2D-She17
		F/	1	16.91	185	2.5	1	0.3	1	TZONE		1109	0	1053	F	0.889	2969	0.35		2D-She17
25	SHL10618	A/	1	17.63	185	2.5	1	0.3	1	TZONE		1107	0	1051	F	0.871	3081	0.34	WT 155x16.5	2D-She18
		F/	1	17.63	185	2.5	1	0.3	1	TZONE		1107	0	1051	F	0.871	3081	0.34		2D-She18
26	SHL10619	A/	1	18.34	185	2.5	1	0.3	1	TZONE		1129	0	1073	F	0.854	3192	0.34	WT 155x16.5	2D-She19
		F/	1	18.34	185	2.5	1	0.3	1	TZONE		1129	0	1073	F	0.854	3192	0.34		2D-She19
27	SHS10201	A/	1	19.67	253	2.5	1	1	1	1&2	0	1240	0	1178	F	0.826	3364	0.35	WT 155x19.5	MD-01 01
		F/	1	19.67	253	2.5	1	1	1	1&2	0	1240	0	1178	F	0.826	3364	0.35		MD-01 01
28	SHS10202	A/	1	20.34	253	2.5	1	1	1	1&2	0	1318	0	1252	F	0.826	3364	0.37	WT 155x19.5	MD-01 02
		F/	1	20.34	253	2.5	1	1	1	1&2	0	1318	0	1252	F	0.826	3364	0.37		MD-01 02
29	SHS10203	A/	1	21.01	253	2.5	1	1	1	1&2	0	1396	0	1326	F	0.826	3364	0.39	WT 155x19.5	MD-01 03
		F/	1	21.01	253	2.5	1	1	1	1&2	0	1396	0	1326	F	0.826	3364	0.39		MD-01 03
30	DEC10101	A/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String01
		F/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String01
31	DEC10102	A/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String02
		F/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String02
32	DEC10103	A/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String03
		F/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String03
33	DEC10104	A/	1	21.6	253	2.42	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String04
		F/	3	21.6	253	2.42	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String04
34	DEC10105	A/	1	21.6	253	2.42	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String05
		F/	3	21.6	253	2.42	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String05
35	DEC10106	A/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String06
		F/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String06

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
36	DEC10107	A/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String07
		F/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String07
37	DEC10108	A/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41	WT 155x19.5	String08
		F/	1	21.6	253	2.5	1	1	1	1&2	0	1447	0	1375	F	0.826	3364	0.41		String08
38	DEC10209	A/	1	21.6	279	2.42	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Lvl09
		F/	3	21.6	279	2.42	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Lvl09
39	DEC10310	A/	1	21.6	280	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef10
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef10
40	DEC10311	A/	1	21.6	280	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef11
		F/	1	21.6	280	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef11
41	DEC10412	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb12
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb12
42	DEC10413	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb13
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb13
43	DEC10414	A/	1	21.6	267	2.42	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb14
		F/	3	21.6	267	2.42	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb14
44	DEC10415	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb15
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb15
45	DEC10416	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb16
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb16
46	DEC10417	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb17
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb17
47	DEC10418	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01 Inb18
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01 Inb18
48	DEC10519	A/	1	21.6	267	2.42	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef19
		F/	3	21.6	267	2.42	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef19
49	DEC10520	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef20
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef20
50	DEC10521	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef21

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef21
51	DEC10522	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef22
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef22
52	DEC10523	A/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41	WT 205x19.5	01Inef23
		F/	1	21.6	268	2.5	1	1	1	1&2	0	1442	0	1370	F	0.826	3364	0.41		01Inef23
53	WTF31501	A/	1	13.6	78	2.5	1	1	1	F1&F2	0	803	0	763	F	0.826	3364	0.23	WT 155x10.5	3DInef01
		F/	1	13.6	78	2.5	1	1	1	F1&F2	0	803	0	763	F	0.826	3364	0.23		3DInef01
54	WTF31502	A/	1	13.6	78	2.5	1	1	1	F1&F2	0	834	0	793	F	0.826	3364	0.24	WT 155x10.5	3DInef02
		F/	1	13.6	78	2.5	1	1	1	F1&F2	0	834	0	793	F	0.826	3364	0.24		3DInef02
55	WTF31503	A/	1	13.6	78	2.5	1	1	1	F1&F2	0	866	0	822	F	0.826	3364	0.24	WT 155x10.5	3DInef03
		F/	1	13.6	78	2.5	1	1	1	F1&F2	0	866	0	822	F	0.826	3364	0.24		3DInef03
56	WTF31604	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	897	0	852	F	0.826	3364	0.25	WT 155x10.5	3DOtbd04
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	897	0	852	F	0.826	3364	0.25		3DOtbd04
57	WTF31605	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	929	0	882	F	0.826	3364	0.26	WT 155x10.5	3DOtbd05
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	929	0	882	F	0.826	3364	0.26		3DOtbd05
58	WTF31606	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	960	0	912	F	0.826	3364	0.27	WT 155x10.5	3DOtbd06
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	960	0	912	F	0.826	3364	0.27		3DOtbd06
59	WTF31607	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	991	0	942	F	0.826	3364	0.28	WT 155x10.5	3DOtbd07
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	991	0	942	F	0.826	3364	0.28		3DOtbd07
60	WTF31608	A/	1	13.6	77	2.5	1	1	1	F1&F2	0	1023	0	971	F	0.826	3364	0.29	WT 155x10.5	3DOtbd08
		F/	1	13.6	77	2.5	1	1	1	F1&F2	0	1023	0	971	F	0.826	3364	0.29		3DOtbd08
61	WTF41701	A/	1	15.2	2474	2.5	1	1	1	7&8	0	287	0	273	F	0.826	3364	0.08	502x418x22/32T	2DInef01
		F/	1	15.2	2474	2.5	1	1	1	7&8	0	287	0	273	F	0.826	3364	0.08		2DInef01
62	WTF41702	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	318	0	302	F	0.826	3364	0.09	WT 180x16.5	2DInef02
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	318	0	302	F	0.826	3364	0.09		2DInef02
63	WTF41703	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	350	0	332	F	0.826	3364	0.1	WT 180x16.5	2DInef03
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	350	0	332	F	0.826	3364	0.1		2DInef03
64	WTF41704	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	381	0	362	F	0.826	3364	0.11	WT 180x16.5	2DInef04
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	381	0	362	F	0.826	3364	0.11		2DInef04

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
65	WTF41705	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	413	0	392	F	0.826	3364	0.12	WT 180x16.5	2DInef05
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	413	0	392	F	0.826	3364	0.12		2DInef05
66	WTF41706	A/	1	15.2	176	2.4	1	1	1	F1&F2	0	444	0	422	F	0.826	3364	0.13	WT 180x16.5	2DInef06
		F/	4	15.2	176	2.4	1	1	1	F1&F2	0	444	0	422	F	0.826	3364	0.13		2DInef06
67	WTF41807	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	475	0	451	F	0.826	3364	0.13	WT 180x16.5	2DInef07
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	475	0	451	F	0.826	3364	0.13		2DInef07
68	WTF41808	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	507	0	481	F	0.826	3364	0.14	WT 180x16.5	2DInef08
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	507	0	481	F	0.826	3364	0.14		2DInef08
69	WTF41809	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	538	0	511	F	0.826	3364	0.15	WT 180x16.5	2DInef09
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	538	0	511	F	0.826	3364	0.15		2DInef09
70	WTF41810	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	569	0	541	F	0.826	3364	0.16	WT 180x16.5	2DInef10
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	569	0	541	F	0.826	3364	0.16		2DInef10
71	WTF41811	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	601	0	571	F	0.826	3364	0.17	WT 180x16.5	2DInef11
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	601	0	571	F	0.826	3364	0.17		2DInef11
72	WTF41812	A/	1	15.2	176	2.4	1	1	1	F1&F2	0	632	0	600	F	0.826	3364	0.18	WT 180x16.5	2DInef12
		F/	4	15.2	176	2.4	1	1	1	F1&F2	0	632	0	600	F	0.826	3364	0.18		2DInef12
73	WTF41913	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	658	0	625	F	0.826	3364	0.19	WT 180x16.5	2DInbd13
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	658	0	625	F	0.826	3364	0.19		2DInbd13
74	WTF41914	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	690	0	655	F	0.826	3364	0.19	WT 180x16.5	2DInbd14
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	690	0	655	F	0.826	3364	0.19		2DInbd14
75	WTF41915	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	721	0	685	F	0.826	3364	0.2	WT 180x16.5	2DInbd15
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	721	0	685	F	0.826	3364	0.2		2DInbd15
76	WTF41916	A/	1	15.2	177	2.5	1	1	1	F1&F2	0	752	0	715	F	0.826	3364	0.21	WT 180x16.5	2DInbd16
		F/	1	15.2	177	2.5	1	1	1	F1&F2	0	752	0	715	F	0.826	3364	0.21		2DInbd16
77	WTF52101	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	862	0	819	F	0.826	3364	0.24	WT 155x10.5	2DInne01
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	862	0	819	F	0.826	3364	0.24		2DInne01
78	WTF52102	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	893	0	848	F	0.826	3364	0.25	WT 155x10.5	2DInne02
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	893	0	848	F	0.826	3364	0.25		2DInne02
79	WTF52203	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	925	0	878	F	0.826	3364	0.26	WT 155x10.5	2DOtbd03

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	925	0	878	F	0.826	3364	0.26		2DOtbd03
80	WTF52204	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	956	0	908	F	0.826	3364	0.27	WT 155x10.5	2DOtbd04
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	956	0	908	F	0.826	3364	0.27		2DOtbd04
81	WTF52205	A/	1	16.2	79	2.42	1	1	1	F1&F2	0	987	0	938	F	0.826	3364	0.28	WT 155x10.5	2DOtbd05
		F/	3	16.2	79	2.42	1	1	1	F1&F2	0	987	0	938	F	0.826	3364	0.28		2DOtbd05
82	WTF52206	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1019	0	968	F	0.826	3364	0.29	WT 155x10.5	2DOtbd06
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1019	0	968	F	0.826	3364	0.29		2DOtbd06
83	WTF52207	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1050	0	997	F	0.826	3364	0.3	WT 155x10.5	2DOtbd07
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1050	0	997	F	0.826	3364	0.3		2DOtbd07
84	WTF52208	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1081	0	1027	F	0.826	3364	0.31	WT 155x10.5	2DOtbd08
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1081	0	1027	F	0.826	3364	0.31		2DOtbd08
85	WTF52209	A/	1	16.2	79	2.5	1	1	1	F1&F2	0	1113	0	1057	F	0.826	3364	0.31	WT 155x10.5	2DOtbd09
		F/	1	16.2	79	2.5	1	1	1	F1&F2	0	1113	0	1057	F	0.826	3364	0.31		2DOtbd09
86	INS10101	A/	1	0.6	341	2.5	1	1	1	1&2	0.5	988	36	973	F	0.867	3111	0.31	WT 205x23	IBS-IB01
		F/	1	0.6	341	2.5	1	1	1	1&2	0.5	988	36	973	F	0.867	3111	0.31		IBS-IB01
87	INS10202	A/	1	1.88	326	2.42	1	1	1	1&2	0.5	838	38	833	F	0.867	3111	0.27	WT 205x23	IbIB-302
		F/	3	1.88	326	2.42	1	1	1	1&2	0.5	838	38	833	F	0.867	3111	0.27		IbIB-302
88	INS10203	A/	1	2.56	326	2.5	1	1	2	TZONE		768	37	765	F	0.874	3064	0.25	WT 205x23	IbIB-303
		F/	1	2.56	326	2.5	1	1	2	TZONE		768	37	765	F	0.874	3064	0.25		IbIB-303
89	INS10204	A/	1	3.24	326	2.5	1	1	2	TZONE		729	32	723	F	0.887	2984	0.24	WT 205x23	IbIB-304
		F/	1	3.24	326	2.5	1	1	2	TZONE		729	32	723	F	0.887	2984	0.24		IbIB-304
90	INS10205	A/	1	3.92	326	2.5	1	1	1	TZONE		720	30	713	F	0.899	2904	0.25	WT 205x23	IbIB-305
		F/	1	3.92	326	2.5	1	1	1	TZONE		720	30	713	F	0.899	2904	0.25		IbIB-305
91	INS10406	A/	1	5.24	260	2.5	1	1	1	F1&F2	0.4	685	44	693	F	0.907	2870	0.24	WT 205x19.5	Ib3P2P06
		F/	1	5.24	260	2.5	1	1	1	F1&F2	0.4	685	44	693	F	0.907	2870	0.24		Ib3P2P06
92	INS10507	A/	1	5.88	255	2.5	1	1	1	F1&F2	0.5	655	48	669	F	0.907	2870	0.23	WT 205x19.5	Ib3P2P07
		F/	1	5.88	255	2.5	1	1	1	F1&F2	0.5	655	48	669	F	0.907	2870	0.23		Ib3P2P07
93	INS10608	A/	1	6.52	255	2.5	1	1	1	F1&F2	0.5	626	52	644	F	0.907	2870	0.22	WT 205x19.5	Ib3P2P08
		F/	1	6.52	255	2.5	1	1	1	F1&F2	0.5	626	52	644	F	0.907	2870	0.22		Ib3P2P08

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
94	INS10609	A/	1	7.16	255	2.5	1	1	1	F1&F2	0.6	596	56	619	F	0.907	2870	0.22	WT 205x19.5	Ib3P2P09
		F/	1	7.16	255	2.5	1	1	1	F1&F2	0.6	596	56	619	F	0.907	2870	0.22		Ib3P2P09
95	INS10710	A/	1	8.4	191	2.5	1	1	1	F1&F2	0.6	536	79	585	F	0.907	2870	0.2	WT 180x16.5	Ib2P1P10
		F/	1	8.4	191	2.5	1	1	1	F1&F2	0.6	536	79	585	F	0.907	2870	0.2		Ib2P1P10
96	INS10811	A/	1	9	191	2.5	1	1	1	F1&F2	0.7	508	84	563	F	0.907	2870	0.2	WT 180x16.5	Ib2P1P11
		F/	1	9	191	2.5	1	1	1	F1&F2	0.7	508	84	563	F	0.907	2870	0.2		Ib2P1P11
97	INS10912	A/	1	9.6	173	2.5	1	1	1	F1&F2	0.7	531	98	598	F	0.907	2870	0.21	WT 180x16.5	Ib2P1P12
		F/	1	9.6	173	2.5	1	1	1	F1&F2	0.7	531	98	598	F	0.907	2870	0.21		Ib2P1P12
98	INS10913	A/	1	10.2	173	2.5	1	1	1	F1&F2	0.7	559	103	629	F	0.907	2870	0.22	WT 180x16.5	Ib2P1P13
		F/	1	10.2	173	2.5	1	1	1	F1&F2	0.7	559	103	629	F	0.907	2870	0.22		Ib2P1P13
99	INS11014	A/	1	11.36	98	2.5	1	1	1	F1&F2	0	612	0	582	F	0.907	2870	0.2	WT 155x10.5	Ib1P3D14
		F/	1	11.36	98	2.5	1	1	1	F1&F2	0	612	0	582	F	0.907	2870	0.2		Ib1P3D14
100	INS11015	A/	1	11.92	98	2.5	1	1	1	F1&F2	0	638	0	606	F	0.907	2870	0.21	WT 155x10.5	Ib1P3D15
		F/	1	11.92	98	2.5	1	1	1	F1&F2	0	638	0	606	F	0.907	2870	0.21		Ib1P3D15
101	INS11116	A/	1	12.48	98	2.5	1	1	1	F1&F2	0	665	0	631	F	0.907	2870	0.22	WT 155x10.5	Ib1P3D16
		F/	1	12.48	98	2.5	1	1	1	F1&F2	0	665	0	631	F	0.907	2870	0.22		Ib1P3D16
102	INS11117	A/	1	13.04	98	2.5	1	1	1	F1&F2	0	691	0	656	F	0.907	2870	0.23	WT 155x10.5	Ib1P3D17
		F/	1	13.04	98	2.5	1	1	1	F1&F2	0	691	0	656	F	0.907	2870	0.23		Ib1P3D17
103	INS11218	A/	1	14.14	98	2.5	1	1	1	F1&F2	0	742	0	705	F	0.907	2870	0.25	WT 155x10.5	IB3D2D18
		F/	1	14.14	98	2.5	1	1	1	F1&F2	0	742	0	705	F	0.907	2870	0.25		IB3D2D18
104	INS11219	A/	1	14.67	98	2.5	1	1	1	F1&F2	0	767	0	728	F	0.907	2870	0.25	WT 155x10.5	IB3D2D19
		F/	1	14.67	98	2.5	1	1	1	F1&F2	0	767	0	728	F	0.907	2870	0.25		IB3D2D19
105	INS11320	A/	1	15.7	98	2.5	1	1	1	F1&F2	0	815	0	774	F	0.907	2870	0.27	WT 155x10.5	Ib2D2D20
		F/	1	15.7	98	2.5	1	1	1	F1&F2	0	815	0	774	F	0.907	2870	0.27		Ib2D2D20
106	INS11421	A/	1	16.76	98	2.5	1	1	1	TZONE		871	0	827	F	0.893	2945	0.28	WT 155x10.5	Ib2DMD21
		F/	1	16.76	98	2.5	1	1	1	TZONE		871	0	827	F	0.893	2945	0.28		Ib2DMD21
107	INS11422	A/	1	17.32	98	2.5	1	1	1	TZONE		916	0	871	F	0.879	3033	0.29	WT 155x10.5	Ib2DMD22
		F/	1	17.32	98	2.5	1	1	1	TZONE		916	0	871	F	0.879	3033	0.29		Ib2DMD22
108	INS11423	A/	1	17.88	98	2.5	1	1	1	TZONE		976	0	927	F	0.865	3120	0.3	WT 155x10.5	Ib2DMD23

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	17.88	98	2.5	1	1	1	TZONE		976	0	927	F	0.865	3120	0.3		Ib2DMD23
109	INS11424	A/	1	18.44	98	2.5	1	1	1	TZONE		1049	0	996	F	0.851	3207	0.31	WT 155x10.5	Ib2DMD24
		F/	1	18.44	98	2.5	1	1	1	TZONE		1049	0	996	F	0.851	3207	0.31		Ib2DMD24
110	INS21601	A/	1	19.67	254	2.5	1	1	1	1&2	0	1239	0	1177	F	0.826	3364	0.35	WT 155x19.5	IbMD0101
		F/	1	19.67	254	2.5	1	1	1	1&2	0	1239	0	1177	F	0.826	3364	0.35		IbMD0101
111	INS21602	A/	1	20.32	254	2.5	1	1	1	1&2	0	1315	0	1249	F	0.826	3364	0.37	WT 155x19.5	IbMD0102
		F/	1	20.32	254	2.5	1	1	1	1&2	0	1315	0	1249	F	0.826	3364	0.37		IbMD0102
112	INS21703	A/	1	20.95	281	2.5	1	1	1	1&2	0	1389	0	1320	F	0.826	3364	0.39	WT 205x19.5	IbMD0103
		F/	1	20.95	281	2.5	1	1	1	1&2	0	1389	0	1320	F	0.826	3364	0.39		IbMD0103
113	INS31801	A/	1	1.2	345	2.42	1	1	1	1&2	0	918	0	872	F	0.867	3111	0.28	WT 205x23	Ob Bhd01
		F/	3	1.2	345	2.42	1	1	1	1&2	0	918	0	872	F	0.867	3111	0.28		Ob Bhd01
114	INS31902	A/	1	1.88	337	2.5	1	1	1	1&2	0	838	0	796	F	0.867	3111	0.26	WT 205x23	Ob Bhd02
		F/	1	1.88	337	2.5	1	1	1	1&2	0	838	0	796	F	0.867	3111	0.26		Ob Bhd02
115	INS31903	A/	1	2.56	337	2.5	1	1	1	TZONE		793	11	764	F	0.874	3064	0.25	WT 205x23	Ob Bhd03
		F/	1	2.56	337	2.5	1	1	1	TZONE		793	11	764	F	0.874	3064	0.25		Ob Bhd03
116	INS31904	A/	1	3.24	337	2.5	1	1	1	TZONE		795	31	784	F	0.887	2984	0.26	WT 205x23	Ob Bhd04
		F/	1	3.24	337	2.5	1	1	1	TZONE		795	31	784	F	0.887	2984	0.26		Ob Bhd04
117	INS31905	A/	1	3.92	337	2.5	1	1	1	TZONE		826	50	832	F	0.899	2904	0.29	WT 205x23	Ob Bhd05
		F/	1	3.92	337	2.5	1	1	1	TZONE		826	50	832	F	0.899	2904	0.29		Ob Bhd05
118	INS32006	A/	1	5.24	264	2.5	1	1	1	F1&F2	0.7	816	72	844	F	0.907	2870	0.29	WT 205x19.5	OB3P2P06
		F/	1	5.24	264	2.5	1	1	1	F1&F2	0.7	816	72	844	F	0.907	2870	0.29		OB3P2P06
119	INS32007	A/	1	5.88	264	2.5	1	1	1	F1&F2	0.7	786	71	814	F	0.907	2870	0.28	WT 205x19.5	OB3P2P07
		F/	1	5.88	264	2.5	1	1	1	F1&F2	0.7	786	71	814	F	0.907	2870	0.28		OB3P2P07
120	INS32008	A/	1	6.52	264	2.5	1	1	1	F1&F2	0.7	756	70	785	F	0.907	2870	0.27	WT 205x19.5	OB3P2P08
		F/	1	6.52	264	2.5	1	1	1	F1&F2	0.7	756	70	785	F	0.907	2870	0.27		OB3P2P08
121	INS32009	A/	1	7.16	264	2.5	1	1	1	F1&F2	0.7	726	70	756	F	0.907	2870	0.26	WT 205x19.5	OB3P2P09
		F/	1	7.16	264	2.5	1	1	1	F1&F2	0.7	726	70	756	F	0.907	2870	0.26		OB3P2P09
122	INS32110	A/	1	8.4	199	2.5	1	1	1	F1&F2	0.7	667	84	714	F	0.907	2870	0.25	WT 180x16.5	OB2P1P10
		F/	1	8.4	199	2.5	1	1	1	F1&F2	0.7	667	84	714	F	0.907	2870	0.25		OB2P1P10

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
123	INS32111	A/	1	9	199	2.5	1	1	1	F1&F2	0.7	639	83	686	F	0.907	2870	0.24	WT 180x16.5	OB2P1P11
		F/	1	9	199	2.5	1	1	1	F1&F2	0.7	639	83	686	F	0.907	2870	0.24		OB2P1P11
124	INS32112	A/	1	9.6	180	2.5	1	1	1	F1&F2	0.7	662	91	715	F	0.907	2870	0.25	WT 180x16.5	OB2P1P12
		F/	1	9.6	180	2.5	1	1	1	F1&F2	0.7	662	91	715	F	0.907	2870	0.25		OB2P1P12
125	INS32113	A/	1	10.2	180	2.5	1	1	1	F1&F2	0.7	690	89	740	F	0.907	2870	0.26	WT 180x16.5	OB2P1P13
		F/	1	10.2	180	2.5	1	1	1	F1&F2	0.7	690	89	740	F	0.907	2870	0.26		OB2P1P13
126	SDK10101	A/	1	19	104	2.5	1	1	1	TZONE		1168	0	1110	F	0.837	3295	0.34	WT 155x10.5	MD Otb01
		F/	1	19	104	2.5	1	1	1	TZONE		1168	0	1110	F	0.837	3295	0.34		MD Otb01
127	SDK10102	A/	1	19	104	2.5	1	1	1	TZONE		1164	0	1106	F	0.837	3295	0.34	WT 155x10.5	MD Otb02
		F/	1	19	104	2.5	1	1	1	TZONE		1164	0	1106	F	0.837	3295	0.34		MD Otb02
128	SDK10203	A/	1	19	102	2.5	1	1	1	TZONE		1160	0	1102	F	0.837	3295	0.33	WT 155x10.5	MD Otb03
		F/	1	19	102	2.5	1	1	1	TZONE		1160	0	1102	F	0.837	3295	0.33		MD Otb03
129	SDK10204	A/	1	19	102	2.42	1	1	1	TZONE		1155	0	1098	F	0.837	3295	0.33	WT 155x10.5	MD Otb04
		F/	3	19	102	2.42	1	1	1	TZONE		1155	0	1098	F	0.837	3295	0.33		MD Otb04
130	SDK10205	A/	1	19	102	2.5	1	1	1	TZONE		1151	0	1093	F	0.837	3295	0.33	WT 155x10.5	MD Otb05
		F/	1	19	102	2.5	1	1	1	TZONE		1151	0	1093	F	0.837	3295	0.33		MD Otb05
131	SDK10206	A/	1	19	102	2.5	1	1	1	TZONE		1146	0	1089	F	0.837	3295	0.33	WT 155x10.5	MD Otb06
		F/	1	19	102	2.5	1	1	1	TZONE		1146	0	1089	F	0.837	3295	0.33		MD Otb06
132	SDK10207	A/	1	19	102	2.5	1	1	1	TZONE		1142	0	1085	F	0.837	3295	0.33	WT 155x10.5	MD Otb07
		F/	1	19	102	2.5	1	1	1	TZONE		1142	0	1085	F	0.837	3295	0.33		MD Otb07
133	SDK10208	A/	1	19	102	2.5	1	1	1	TZONE		1137	0	1080	F	0.837	3295	0.33	WT 155x10.5	MD Otb08
		F/	1	19	102	2.5	1	1	1	TZONE		1137	0	1080	F	0.837	3295	0.33		MD Otb08
134	SDK10309	A/	1	19	102	2.42	1	1	1	TZONE		1131	0	1074	F	0.837	3295	0.33	WT 155x10.5	MD Inb09
		F/	3	19	102	2.42	1	1	1	TZONE		1131	0	1074	F	0.837	3295	0.33		MD Inb09
135	SDK10310	A/	1	19	102	2.5	1	1	1	TZONE		1126	0	1070	F	0.837	3295	0.32	WT 155x10.5	MD Inb10
		F/	1	19	102	2.5	1	1	1	TZONE		1126	0	1070	F	0.837	3295	0.32		MD Inb10
136	SDK10311	A/	1	19	102	2.5	1	1	1	TZONE		1122	0	1066	F	0.837	3295	0.32	WT 155x10.5	MD Inb11
		F/	1	19	102	2.5	1	1	1	TZONE		1122	0	1066	F	0.837	3295	0.32		MD Inb11
137	SDK10312	A/	1	19	102	2.5	1	1	1	TZONE		1118	0	1062	F	0.837	3295	0.32	WT 155x10.5	MD Inb12

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	1	19	102	2.5	1	1	1	TZONE		1118	0	1062	F	0.837	3295	0.32		MD Inb12
138	SDK10313	A/	1	19	102	2.5	1	1	1	TZONE		1114	0	1058	F	0.837	3295	0.32	WT 155x10.5	MD Inb13
		F/	1	19	102	2.5	1	1	1	TZONE		1114	0	1058	F	0.837	3295	0.32		MD Inb13
139	SDK10314	A/	1	19	102	2.42	1	1	1	TZONE		1109	0	1054	F	0.837	3295	0.32	WT 155x10.5	MD Inb14
		F/	3	19	102	2.42	1	1	1	TZONE		1109	0	1054	F	0.837	3295	0.32		MD Inb14
140	SDK10315	A/	1	19	102	2.5	1	1	1	TZONE		1105	0	1050	F	0.837	3295	0.32	WT 155x10.5	MD Inb15
		F/	1	19	102	2.5	1	1	1	TZONE		1105	0	1050	F	0.837	3295	0.32		MD Inb15
141	SDK10316	A/	1	19	102	2.5	1	1	1	TZONE		1101	0	1046	F	0.837	3295	0.32	WT 155x10.5	MD Inb16
		F/	1	19	102	2.5	1	1	1	TZONE		1101	0	1046	F	0.837	3295	0.32		MD Inb16
142	SDK10317	A/	1	19	102	2.5	1	1	1	TZONE		1097	0	1042	F	0.837	3295	0.32	WT 155x10.5	MD Inb17
		F/	1	19	102	2.5	1	1	1	TZONE		1097	0	1042	F	0.837	3295	0.32		MD Inb17
143	SDK10418	A/	1	19	102	2.5	1	1	1	TZONE		1092	0	1038	F	0.837	3295	0.31	WT 155x10.5	MD Inn18
		F/	1	19	102	2.5	1	1	1	TZONE		1092	0	1038	F	0.837	3295	0.31		MD Inn18
144	SDK10519	A/	1	19	102	2.42	1	1	1	TZONE		1088	0	1034	F	0.837	3295	0.31	WT 155x10.5	MD Inb19
		F/	3	19	102	2.42	1	1	1	TZONE		1088	0	1034	F	0.837	3295	0.31		MD Inb19
145	SDK10520	A/	1	19	102	2.5	1	1	1	TZONE		1084	0	1030	F	0.837	3295	0.31	WT 155x10.5	MD Inb20
		F/	1	19	102	2.5	1	1	1	TZONE		1084	0	1030	F	0.837	3295	0.31		MD Inb20
146	SDK10521	A/	1	19	102	2.5	1	1	1	TZONE		1080	0	1026	F	0.837	3295	0.31	WT 155x10.5	MD Inb21
		F/	1	19	102	2.5	1	1	1	TZONE		1080	0	1026	F	0.837	3295	0.31		MD Inb21
147	SDK10522	A/	1	19	102	2.5	1	1	1	TZONE		1075	0	1022	F	0.837	3295	0.31	WT 155x10.5	MD Inb22
		F/	1	19	102	2.5	1	1	1	TZONE		1075	0	1022	F	0.837	3295	0.31		MD Inb22
148	SDK10523	A/	1	19	102	2.5	1	1	1	TZONE		1071	0	1018	F	0.837	3295	0.31	WT 155x10.5	MD Inb23
		F/	1	19	102	2.5	1	1	1	TZONE		1071	0	1018	F	0.837	3295	0.31		MD Inb23
149	SDK10524	A/	1	19	3421	2.5	1	1	1	TZONE		1067	0	1014	F	0.837	3295	0.31	W/T 403x165	MD Inb24
		F/	1	19	3421	2.5	1	1	1	TZONE		1067	0	1014	F	0.837	3295	0.31		MD Inb24

Table I.4 Phase A Fatigue Analysis of Class F Flat Bars for Ship I

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ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP : Midship
LxBxDxd = 194.00x 29.50x 21.60x 7.00(m)
Hull-Girder Moment of Inertia Ivert. 2449110.(cm2-m2) Ihoriz. 3991371.(cm2-m2)
Neutral Axis Height 9.06(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 100.00m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 286082.(tf-m) MW(horiz.) 208664.(tf-m)

Cutout LABEL	**ID**	**LOC**	**Dist. from BL(m)**	**Long`l Spacing (m)**	**Long`l Length (m)**	**Local Load Range**		**Support Areas**		**SCF**	**Stress Range (kg/cm2)**			**FATIG CLASS**	**Long Term Distr. Factor**	**Permissible Stress (kg/cm2) PS**	**fR/PS**
						Head (m)	**Force (tf)**	**As (cm^2}**	**Ac (cm^2}**		**fs**	**fL**	**fRi**				
BTM10801	1	1	0.08	0.625	2.42	3.95	6.13	0	90.9	1.5	64	966	971	F	0.867	3111	0.31
		2	0.08	0.625	2.42	3.95	6.13	0	90.9	1	64	966	969	F	0.867	3111	0.31
[Weld Throat]			0.08	0.625	2.42	3.95	6.13	[Asw]=	0	1.25	64	0	*****	W	0.867	1970	NaN
BTM10802	1	1	0.16	0.625	2.42	3.95	6.12	0	90.9	1.5	64	959	964	F	0.867	3111	0.31
		2	0.16	0.625	2.42	3.95	6.12	0	90.9	1	64	959	961	F	0.867	3111	0.31
[Weld Throat]			0.16	0.625	2.42	3.95	6.12	[Asw]=	0	1.25	64	0	*****	W	0.867	1970	NaN
BTM10803	1	1	0.24	0.635	2.42	3.94	6.21	0	90.9	1.5	65	954	959	F	0.867	3111	0.31
		2	0.24	0.635	2.42	3.94	6.21	0	90.9	1	65	954	956	F	0.867	3111	0.31
[Weld Throat]			0.24	0.635	2.42	3.94	6.21	[Asw]=	0	1.25	65	0	*****	W	0.867	1970	NaN
BLG10101	1	1	0.67	0.698	2.3	3.92	6.45	0	48.4	1.5	127	1009	1027	F	0.867	3111	0.33
		2	0.67	0.698	2.3	3.92	6.45	0	48.4	1	127	1009	1017	F	0.867	3111	0.33
[Weld Throat]			0.67	0.698	2.3	3.92	6.45	[Asw]=	0	1.25	127	0	*****	W	0.867	1970	NaN

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
BLG10102	1	1	1.28	0.73	2.3	3.89	6.69	0	48.4	1.5	131	960	980	F	0.867	3111	0.32
		2	1.28	0.73	2.3	3.89	6.69	0	48.4	1	131	960	969	F	0.867	3111	0.31
[Weld Throat]			1.28	0.73	2.3	3.89	6.69	[Asw]=	0	1.25	131	0	*****	W	0.867	1970	NaN
DEC10104	2	1	21.6	0.557	2.42	0	0	0	12.2	1.5	0	1375	1375	F	0.826	3364	0.41
		2	21.6	0.557	2.42	0	0	0	12.2	1	0	1375	1375	F	0.826	3364	0.41
[Weld Throat]			21.6	0.557	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10105	2	1	21.6	0.557	2.42	0	0	0	12.2	1.5	0	1375	1375	F	0.826	3364	0.41
		2	21.6	0.557	2.42	0	0	0	12.2	1	0	1375	1375	F	0.826	3364	0.41
[Weld Throat]			21.6	0.557	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10209	2	1	21.6	0.565	2.42	0	0	0	23.3	1.5	0	1370	1370	F	0.826	3364	0.41
		2	21.6	0.565	2.42	0	0	0	23.3	1	0	1370	1370	F	0.826	3364	0.41
[Weld Throat]			21.6	0.565	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10414	2	1	21.6	0.6	2.42	0	0	0	23.3	1.5	0	1370	1370	F	0.826	3364	0.41
		2	21.6	0.6	2.42	0	0	0	23.3	1	0	1370	1370	F	0.826	3364	0.41
[Weld Throat]			21.6	0.6	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
DEC10519	2	1	21.6	0.61	2.42	0	0	0	23.3	1.5	0	1370	1370	F	0.826	3364	0.41
		2	21.6	0.61	2.42	0	0	0	23.3	1	0	1370	1370	F	0.826	3364	0.41
[Weld Throat]			21.6	0.61	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.826	2127	NaN
SDK10204	2	1	19	0.64	2.42	0	0	0	18.4	1.5	0	1098	1098	F	0.837	3295	0.33
		2	19	0.64	2.42	0	0	0	18.4	1	0	1098	1098	F	0.837	3295	0.33
[Weld Throat]			19	0.64	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.837	2084	NaN
SDK10314	2	1	19	0.6	2.42	0	0	0	16.2	1.5	0	1054	1054	F	0.837	3295	0.32
		2	19	0.6	2.42	0	0	0	16.2	1	0	1054	1054	F	0.837	3295	0.32
[Weld Throat]			19	0.6	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.837	2084	NaN
SDK10519	2	1	19	0.6	2.42	0	0	0	16.2	1.5	0	1034	1034	F	0.837	3295	0.31
		2	19	0.6	2.42	0	0	0	16.2	1	0	1034	1034	F	0.837	3295	0.31
[Weld Throat]			19	0.6	2.42	0	0	[Asw]=	0	1.25	0	0	*****	W	0.837	2084	NaN

APPENDIX J

FATIGUE ANALYSIS SUMMARY FOR SHIP J

Table J.1 Phase A Fatigue Analysis of Class F2 Longitudinals for Ship J

ABS\SAFEHULL\CFATIGUE V6.00 (2000 Rules)
SHIP :
LxBxDxd = 150.79x 16.31x 11.83x 5.03(m)
Hull-Girder Moment of Inertia Ivert. 231939.(cm2-m2) Ihoriz. 347129.(cm2-m2)
Neutral Axis Height 5.74(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR LONGITUDINAL STIFFENERS
S U M M A R Y
Special Location at 77.72m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 94216.(tf-m) MW(horiz.) 75632.(tf-m)
******** "Net" Ship ******** Local Cf=0.95 Cw=0.75 Long Perm.

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
1	BTM10101	A/	2	0	416	2.338	1	1	2	1&2	5.22	2189	336	2039	F2	0.893	2590	0.79	12x4x22#I-T	A1
		F/	4	0	416	2.338	1	1	2	1&2	5.22	2189	336	2039	F2	0.893	2590	0.79		A1
2	BTM10202	A/	2	0	416	2.338	1	1	2	1&2	5.2	2118	333	1979	F2	0.893	2590	0.76	12x4x22#I-T	A2
		F/	4	0	416	2.338	1	1	2	1&2	5.2	2118	333	1979	F2	0.893	2590	0.76		A2
3	BTM10403	A/	2	1	416	2.338	1	1	2	1&2	5.16	1993	335	1880	F2	0.893	2590	0.73	12x4x22#I-T	B2
		F/	4	1	416	2.338	1	1	2	1&2	5.16	1993	335	1880	F2	0.893	2590	0.73		B2
4	BLG10101	A/	2	1	406	2.338	1	1	2	1&2	5.1	1805	341	1733	F2	0.893	2590	0.67	12x4x22#I-T	C1
		F/	4	1	406	2.338	1	1	2	1&2	5.1	1805	341	1733	F2	0.893	2590	0.67		C1
5	BLG10202	A/	2	2	219	2.338	1	1	1	TZONE		1788	755	2416	F2	0.893	2590	0.93	12x4x14#I-T	C2
		F/	4	2	219	2.338	1	1	1	TZONE		1788	755	2416	F2	0.893	2590	0.93		C2
6	SHL10201	A/	2	3	192	2.338	1	1	1	F1&F2	8.28	1982	1085	2913	F2	0.931	2429	1.2	12x4x14#I-T	D3
		F/	4	3	192	2.338	1	1	1	F1&F2	8.28	1982	1085	2913	F2	0.931	2429	1.2		D3
7	SHL10202	A/	2	4	192	2.338	1	1	1	F1&F2	9.74	1941	1418	3191	F2	0.931	2429	1.31	12x4x14#I-T	D3

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	4	4	192	2.338	1	1	1	F1&F2	9.74	1941	1418	3191	F2	0.931	2429	1.31		D3
8	SHL10403	A/	2	5	168	2.338	1	0.55	1	F1&F2	12.79	1787	1108	2751	F2	0.931	2429	1.13	10x4x11.5#I-T	E2
		F/	4	5	168	2.338	1	0.55	1	F1&F2	12.79	1787	1108	2751	F2	0.931	2429	1.13		E2
9	SHL10404	A/	2	6	168	2.338	1	0.32	1	F1&F2	11.32	1779	542	2206	F2	0.931	2429	0.91	10x4x11.5#I-T	E2
		F/	4	6	168	2.338	1	0.32	1	F1&F2	11.32	1779	542	2206	F2	0.931	2429	0.91		E2
10	SHL10505	A/	2	7	122	2.338	1	0.3	1	F1&F2	10	1904	554	2335	F2	0.931	2429	0.96	8x4x10#I-T	F1
		F/	4	7	122	2.338	1	0.3	1	F1&F2	10	1904	554	2335	F2	0.931	2429	0.96		F1
11	SHL10506	A/	2	7	122	2.338	1	0.3	1	F1&F2	8.81	2004	462	2343	F2	0.931	2429	0.96	8x4x10#I-T	F1
		F/	4	7	122	2.338	1	0.3	1	F1&F2	8.81	2004	462	2343	F2	0.931	2429	0.96		F1
12	SHL10507	A/	2	8	122	2.338	1	0.3	1	F1&F2	7.62	2103	400	2378	F2	0.931	2429	0.98	8x4x10#I-T	F1
		F/	4	8	122	2.338	1	0.3	1	F1&F2	7.62	2103	400	2378	F2	0.931	2429	0.98		F1
13	SHL10508	A/	2	9	122	2.338	1	0.3	1	F1&F2	6.43	2203	335	2411	F2	0.931	2429	0.99	8x4x10#I-T	F1
		F/	4	9	122	2.338	1	0.3	1	F1&F2	6.43	2203	335	2411	F2	0.931	2429	0.99		F1
14	SHS10201	A/	2	10	125	2.338	1	1	1	TZONE		1656	793	2326	F2	0.882	2651	0.88	8x4x10#I-T	G2
		F/	4	10	125	2.338	1	1	1	TZONE		1656	793	2326	F2	0.882	2651	0.88		G2
15	SHS10202	A/	2	11	125	2.338	1	1	1	1&2	0	2091	0	1986	F2	0.855	2804	0.71	8x4x10#I-T	G2
		F/	4	11	125	2.338	1	1	1	1&2	0	2091	0	1986	F2	0.855	2804	0.71		G2
16	DEC10101	A/	2	12	125	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	Str
		F/	4	12	125	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		Str
17	DEC10102	A/	2	12	125	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	Str
		F/	4	12	125	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		Str
18	DEC10203	A/	2	12	123	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	123	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
19	DEC10204	A/	2	12	123	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	123	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
20	DEC10205	A/	2	12	123	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	123	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
21	DEC10306	A/	2	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
22	DEC10307	A/	2	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
23	DEC10308	A/	2	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	4	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
24	DEC10309	A/	2	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	122	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
25	DEC10410	A/	2	12	121	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	121	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
26	DEC10411	A/	2	12	121	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81	8x4x10#I-T	
		F/	4	12	121	2.338	1	1	1	1&2	0	2393	0	2273	F2	0.855	2804	0.81		
27	INB10101	A/	2	1	148	2.338	1	1	2	1&2	0.5	1874	86	1862	F2	0.893	2590	0.72	10x4x11.5#I-T	IB A
		F/	4	1	148	2.338	1	1	2	1&2	0.5	1874	86	1862	F2	0.893	2590	0.72		IB A
28	INB10302	A/	2	1	146	2.338	1	1	2	1&2	0.5	1865	82	1850	F2	0.893	2590	0.71	10x4x11.5#I-T	IB B2
		F/	4	1	146	2.338	1	1	2	1&2	0.5	1865	82	1850	F2	0.893	2590	0.71		IB B2
29	INB10403	A/	2	1	146	2.338	1	1	2	1&2	0.49	1825	85	1814	F2	0.893	2590	0.7	10x4x11.5#I-T	IB B3
		F/	4	1	146	2.338	1	1	2	1&2	0.49	1825	85	1814	F2	0.893	2590	0.7		IB B3
30	INB10504	A/	2	2	106	2.338	1	1	2	1&2	0.44	1666	96	1675	F2	0.893	2590	0.65	8x4x10#I-T	IB B4
		F/	4	2	106	2.338	1	1	2	1&2	0.44	1666	96	1675	F2	0.893	2590	0.65		IB B4
31	INB10705	A/	2	2	104	2.338	1	1	2	1&2	0.36	1409	76	1410	F2	0.893	2590	0.54	8x4x10#I-T	IB C1
		F/	4	2	104	2.338	1	1	2	1&2	0.36	1409	76	1410	F2	0.893	2590	0.54		IB C1
32	INB10806	A/	2	3	90	2.338	1	1	2	1&2	0.23	1011	55	1013	F2	0.893	2590	0.39	8x4x10#I-T	IB C2
		F/	4	3	90	2.338	1	1	2	1&2	0.23	1011	55	1013	F2	0.893	2590	0.39		IB C2
33	INB10807	A/	2	4	90	2.338	1	1	2	1&2	0.16	787	37	783	F2	0.893	2590	0.3	8x4x10#I-T	IB C2
		F/	4	4	90	2.338	1	1	2	1&2	0.16	787	37	783	F2	0.893	2590	0.3		IB C2
34	NBG10101	A/	4	1	6	2.438	1	1	1	1&2	0	2034	0	1932	F2	0.893	2590	0.75	4x2.28x3.25#T	Gir2
		F/	4	1	6	2.438	1	1	1	1&2	0	2034	0	1932	F2	0.893	2590	0.75		Gir2
35	NBG20201	A/	4	1	6	2.438	1	1	1	1&2	0	1981	0	1882	F2	0.893	2590	0.73	4x2.28x3.25#T	Gir4
		F/	4	1	6	2.438	1	1	1	1&2	0	1981	0	1882	F2	0.893	2590	0.73		Gir4
36	NBG30301	A/	4	1	82	2.438	1	1	1	1&2	0	1905	0	1810	F2	0.893	2590	0.7	5x4x7.5#T	Gir6
		F/	4	1	82	2.438	1	1	1	1&2	0	1905	0	1810	F2	0.893	2590	0.7		Gir6
37	SDK10101	A/	2	9	69	2.338	1	1	1	TZONE		2052	0	1949	F2	0.92	2473	0.79	5x4x5.75#T	2nd 4
		F/	4	9	69	2.338	1	1	1	TZONE		2052	0	1949	F2	0.92	2473	0.79		2nd 4
38	SDK10102	A/	2	9	69	2.338	1	1	1	TZONE		1905	0	1810	F2	0.92	2473	0.73	5x4x5.75#T	2nd 4
		F/	4	9	69	2.338	1	1	1	TZONE		1905	0	1810	F2	0.92	2473	0.73		2nd 4
39	SDK10203	A/	2	9	68	2.338	1	1	1	TZONE		1759	0	1671	F2	0.92	2473	0.68	5x4x5.75#T	2nd 3

STF #	SafeHull STF ID	TOE	ID	Dist. from BL (m)	SM (cm3)	Unsup Span (m)	Ct	Cy	LP#	LC#	Local Load Range (m)	Stress Range (kg/cm2)		f_R	FATIG CLASS	Long Term Distr Factor	Perm. Stress (kg/cm2)		SCANT-LINGS	USER DEFINED ID
												f_{RG}	f_{RL}				P_S	fR/PS		
		F/	4	9	68	2.338	1	1	1	TZONE		1759	0	1671	F2	0.92	2473	0.68		2nd 3
40	SDK10204	A/	2	9	68	2.338	1	1	1	TZONE		1613	0	1532	F2	0.92	2473	0.62	5x4x5.75#T	2nd 3
		F/	4	9	68	2.338	1	1	1	TZONE		1613	0	1532	F2	0.92	2473	0.62		2nd 3
41	SDK10305	A/	2	9	68	2.338	1	1	1	TZONE		1466	0	1393	F2	0.92	2473	0.56	5x4x5.75#T	2nd 2
		F/	4	9	68	2.338	1	1	1	TZONE		1466	0	1393	F2	0.92	2473	0.56		2nd 2
42	SDK10306	A/	2	9	68	2.338	1	1	1	TZONE		1339	0	1272	F2	0.92	2473	0.51	5x4x5.75#T	2nd 2
		F/	4	9	68	2.338	1	1	1	TZONE		1339	0	1272	F2	0.92	2473	0.51		2nd 2
43	SDK10307	A/	2	9	68	2.338	1	1	1	TZONE		1211	0	1151	F2	0.92	2473	0.47	5x4x5.75#T	2nd 2
		F/	4	9	68	2.338	1	1	1	TZONE		1211	0	1151	F2	0.92	2473	0.47		2nd 2
44	SDK10308	A/	2	9	68	2.338	1	1	1	TZONE		1084	0	1030	F2	0.92	2473	0.42	5x4x5.75#T	2nd 2
		F/	4	9	68	2.338	1	1	1	TZONE		1084	0	1030	F2	0.92	2473	0.42		2nd 2
45	SDK10409	A/	2	9	68	2.338	1	1	1	TZONE		957	0	909	F2	0.92	2473	0.37	5x4x5.75#T	2nd 1
		F/	4	9	68	2.338	1	1	1	TZONE		957	0	909	F2	0.92	2473	0.37		2nd 1
46	SDK10410	A/	2	9	68	2.338	1	1	1	TZONE		843	0	801	F2	0.92	2473	0.32	5x4x5.75#T	2nd 1
		F/	4	9	68	2.338	1	1	1	TZONE		843	0	801	F2	0.92	2473	0.32		2nd 1
47	SDK10411	A/	2	9	68	2.338	1	1	1	TZONE		730	0	693	F2	0.92	2473	0.28	5x4x5.75#T	2nd 1
		F/	4	9	68	2.338	1	1	1	TZONE		730	0	693	F2	0.92	2473	0.28		2nd 1

Table J.2 Phase A Fatigue Analysis of Class F2 Flat Bars for Ship J

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SHIP :
LxBxDxd = 150.79x 16.31x 11.83x 5.03(m)
Hull-Girder Moment of Inertia Ivert. 231939.(cm2-m2) Ihoriz. 347129.(cm2-m2)
Neutral Axis Height 5.74(m) above baseline
Slamming factor for deck and bottom structures, ms= 1.000
FATIGUE CONTROL FOR FLAT-BAR SUPPORT STIFFENERS OF LONGITUDINALS
S U M M A R Y
Special Location at 77.72m from AP (0.485 L from aft end of L)
Scantling Group # 1
Range of Wave-induced Bending Moment MW(vert.) 94216.(tf-m) MW(horiz.) 75632.(tf-m)

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
BTM10101	1	1	0.04	0.764	2.338	5.22	9.55	7.1 28	.5 1	0.5	255	2039	2074	F2	0.893	2590	0.8
		2	0.04	0.764	2.338	5.22	9.55	7.1	28.5	1.25	255	2039	2064	F2	0.893	2590	0.8
[Weld Throat]			0.04	0.764	2.338	5.22	9.55	[Asw]=	4.8	1.25	255	0	473	W	0.893	1868	0.25
BTM10202	1	1	0.21	0.762	2.338	5.2	9.48	7.1	28.5	1.5	253	1979	2015	F2	0.893	2590	0.78
		2	0.21	0.762	2.338	5.2	9.48	7.1	28.5	1.25	253	1979	2004	F2	0.893	2590	0.77
[Weld Throat]			0.21	0.762	2.338	5.2	9.48	[Asw]=	4.8	1.25	253	0	470	W	0.893	1868	0.25
BTM10403	1	1	0.52	0.772	2.338	5.16	9.54	7.1	28.5	1.5	255	1880	1919	F2	0.893	2590	0.74
		2	0.52	0.772	2.338	5.16	9.54	7.1	28.5	1.25	255	1880	1907	F2	0.893	2590	0.74
[Weld Throat]			0.52	0.772	2.338	5.16	9.54	[Asw]=	4.8	1.25	255	0	473	W	0.893	1868	0.25
BLG10101	1	1	0.98	0.776	2.338	5.1	9.48	7.1	28.5	1.5	253	1733	1774	F2	0.893	2590	0.68
		2	0.98	0.776	2.338	5.1	9.48	7.1	28.5	1.25	253	1733	1762	F2	0.893	2590	0.68
[Weld Throat]			0.98	0.776	2.338	5.1	9.48	[Asw]=	4.8	1.25	253	0	470	W	0.893	1868	0.25
BLG10202	1	1	1.83	0.779	2.338	6.07	11.33	7.1	27.5	1.5	311	2416	2461	F2	0.893	2590	0.95
		2	1.83	0.779	2.338	6.07	11.33	7.1	27.5	1.25	311	2416	2447	F2	0.893	2590	0.94
[Weld Throat]			1.83	0.779	2.338	6.07	11.33	[Asw]=	4.8	1.25	311	0	577	W	0.893	1868	0.31
SHL10201	1	1	3.04	0.719	2.338	8.28	14.27	7.1	27.5	1.5	392	2913	2972	F2	0.931	2429	1.22

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
		2	3.04	0.719	2.338	8.28	14.27	7.1	27.5	1.25	392	2913	2954	F2	0.931	2429	1.22
[Weld Throat]			3.04	0.719	2.338	8.28	14.27	[Asw]=	4.8	1.25	392	0	727	W	0.931	1750	0.42
SHL10202	1	1	3.69	0.798	2.338	9.74	18.65	5.9	22.9	1.5	616	3191	3322	F2	0.931	2429	1.37
		2	3.69	0.798	2.338	9.74	18.65	5.9	22.9	1.25	616	3191	3282	F2	0.931	2429	1.35
[Weld Throat]			3.69	0.798	2.338	9.74	18.65	[Asw]=	4.8	1.25	616	0	950	W	0.931	1750	0.54
SHL10403	2	1	5.27	0.762	2.338	12.79	23.36	5.9	18.7	1.5	492	2751	2848	F2	0.931	2429	1.17
		2	5.27	0.762	2.338	12.79	23.36	5.9	18.7	1.25	492	2751	2819	F2	0.931	2429	1.16
[Weld Throat]			5.27	0.762	2.338	12.79	23.36	[Asw]=	4.8	1.25	492	0	759	W	0.931	1750	0.43
SHL10404	2	1	6.02	0.72	2.338	11.32	19.54	5.9	18.7	1.5	241	2206	2235	F2	0.931	2429	0.92
		2	6.02	0.72	2.338	11.32	19.54	5.9	18.7	1.25	241	2206	2226	F2	0.931	2429	0.92
[Weld Throat]			6.02	0.72	2.338	11.32	19.54	[Asw]=	4.8	1.25	241	0	372	W	0.931	1750	0.21
SHL10505	3	1	6.7	0.644	2.338	10	15.44	5.9	14.8	1.5	213	2335	2357	F2	0.931	2429	0.97
		2	6.7	0.644	2.338	10	15.44	5.9	14.8	1.25	213	2335	2350	F2	0.931	2429	0.97
[Weld Throat]			6.7	0.644	2.338	10	15.44	[Asw]=	4.8	1.25	213	0	328	W	0.931	1750	0.19
SHL10506	3	1	7.31	0.61	2.338	8.81	12.88	5.9	14.8	1.5	178	2343	2358	F2	0.931	2429	0.97
		2	7.31	0.61	2.338	8.81	12.88	5.9	14.8	1.25	178	2343	2353	F2	0.931	2429	0.97
[Weld Throat]			7.31	0.61	2.338	8.81	12.88	[Asw]=	4.8	1.25	178	0	274	W	0.931	1750	0.16
SHL10507	3	1	7.92	0.61	2.338	7.62	11.14	5.9	14.8	1.5	154	2378	2389	F2	0.931	2429	0.98
		2	7.92	0.61	2.338	7.62	11.14	5.9	14.8	1.25	154	2378	2386	F2	0.931	2429	0.98
[Weld Throat]			7.92	0.61	2.338	7.62	11.14	[Asw]=	4.8	1.25	154	0	237	W	0.931	1750	0.14
SHL10508	3	1	8.53	0.606	2.338	6.43	9.34	5.9	14.8	1.5	129	2411	2419	F2	0.931	2429	1
		2	8.53	0.606	2.338	6.43	9.34	5.9	14.8	1.25	129	2411	2417	F2	0.931	2429	0.99
[Weld Throat]			8.53	0.606	2.338	6.43	9.34	[Asw]=	4.8	1.25	129	0	199	W	0.931	1750	0.11
SHS10201	3	1	10.01	0.876	2.338	3.22	6.77	4.9	12.3	1.5	372	2326	2392	F2	0.882	2651	0.9
		2	10.01	0.876	2.338	3.22	6.77	4.9	12.3	1.25	372	2326	2372	F2	0.882	2651	0.89
[Weld Throat]			10.01	0.876	2.338	3.22	6.77	[Asw]=	4.8	1.25	372	0	480	W	0.882	1910	0.25
SHS10202	3	1	10.88	0.91	2.338	0	0	4.9	12.3	1.5	0	1986	1986	F2	0.855	2804	0.71
		2	10.88	0.91	2.338	0	0	4.9	12.3	1.25	0	1986	1986	F2	0.855	2804	0.71
[Weld Throat]			10.88	0.91	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10101	3	1	11.85	0.718	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.85	0.718	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.85	0.718	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
DEC10102	3	1	11.88	0.768	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.88	0.768	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.88	0.768	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10203	3	1	11.91	0.768	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.91	0.768	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.91	0.768	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10204	3	1	11.93	0.762	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.93	0.762	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.93	0.762	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10205	3	1	11.95	0.724	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.95	0.724	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.95	0.724	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10306	3	1	11.96	0.686	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.96	0.686	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.96	0.686	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10307	3	1	11.96	0.686	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.96	0.686	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.96	0.686	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10308	3	1	11.97	0.686	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.97	0.686	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.97	0.686	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10309	3	1	11.98	0.648	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.98	0.648	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.98	0.648	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10410	3	1	11.98	0.61	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.98	0.61	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.98	0.61	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
DEC10411	3	1	11.98	0.458	2.338	0	0	3.8	9.5	1.5	0	2273	2273	F2	0.855	2804	0.81
		2	11.98	0.458	2.338	0	0	3.8	9.5	1.25	0	2273	2273	F2	0.855	2804	0.81
[Weld Throat]			11.98	0.458	2.338	0	0	[Asw]=	4.8	1.25	0	0	0	W	0.855	2017	0
INB10101	2	1	1.37	0.724	2.338	0.5	0.87	7.1	22.5	1.5	28	1862	1863	F2	0.893	2590	0.72
		2	1.37	0.724	2.338	0.5	0.87	7.1	22.5	1.25	28	1862	1862	F2	0.893	2590	0.72

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
[Weld Throat]			1.37	0.724	2.338	0.5	0.87	[Asw]=	4.8	1.25	28	0	52	W	0.893	1868	0.03
INB10302	2	1	1.39	0.686	2.338	0.5	0.82	7.1	22.5	1.5	26	1850	1850	F2	0.893	2590	0.71
		2	1.39	0.686	2.338	0.5	0.82	7.1	22.5	1.25	26	1850	1850	F2	0.893	2590	0.71
[Weld Throat]			1.39	0.686	2.338	0.5	0.82	[Asw]=	4.8	1.25	26	0	49	W	0.893	1868	0.03
INB10403	2	1	1.49	0.728	2.338	0.49	0.85	7.1	22.5	1.5	27	1814	1815	F2	0.893	2590	0.7
		2	1.49	0.728	2.338	0.49	0.85	7.1	22.5	1.25	27	1814	1814	F2	0.893	2590	0.7
[Weld Throat]			1.49	0.728	2.338	0.49	0.85	[Asw]=	4.8	1.25	27	0	51	W	0.893	1868	0.03
INB10504	3	1	1.83	0.658	2.338	0.44	0.7	7.1	17.8	1.5	27	1675	1675	F2	0.893	2590	0.65
		2	1.83	0.658	2.338	0.44	0.7	7.1	17.8	1.25	27	1675	1675	F2	0.893	2590	0.65
[Weld Throat]			1.83	0.658	2.338	0.44	0.7	[Asw]=	4.8	1.25	27	0	49	W	0.893	1868	0.03
INB10705	3	1	2.47	0.626	2.338	0.36	0.54	7.1	17.8	1.5	21	1410	1410	F2	0.893	2590	0.54
		2	2.47	0.626	2.338	0.36	0.54	7.1	17.8	1.25	21	1410	1410	F2	0.893	2590	0.54
[Weld Throat]			2.47	0.626	2.338	0.36	0.54	[Asw]=	4.8	1.25	21	0	38	W	0.893	1868	0.02
INB10806	3	1	3.45	0.61	2.338	0.23	0.34	5.9	14.8	1.5	16	1013	1013	F2	0.893	2590	0.39
		2	3.45	0.61	2.338	0.23	0.34	5.9	14.8	1.25	16	1013	1013	F2	0.893	2590	0.39
[Weld Throat]			3.45	0.61	2.338	0.23	0.34	[Asw]=	4.8	1.25	16	0	24	W	0.893	1868	0.01
INB10807	3	1	4	0.59	2.338	0.16	0.22	5.9	14.8	1.5	10	783	783	F2	0.893	2590	0.3
		2	4	0.59	2.338	0.16	0.22	5.9	14.8	1.25	10	783	783	F2	0.893	2590	0.3
[Weld Throat]			4	0.59	2.338	0.16	0.22	[Asw]=	4.8	1.25	10	0	16	W	0.893	1868	0.01
SDK10101	4	1	9.13	0.799	2.338	0	0	4.6	7.3	1.5	0	1949	1949	F2	0.92	2473	0.79
		2	9.13	0.799	2.338	0	0	4.6	7.3	1.25	0	1949	1949	F2	0.92	2473	0.79
SDK10102	4	1	9.13	0.788	2.338	0	0	4.6	7.3	1.5	0	1810	1810	F2	0.92	2473	0.73
		2	9.13	0.788	2.338	0	0	4.6	7.3	1.25	0	1810	1810	F2	0.92	2473	0.73
SDK10203	4	1	9.13	0.788	2.338	0	0	4.6	7.3	1.5	0	1671	1671	F2	0.92	2473	0.68
		2	9.13	0.788	2.338	0	0	4.6	7.3	1.25	0	1671	1671	F2	0.92	2473	0.68
SDK10204	4	1	9.13	0.787	2.338	0	0	4.6	7.3	1.5	0	1532	1532	F2	0.92	2473	0.62
		2	9.13	0.787	2.338	0	0	4.6	7.3	1.25	0	1532	1532	F2	0.92	2473	0.62
SDK10305	4	1	9.13	0.736	2.338	0	0	4.6	7.3	1.5	0	1393	1393	F2	0.92	2473	0.56
		2	9.13	0.736	2.338	0	0	4.6	7.3	1.25	0	1393	1393	F2	0.92	2473	0.56
SDK10306	4	1	9.13	0.686	2.338	0	0	4.6	7.3	1.5	0	1272	1272	F2	0.92	2473	0.51
		2	9.13	0.686	2.338	0	0	4.6	7.3	1.25	0	1272	1272	F2	0.92	2473	0.51
SDK10307	4	1	9.13	0.686	2.338	0	0	4.6	7.3	1.5	0	1151	1151	F2	0.92	2473	0.47

Cutout LABEL	ID	LOC	Dist. from BL(m)	Long`l Spacing (m)	Long`l Length (m)	Local Load Range		Support Areas		SCF	Stress Range (kg/cm2)			FATIG CLASS	Long Term Distr. Factor	Permissible Stress (kg/cm2) PS	fR/PS
						Head (m)	Force (tf)	As (cm^2}	Ac (cm^2}		fs	fL	fRi				
		2	9.13	0.686	2.338	0	0	4.6	7.3	1.25	0	1151	1151	F2	0.92	2473	0.47
SDK10308	4	1	9.13	0.685	2.338	0	0	4.6	7.3	1.5	0	1030	1030	F2	0.92	2473	0.42
		2	9.13	0.685	2.338	0	0	4.6	7.3	1.25	0	1030	1030	F2	0.92	2473	0.42
SDK10409	4	1	9.13	0.647	2.338	0	0	4.6	7.3	1.5	0	909	909	F2	0.92	2473	0.37
		2	9.13	0.647	2.338	0	0	4.6	7.3	1.25	0	909	909	F2	0.92	2473	0.37
SDK10410	4	1	9.13	0.61	2.338	0	0	4.6	7.3	1.5	0	801	801	F2	0.92	2473	0.32
		2	9.13	0.61	2.338	0	0	4.6	7.3	1.25	0	801	801	F2	0.92	2473	0.32
SDK10411	4	1	9.13	0.458	2.338	0	0	4.6	7.3	1.5	0	693	693	F2	0.92	2473	0.28
		2	9.13	0.458	2.338	0	0	4.6	7.3	1.25	0	693	693	F2	0.92	2473	0.28

APPENDIX K

OPNAV Instruction 4700.7J
Maintenance Policy for Naval Ships
December 4, 1992

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OPNAV Instruction 4700.7J
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December 4, 1992

References:

(a) OPNAVNOTE 4700, Notional Durations, Intervals, and Repair Man-Days for Depot-Level Maintenance Availabilities of United States Navy Ships of 2 Dec 92

(b) OPNAVINST 4780.6C, Procedures for Administering Service Craft and Boats in the U.S. Navy

(c) OPNAVINST 4720.2E, Policy for Fleet Modernization Program (FMP)

(d) MIL-STD-1388, Logistics Support Analysis

(e) MIL-P-24534 , Planned Maintenance System: Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation

(f) OPNAVINST 4790.4B, Ships' Maintenance and Material Management (3-M) Manual

1. Purpose. To establish policy and responsibility for determining, authorizing, planning, scheduling, performing, and evaluating maintenance of ships, to ensure quality, safety, and operational readiness.

2. Scope

a. This instruction applies to all ships of the United States Navy (active and reserve), except civilian operated ships assigned to the Military Sealift Command. Throughout this instruction, the term "ship" refers to all surface ships, aircraft carriers, submarines, and those patrol and service craft specified in reference (a). Reference (b) provides policy and guidance for maintenance of service craft and boats not addressed in reference (a).

b. The Ship Maintenance Program is one of two major components of the Navy's program for maintenance and modernization of ships, which, in its entirety, defines and manages the material condition requirements and the configuration of Navy ships. The Ship Maintenance Program is designed to keep ships at the highest level of material condition practicable, and to provide reasonable assurance of their availability for operations to the Fleet Commanders. The second major component, the Fleet Modernization Program (FMP), is designed to maintain the integrity of ship configuration as changes are authorized. While the maintenance and modernization programs and budgets are distinct, the programs are closely related in their planning and execution. This instruction addresses the Ship Maintenance Program, with reference to modernization, as necessary. The Fleet Modernization Program is addressed by reference (c).

c. This instruction applies to the three echelons of maintenance: organizational-, intermediate-, and depot-level. Enclosures (l), (2), and (3), respectively, address these maintenance echelons.

3. Policy

a. Ships shall be maintained in a safe material condition, adequate to allow accomplishment of assigned missions.

b. Maintenance for new acquisition ships, systems, and equipment shall be based on Reliability-Centered Maintenance (RCM) principles in order to achieve readiness objectives in the most cost-effective manner, as outlined in reference (d). Maintenance plans for in-service ships, systems, and equipment should be reviewed and modified to incorporate RCM principles in areas where it can be determined that the expected results will be commensurate with associated costs.

c. Condition-Based Maintenance (CBM) diagnostics, inspections, and tests shall be utilized to the maximum extent practicable to determine performance and material condition of, and to schedule corrective maintenance actions for ships, systems, and equipment. CBM is based on objective evidence of actual or predictable failure of a ship's installed systems or components. This includes:

(1) Condition-directed maintenance based on objective evidence of actual or potential failure, or valid condition trend information.

(2) Adjustments to time-directed preventive maintenance such as oil changes, greasing, component software changeouts, and periodic checks based on valid engineering analysis such as the assessment of the as-found material condition of components or systems when they are disassembled for maintenance, or age-reliability analysis.

d. Maintenance actions shall be either preventive or corrective. Preventive maintenance actions shall be selected using RCM principles, which maximize the reliability of ships and minimize the total maintenance workload.

(1) Preventive maintenance actions are those actions intended to prevent or discover functional failures.

(2) Corrective maintenance actions are those actions intended to return or restore equipment to acceptable performance levels.

e. Maintenance actions shall be authorized to be performed by the lowest maintenance echelon that can ensure proper accomplishment, taking into consideration urgency, priority, capability, capacity, and cost.

(1) RCM-applicable and RCM-effective preventive maintenance actions, as defined in reference (e), shall be performed at all maintenance echelons, as authorized. Preventive maintenance for new acquisition ships, systems, and equipment shall be RCM-developed in accordance with references (d) and (e). Preventive maintenance actions for in-service ships, systems, and equipment should be reviewed and modified to incorporate RCM principles when it can be determined that the expected results will be cost effective.

(2) All organizational-level preventive maintenance actions shall be documented on Maintenance Index Pages (MIPs) in the ship's Planned Maintenance System (PMS) and managed by ship's force in accordance with the Maintenance and Material Management (3-M) system, reference (f).

(3) All intermediate- and depot-level preventive maintenance actions shall be documented as Master Job Catalog (MJC) items in the Maintenance Resource Management System (MRMS), or in an alternate Chief of Naval Operations (CNO) approved maintenance management system, and managed by fleet-designated subordinate activities in accordance with fleet guidelines.

(4) Preventive maintenance actions shall be:

(a) Detailed on Maintenance Requirements Cards (MRCS) for organizational-level accomplishment, and as MJC items for intermediate- and depot-level accomplishment.

(b) Scheduled in accordance with the 3-M system for organizational-level accomplishment.

(c) Scheduled in accordance with the Periodic Maintenance Requirements Scheduling Subsystem of MRMS or an alternate CNO-approved maintenance scheduling system for intermediate- and depot-level accomplishment.

(d) Accomplished as scheduled.

(5) RCM-applicable and RCM-effective corrective maintenance actions may be required to restore systems or equipment to full operation, to bring operation to within specified parameters, or to ensure safe operations.

(a) The decision to perform corrective maintenance shall be based on actual equipment condition.

(b) Safety related corrective maintenance is mandatory and shall be accomplished at the earliest opportunity.

(c) The corrective maintenance action selected (i.e., repair, replacement, or alteration) shall be based on optimizing cost and reliability considerations. Execution shall be in accordance with applicable repair or installation standards or specific technical documentation.

f. The Current Ship's Maintenance Project (CSMP) shall be the primary repository of information concerning the material condition of the ship and shall be maintained by ship's force in a complete and current status at all times.

(1) The CSMP shall be used by the ship to document all deferred preventive and corrective maintenance requirements regardless of the source of the requirements. These deferred items shall be validated by ship's force and entered into the CSMP in accordance with reference (f) guidelines.

(2) The CSMP shall include deferred material deficiencies reported by headquarters or fleet inspections such as Underwater Ship Husbandry Inspections, Underway Material Inspections, and Propulsion Examining Board Examinations. Where practical, deficiencies identified from these inspections should be provided to the ship in electronic format compatible with CSMP automated format to avoid imposition of laborious data entry requirements on ship's force.

g. A Maintenance Program shall be developed, within existing infrastructure, for each ship class. The Maintenance Program for each ship class shall:

(1) Be defined, for CNO (N85, N86, N87, or N88) approval, in a Maintenance Program Master Plan. The Maintenance Program Master Plan provides a general overview of the cognizant Program Executive Offices (PEOs), Direct Reporting Program Managers (DRPMs), or Ship Program Manager's (SPMs) maintenance plan for the ship class. It specifies key elements, such as: depot-level availability intervals and durations, frequency of intermediate-level availabilities, and any special maintenance, maintenance support, or infrastructure requirements.

(2) Be documented in a Class Maintenance Plan (CMP), for Commander, Naval Sea Systems Command (COMNAVSEASYSCOM) approval. For new ship classes, the CMP shall be based on logistics support analysis, reference (d). The CMP is a detailed, comprehensive document for Maintenance Program Master Plan implementation. CMPS, for in-service ship classes, should be reviewed and modified to comply with reference (d) when it can be determined that the expected results will be commensurate with associated costs.
   (a) The CMP shall include all preventive maintenance actions (organizational-, intermediate-, and depot-level) with engineered periodicities. An engineered periodicity is the recommended periodicity for accomplishment of a maintenance action, and is based upon an engineering analysis of all relevant technical maintenance history information, including material condition and performance feedback data.
   (b) Details concerning development and implementation of Maintenance Program Master Plans and CMPS are provided in enclosure (4).
(3) Emphasize the accomplishment of maintenance actions performed on a continuous basis throughout the ship's life cycle, using RCM and CBM principles.
(4) Emphasize assignment of maintenance actions to the lowest maintenance echelon that can ensure proper accomplishment, taking into consideration urgency, priority, capability, capacity, and cost.
(5) Provide a selection of special support alternatives. (e.g., rotatable pools, insurance item management, or dedicated maintenance husbandry agents, such as Port Engineers or AEGIS Homeport Engineering Teams) whose use would be determined through the evaluation of technical and economic criteria.
(6) Minimize the time ships spend in depot maintenance by ensuring that depot maintenance availability notional intervals and durations are an integral part of both the acquisition and the life-cycle maintenance strategy for ships, and are determined by maintenance requirements, and not by anticipated modernization requirements. The installation of new alterations should be planned and scheduled to conform to these notional depot maintenance intervals and durations. Actual availability durations will be altered as necessary to accomplish all required maintenance and modernization actions.
(7) Ensure that ships and other fleet activities are as self-sufficient as practicable. The Navy should drive increasingly toward "one way of doing business" for ship maintenance, authorizing variances only where a compelling case is made and approved. Self-sufficiency shall not be interpreted as authorization or direction to independently develop and support class or ship-unique maintenance processes, or information systems. Within the framework of this vision, maintenance programs shall utilize the following resources, enhancing self-sufficiency:
   (a) Reliable on-site or onboard technical decision-making support programs, such as the Miniature/Microminiature (2M) Electronic Repair Program and Mobile Technical Units (MOTUS), described in enclosures (5) and (6), respectively.
   (b) Accurate technical information and data about system and equipment performance requirements, operating procedures, and maintenance and repair technical requirements and procedures. The key to this is the effectiveness of

the Integrated Logistic Support (ILS) program and the manner in which that program is integrated into the larger Navy maintenance infrastructure.

(c) Effective processes and tools to minimize the labor hours required to: identify, locate, extract, and apply information and data required to perform work correctly the first time, and to accurately report work completion data. Examples are: the Advanced Technical Information System (ATIS), Maintenance Resource Management System (MRMS), Shipboard Non-tactical Auto Data Processing (SNAP) Program, Organizational Maintenance Management System (OMMS), and the Advanced Industrial Management (AIM) Program.

h. Intermediate Maintenance Activities (IMAs) are fleet assets to be utilized for accomplishment of maintenance and modernization that is beyond organizational-level capability or capacity, but not requiring depot-level assets. Intermediate-level maintenance is addressed further in enclosure (2). Maintenance of ship systems and equipment shall be performed by qualified personnel using correct procedures and material in accordance with technical requirements issued by the appropriate technical authority. Policy and direction promulgated by the Fleet Commanders in Chief (FLTCINCS), COMNAVSEASYSCOM, or their subordinate activities shall comply with such technical requirements. FLTCINCS and COMNAVSEASYSCOM shall ensure the establishment of procedures addressing deviations in technical requirements. These procedures shall:

(1) Ensure that the activity, when finding itself unable to comply with technical requirements, recommends to the appropriate technical authority a repair that the activity considers achievable and that will ensure that the needs of the fleet are satisfied.

(2) Differentiate between categories of repair, and identify, by each category of repair, the appropriate technical authority that can authorize deviation from technical requirements.

(3) Ensure work does not proceed until concurrence from appropriate technical authority is received.

(4) Ensure cognizant technical authority revises applicable technical requirements, or documents a deviation from technical requirements, to reflect resolution of the repair.

i. Depot maintenance activities perform maintenance and modernization work that is beyond intermediate-level capability or capacity. Depot-level maintenance is addressed in enclosure (3).

j. Ship configuration shall be controlled through a formal change process that provides for updating of the Ship’s Configuration and Logistics Support Information System (SCLSIS) database.

k. Equipment and components installed in Navy ships shall be standardized to the maximum extent practicable to minimize life cycle logistics support costs. This means that maintenance and modernization changes, as well as new construction changes, should emphasize the use of equipment and components already supported by the Federal Supply System to the maximum extent practicable, with due consideration to life cycle cost, reliability, and maintainability.

l. Effective Integrated Logistics Support (ILS) and the resources required to implement the Maintenance Program over the life cycle of each new ship class shall be programmed and budgeted in sufficient time to ensure that support is in place by no later than the end of the lead ship's post-shakedown availability. For systems being introduced for in-service ships, ILS resources shall be programmed and budgeted to ensure support is in place coincident with fleet

m. Drydocking shall be planned and scheduled in accordance with the ship's Maintenance Program Master Plan and Class Maintenance Plan. Underwater Ship Husbandry (UWSH) inspection, maintenance, or repair actions shall be planned and accomplished in accordance with reference (j) .

(1) In the event drydocking maintenance actions are required before planned, a review of current UWSH capabilities shall be undertaken by the responsible repair activity to determine if drydocking is necessary or if emergent drydock time can be reduced cost effectively, by accomplishing repairs with qualified divers using approved procedures.

(2) Whenever feasible, UWSH maintenance actions should provide permanent repairs to avoid subsequent drydock rework costs . Where permanent repairs are not feasible, temporary repairs shall be accomplished, within technical and cost constraints, to support ship operations until the next regularly scheduled drydocking.

4. <u>Responsibilities</u>

a. Chief of Naval Operations (CNO). The CNO is responsible for maintaining the overall readiness of naval forces. This includes the responsibility for planning and programming resources required for the acquisition, life cycle management, maintenance, and modernization of Navy ships.

(1) CNO (N43), as the CNO staff (OPNAV) point of contact for all Ship Maintenance Program issues that cross Operational Forces Resource Sponsor boundaries, will:

(a) Coordinate the Ship Maintenance Program with the Operational Forces Resource Sponsors (N85, N86, N87, and N88), FLTCINCS, COMNAVSEASYSCOM, PEOS, and DRPMs, as required.

(b) Concur with all Maintenance Program Master Plans prior to approval by cognizant Operational Forces Resource Sponsors.

(c) Assess ship maintenance requirements, identify funding and other program deficiencies, and recommend resolutions to properly execute the Ship Maintenance Program.

(d) Document, via reference (a) , approved Maintenance Program Master Plan depot maintenance availability notional durations, intervals, and repair man-days for all ship classes to be used for scheduling, programming, and budgeting purposes.

(e) Approve the location and dates of all CNO-scheduled depot maintenance availabilities.

(2) Operational Forces Resource Sponsors (N85, N86, N87, and N88) will:

(a) Approve all Maintenance Program Master Plans for their respective platforms and monitor compliance.

(b) Plan and program the resources required to fully support the Maintenance Program Master Plans, including: organizational-, intermediate-, and depot-level maintenance; ship acquisition; and ship disposition.

(3) The Deputy Chief of Naval Operations (Manpower and Personnel), CNO (Nl), will provide trained, qualified military personnel to perform maintenance at all levels.

b. FLTCINCS. The FLTCINCS are responsible for the material condition of their assigned ships. The FLTCINCS shall:

(1) Identify and authorize required maintenance actions, using condition, cost, schedule, and mission trade-offs, as required.
(2) Ensure that ship's force, IMA, and SRF maintenance actions are planned and accomplished by qualified personnel using correct procedures and materials in accordance with cognizant technical requirements.
(3) Approve those changes to CNO-scheduled depot maintenance availabilities authorized by enclosure (3) .
(4) Implement standard maintenance policies between the Atlantic and Pacific fleets.
(5) Participate in the development and implementation of each CMP.
(6) Promote self-sufficiency of fleet ships and activities.
(7) Fund ship systems Direct Fleet Support (DFS) services provided by the Naval Sea Systems Command and its subordinate activities on a cost reimbursable basis.
(8) Provide feedback of resource expenditures and as-found material condition to the 3-M System. Resource expenditure feedback is required in detail sufficient for continuous improvement of depot-level planning, programming, and budgeting. As-found material condition feedback is required in detail sufficient to support refinement and validation of technical requirements, to perform engineering analysis, and to schedule subsequent maintenance actions.
(9) Comply with additional responsibilities issued in enclosures to this instruction.

c. COMNAVSEASYSCOM. As the lead hardware systems commander for ship life cycle management, COMNAVSEASYSCOM shall:

(1) Establish Hull, Mechanical, and Electrical (HM&E) and combat systems technical requirements and provide the technical support necessary to maintain the material condition of all ships.
(2) Command the Naval Shipyards (NSYS) and Supervisors of Shipbuilding, Conversion and Repair (SUPSHIPs).
(3) Ensure that NSYS and SUPSHIPs execute ship maintenance and modernization within the scope of work authorized, employing prescribed technical and quality standards, specifications, and requirements in an efficient manner.

(4) Issue and maintain current Navy equipment drawings, technical manuals, repair standards, maintenance and test requirements, and process controls as required for ship, system, and equipment operation and maintenance.
(5) Assist and advise FLTCINCS and Type Commanders (TYCOMS) in Condition-Based Maintenance implementation.
(6) Develop RCM-based material condition diagnostic systems needed for more effective maintenance decision-making, and develop or integrate information systems required to support increased maintenance self-sufficiency of ships and other fleet activities.
(7) Manage the ship's 3-M System as specified in reference (f).
(8) Provide ship system DFS services on a cost-reimbursable basis as requested by the FLTCINCS. This support includes advice, instruction, and training of fleet personnel under the operational control of Fleet Commanders. It also includes reviews, tests, and inspections to evaluate the effectiveness and material condition of ship equipment and systems.
(9) Comply with additional responsibilities issued in enclosures to this instruction.

d. PEOS, DRPMs, and SPMS. PEOS, DRPMs, and SPMS shall:
(1) Assist and advise FLTCINCS and TYCOMS in condition-based maintenance implementation.
(2) Develop RCM-based material condition diagnostic systems needed for more effective maintenance decision-making, and develop or integrate information systems required to support increased maintenance self-sufficiency of ships and other fleet activities.
(3) Issue and maintain current selected record data, ship drawings, and ship-class-specific technical manuals.
(4) Analyze in-service operational data and maintenance feedback through 3-M maintenance data, casualty reports, repair activity discrepancy reports, guarantee and warranty deficiencies and other reporting sources to determine design and process improvements and to refine maintenance requirements.
(5) Approve those changes to CNO-scheduled depot maintenance availabilities authorized by enclosure (3) .
(6) Comply with additional responsibilities issued in enclosures to this instruction.

e. Chief of Naval Personnel (CHNAVPERS). CHNAVPERS is responsible for providing trained, qualified, military personnel, as specified by current manpower authorization, to perform organizational and intermediate levels of maintenance.

f. Chief of Naval Education and Training (CNET). CNET shall provide effective training in maintenance skills for military personnel in accordance with reference (p) and modify training programs to enhance quality maintenance as described in enclosure (7). RCM, CBM, and quality maintenance concepts and methods shall be included in shipboard watchstanders, equipment operators, maintainers, supervisors, planners, and engineering training programs.

APPENDIX L

S9086–CN–STM–040
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APPENDIX L

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The information cited below represents selected extracts from the Naval Ship's Technical Manual related to requirements for inspecting the structure of ships in service.

Naval Ship's Technical Manual Chapter 074, Volume 2. Nondestructive Testing of Metals, Qualification and Certification Requirements for Naval Personnel (non-Nuclear)

Table 074-11. Mandatory Reference Documents

Identification	Title
MIL-STD-1688	Fabrication, Welding, & Inspection of HY-80/100 Submarine Applications
MIL-STD-1689	Fabrication, Welding, & Inspection of Noncombatant Ship Structures
NAVSEA 0900 - LP - 003 - 9000	Radiography Standard for Production & Repair Welds
NAVSEA 0900 - LP - 003 - 8000	Surface Inspection Acceptance Standards for Metals (NOTE: Includes MT, PT & Visual Inspection)
NAVSEA 0900-LP-001 -7000	Fabrication & Inspection of Brazed Piping Joints
MIL-STD-278	Standard for Welding & Allied Processes on Piping and Machinery
MIL-STD-271	Requirements for Nondestructive Testing Methods
AWS A2.4	American Welding Society: Symbols for Welding and Nondestructive Testing
NAVSEA 0900 - LP - 999 - 9000	Acceptance Standards for Surface Finish of Flame or Arc-Cut Material
MIL-STD-248	Welding and Brazing Procedure and Performance Qualification
NAVPERS 15105	Manual of Navy Enlisted Classification
ASTM-E-446	Reference Radiographs for Steel Castings Up to 2 Inches in Thickness
ASTM-E-155	Reference Radiographs for Aluminum and Magnesium Castings
ASTM-E-186	Reference Radiographs for Heavy Walled (2 to 4-1/2 in.) Steel Castings
ASTM-E-272	Reference Radiographs for High Strength Copper Base and Nickel Copper Alloy Castings
ASTM-E-310	Radiographs Acceptance Criteria for Tin Bronze Castings
MIL-STD-2195(SH)	Inspection Procedures for Detection and Measurement of Dealloying Corrosion on Aluminum Bronze and Nickel Aluminum Bronze Components

Table 074-12. Guidance Reference Documents

Identification	Title	Publisher
ASTM - E - 125	Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings	American Society for Testing and Materials
VOLUMES I and 11	Nondestructive Testing Handbook	American Society for Non-destructive Testing
VOLUMES I thru % 2nd edition	Programmed Instruction Handbooks Radiography in Modern Industry	American Society for Non-destructive Testing Eastman Kodak Company
ASTM Std.	Methods of Testing Metals—Part 3	American Society for Testing and Materials
Section 1 No. 1 H-55	Welding Handbook Living with Radiation Quality and Reliability Assurance Handbook Non-destructive Testing Series; Radiography	American Welding Society U.S. Atomic Energy Commission Government Printing Office
Recommended Practice SNT-TC-LA June 1980 Edition	American Society for Non - destructive Testing Recommended Practice SNT-TC-LA	American Society for Non - Destructive Testing Inc., 4153 Arlingate Plaza Caller #28518 Columbus, OH 43228-0518

Naval Ship's Technical Manual, Chapter 079. Damage Control
Volume 4—Compartment Testing and Inspection

079–50.1.1 Surface Ship and Submarine Survivability. Structural integrity and compartment tightness contribute to surface ship and submarine survivability. Structural integrity refers to the ability of the ship's structure to withstand loads without experiencing structural failure. Loss of structural integrity generally results in the inability of the ship to perform one or more of its missions. Compartment tightness refers to the ability of the compartment boundaries to prevent unwanted fluid or gas leakage, which could injure personnel or damage equipment. Ships are designed and built with sufficient structural integrity and compartment tightness to survive in both peacetime and wartime. Operating the ship safely and surviving in both peacetime and wartime depends on maintaining structural integrity and compartment tightness and using compartment tightness to protect the ship, its personnel and equipment after damage. To accomplish this, a schedule of tests and inspections must be vigorously observed and maintained.

079–50.2.12 Structural Integrity. Structural integrity means the ability of the ship's structure to withstand a variety of loads (forces applied to structure) without experiencing structural failure. If the ship's structure is damaged, it loses some, or all, of its structural integrity. The following damage compromises structural integrity:

(a) Corrosion, which reduces the thickness of structure.

(b) Bending or buckling of structure. Because ships must operate in waves and with a number of different loading conditions (weapons or cargo loads), much of the ship's structure must be strong both when compressed (pushed together from the ends) and when in tension (pulled from the ends). The ability of a structure to stand up to compression depends on the plate thickness, stiffener size and its configuration. If the structure buckles it loses most of its strength and will no longer support compression.

(c) Breaks in structural continuity. This includes cracking and holes due to damage or unauthorized cutting. Because ships must operate in waves and with a number of different loading conditions (weapons or cargo loads), much of the ship's structure must be strong both when compressed (pushed together from the ends) and when in tension (pulled from the ends). If there are breaks in the ship's structure, it will no longer be able to resist tension. Shipboard structure is discussed in NSTM Chapter 100, Hull Structures.

079-53.1 Applicability

079-53.1.1 Surface Ship structural integrity testing and inspection and tightness testing and inspection requirements are referenced in Table 079-53-1.

Table 079-53-1. Source Documents for Compartment Inspection and Test Requirements for Surface Ships

Naval Ships' Technical Manual

General requirements for compartment inspection.	Damage Control: Compartment Testing and Inspection	NSTM 079, Volume 4 DOC NO: S9086–CN–STM–040
Inspection of Infrequently Entered Spaces – Includes Double–bottoms, Voids, Cofferdams, Ballast	Inspections, Tests, Records and Reports	NSTM 090 DOC NO: S9086–CZ–STM–000
Tanks, Potable Water, Reserve Feed Tanks, Fuel Tanks, JP–5 Tanks and Gasoline Tanks		
Inspection for Corrosion – Includes General Corrosion, Pitting, Exfoliation, Galvanic, Stress, Fretting, Crevice Corrosion of Bilges, Galley, Scullery, Tanks, Voids and Shaft Alley	Inspections, Tests, Records and Reports	NSTM 090 DOC NO: S9086–CZ–STM–000
Inspections for Corrosion and Structural Damage	Hull Structure	NSTM 100 DOC NO: S9086–DA–STM–000 NSN: 0901–LP–100–0010
Fuel Tank Inspection and Cleaning	Ship Fuel and Fuel Systems	NSTM 541 DOC NO: S9086–SN–STM–010
JP–5 Tank	Tank Inspection and Cleaning	NSTM 542 DOC NO: S9086–SP–STM–010
Gasoline/MOGAS	Storage Tank Flush	NSTM 542 DOC NO: S9086–SP–STM–010
Lubricating Oil	Flushing of Lube Oil System	NSTM 262 DOC NO: S9086–H7–STM–010
Collection, Holding and Transfer	Inspection	NSTM 593 DOC NO: S9086–T8–STM–010
Tank Preservation	Preservation of Ships in Service	NSTM 631 DOC NO: S9086–VD–STM–010 V1, V2, V3

PLANNED MAINTENANCE REQUIREMENTS

Compartment Visual Inspection	Inspect compartment/space as applicable to work center (DCPO Compartment Inspection)	MRC 62 W31A N (All ships)
Compartment Sonic Inspection (SI)	Perform ultrasonic inspection of watertight and airtight boundaries	MRC 97 B1WL N (All ships)

Collective Protection System (CPS)	Boundaries Perform zone pressurization test of CPS system	MRC C1XP on MIP 5121/017 MRC B7DR on MIP 5121/013
JP–5 Storage Tanks	Clean and Inspect	MRC X98W on MIPS 5420/Z01, 5420/006, 5420/008
	Request depot clean, inspect and preserve	MIP 1231/001
JP–5 Service (Head) Tanks	Clean and Inspect	MRC X98W on MIPS 5420/Z01, 5420/006, 5420/008 MRC C1BE on MRC 1231/002
JP–5 Emergency Service (Emergency Head) Tanks	Clean and inspect	MRC C1BE on MIP 1230/002
	Request repair activity to gas free, clean and inspect	MIP 1230/Z01 MIP 1230/001
JP–5 Drain/Sump/ Contamination Tank	Clean and inspect	MRC X98W on MIP–5420/Z01, 5420/006, 5420/008
Fuel Oil Cargo	Tank Clean and inspect	MRC B6NG on MIP 1231/004
Fuel Oil Storage Tank – Uncompensated Systems	Clean and inspect	MRC B6NG on MIP 1231/004 MRC A9QT on MIP 1230/004 MRC Z24M on MIP 1231/002
	Request repair activity/depot to clean and inspect	MIP 1231/004 MIP 1230/005
Diesel Fuel Marine Tank	Clean and inspect	MRC X93N on MIP 1231/001
	Request depot clean, inspect and preserve	MIP 1231/001
Fuel Oil Storage Tanks – Compensated System	Request repair activity to gas–free and inspect one bank	MIP 1230/Z01 MIP 1230/001
Fuel Oil Service Tank (Head Tank), Emergency Service Tank	Clean and inspect	MRC B6NG on MIP 1231/004 MRC X78F on MIP 1230/002 MRC C1BE on MIP 1230/002
(Emergency Head Tank), and Fuel Gravity Feed Tank		MRC A9QS on MIP 1230/004
	Request repair activity to gas–free, clean and inspect	MIP 1230/Z01 MIP 1230/001
	Request depot clean, inspect and preserve	MIP 1230/005
Potable Water Tank(s)	Clean and inspect	MRC A9QW on MIP 1230/004 MRC B6NH on MIP 1231/004
	Request depot inspect and preserve	MIP 1231/001
Feedwater Tank	Clean and inspect	MRC A9QW on MIP

		1230/004
Contaminated Oil Tank	Clean and inspect	MRC B6NJ on MIP 1231/004 MRC Y73C on MIP 1231/001
	Request depot clean, inspect preserve	MIP 1230/005
Ballast Tanks	Clean and inspect	MRC X78G on MIP 1230/002 MRC Z77X on MIP 1230/003 MRC A9QU on MIP 1230/004
	Request depot clean, inspect and preserve	MIP 1230/005 MIP 1231/001
Double Bottom Tanks	Clean and inspect unused tanks	MRC X78G on MIP 1230/002 MRC Z77X on MIP 1230/003
Voids and Cofferdams	Clean and inspect	MRC X78G on MIL 1230/002 MRC Z77X on MIP 1230/003 MRC A9QV on MIP 1230/004
Lube Oil Storage Tank	Clean and inspect	MRC C3VN on MIP 1230/004
	Request depot clean, inspect and preserve	MIP 1231/001 MIP 1230/005
Waste Water Tank	Clean and inspect	MRC Y73C on MIP 1231/001
Contaminated, Holding and Transfer Tank	Request repair activity clean and inspect	MIP 5931/001 MIP 5931/002 MIP 5931/005 MIP 5931/006 MIP 5931/008 MIP 5931/015 MIP 5931/016 MIP 5931/017 MIP 5931/018 MIP 5931/021

079–53.2 Structural Integrity.

079–53.2.1 Recognizing Structural Concerns. Structural aspects of cutting holes, watertightness, shoring, storm damage, cracking, deflection of structure, ordnance foundations and weight changes are given in NSTM Chapter 100, Hull Structures. NSTM Chapter 100 also provides requirements for shipyard structural examination.

079–53.3.7 Incidental Inspections. When performing planned maintenance listed in Table 079–53–1, entry into infrequently entered tanks, voids, cofferdams or other compartments should be used as an opportunity for a complete material inspection. If this is not possible, workers should be alert for material discrepancies, particularly of the preservation system, and list them for correction.

Naval Ships' Technical Manual, Chapter 081
Waterborne Underwater Hull Cleaning of Navy Ships

081–1.1.1.1 Total ship performance and Fleet capability can be enhanced by waterborne cleaning and maintenance (in place of drydocking for cleaning). This practice increases ship availability and minimizes associated costs. Removal of fouling while the ship is waterborne can restore most, if not all, of the post-drydocking performance and economy of operation. Regular hull cleaning prevents calcareous fouling from progressing to a point where fouling damages underlying anticorrosive paint coatings. The specific advantages are described in the following paragraphs.

081–1.1.5 Extended Paint Service Life. The service life of a properly applied non-ablative vinyl anti-fouling paint system, normally 2 years, can be extended to as much as 7 or more years when supported over its lifetime by regularly scheduled inspections and periodic cleanings as part of the hull cleaning program. The service life of a properly applied ablative antifouling paint system, normally 5 to 7 years, can be maintained and extended when supported over its lifetime by regularly scheduled inspections and periodic cleanings as part of the hull cleaning program.

081–1.1.6 Corrosion Control. Calcareous fouling accelerates paint system failure, thereby increasing the hull structure's susceptibility to corrosion.

081–1.3.4 Docking Block Bearing Surfaces. The unpainted surfaces that rested on the docking blocks during the most recent drydocking are more susceptible to fouling than the rest of the underwater body. These surfaces often can be identified by the sharp delineation of fouling at their boundaries. Fouling ratings of FR–70 or above are common over these bearing surfaces. Particular attention to hull plating condition is critical in these areas because of their greater susceptibility to corrosion.

081–2.1 Cleaning Interval Criteria and Scheduling
081–2.1.1 General. Since the effects of fouling on speed and power may vary among ship classes, and since the rates of fouling growth will vary with the condition of the antifouling paint system, the quality and number of prior cleanings, and the ship's geographical area and operational profile, no specific cleaning intervals can be stated. It is therefore imperative that all ships be scheduled for precleaning inspection on regular intervals to determine if cleaning is necessary. Delaying full hull cleaning to the point where a significant amount of hard fouling has formed (fouling rating (FR) 50 and above for non-ablative anti-fouling paints; FR-40 for ablative and self–polishing paints) can result in damage to the paint system.

081–2.1.1.1 For hull cleaning and scheduling purposes, the following definitions apply:
FULL CLEANING: The term full cleaning refers to the cleaning of the entire underwater hull surface (that is, painted surfaces), propellers, and shafts.
INTERIM CLEANING: The term interim cleaning refers to the cleaning of propellers and shafts only. Interim cleanings are normally scheduled for all ships between regular full cleanings to take advantage of the significant fuel savings benefits of operating with clean, smooth running gear. Approximately 50 percent of the entire fuel savings benefit of cleaning an entire hull (that

is, full cleaning) is attributable to the cleaning of propellers and shafts. All ships, irrespective of the hull coating formulation, will benefit from routine interim cleanings and inspections.

081–2.1.8.1 Should areas of significant paint failure be discovered during a precleaning or postcleaning hull inspection, the painted areas of the hull shall not be subjected to further cleaning without specific Type Commander (TYCOM) approval. A guide for assessing risk to failing paint is provided in Table 081–2–1. Assistance in determining severity of failure and hull protection is provided in paragraph 081–2.1.9, Table 081–1–2, and Figure 081–1–2.

081–2.1.9 Hull Protection Systems. The two systems that protect a ship's hull from corrosion deterioration are the anticorrosive paint system and the impressed current or sacrificial anode cathodic protection system. The interaction of these two systems and their ability to adequately protect the hull from corrosion is interdependent on several factors. Because hull cleaning inspections reveal the most comprehensive information on these system activities, thresholds are provided which indicate marginal or failing hull protection systems. The threshold for ships outfitted with impressed current cathodic protection systems is 10 percent bare metal observed on the underwater hull. Thresholds for ships with sacrificial anode systems are 5 percent bare metal or an observation of any inactive anodes. For ships with sacrificial anode systems, a hull potential survey should be conducted whenever either of these thresholds is observed.

Naval Ship's Technical Manual Chapter 090, Inspections, Tests, Records, and Reports

090-1.3 Materiel Inspections of Active and Inactive Ships and Service Craft. As required by Title 10 U.S. Code 7304 and Article 0321, U.S. Navy Regulations, the Board of Inspection and Survey (INSURV) shall:

- Examine each naval ship at least once every 3 years, if practicable, to determine its materiel condition.
- Report any ship found unfit for continued service to higher authority.
- Perform other inspections and trials of naval ships and service craft as directed by the Chief of Naval Operations (CNO). Surveys are directed by CNO on an individual basis.

090-1.51 Inspection of Infrequently Entered Spaces. Frequently entered spaces are inspected on a regular schedule; however, some infrequently entered spaces are inspected only when considered necessary by the Operational Commander. The special precautions observed prior to entering or working such spaces are described in paragraphs 090-1.52 through 090-1.54.

090-1.52 Double-Bottoms, Voids, Cofferdams, and Ballast Tanks. Unless special inspections are necessary at more frequent intervals because of unusual conditions or because of suspected unsatisfactory conditions, ballast tanks (except ballast tanks used also for fuel) and unused double-bottom tanks, voids, and cofferdams shall be inspected at scheduled drydockings. Specific attention shall be given to inspecting tank sounding tubes and striker plates. There have been instances where a sounding bob has worn a hole, first through the striker plate and then through the hull plating. For inert gas-filled cofferdams, inspections are required only during scheduled drydockings or when work is necessary. In instances where severe corrosion is present upon inspection and corrective measures are taken, the affected space shall be reinspected six months later to ensure that corrosion has not recurred. Maintenance Requirement Cards (MRCS) shall be used where applicable and pertinent materiel conditions reported on OPNAV Form 4790/2K.

090-1.53 Freshwater and Reserve Feed Tanks. Double bottoms and tanks ordinarily filled with fresh water (including associated check valves in tank overflow piping, sounding tubes, striker plates, and terminals of air escape piping) shall be inspected at a naval shipyard during scheduled drydockings or when emptied and opened for any purpose. Information regarding the materiel condition of these tanks and associated structures should be recorded on OPNAV Form 4790/2K for inclusion in the Maintenance Data System.

090-1.54 Fuel Tanks and JP-5 Fuel and Gasoline Tanks. Instructions for detailed inspection of fuel tanks are contained in NSTM Chapter 541, Petroleum Fuel Stowage, Use and Testing, and for JP-5 fuel and gasoline tanks in NSTM Chapter 542 (9150), Gasoline and JP-5 Fuel Systems. MRCs shall be used where applicable.

090-1.55 Inspection for Corrosion. Visual inspection of most compartments or machinery for corrosion will indicate whether corrosion-related base metal deterioration has occurred. If the metal is coated with paint or some other corrosion-resistant material, inspection can indicate the extent of coating failure. If a partial failure is in evidence, the inspector will determine the percentage of ineffective coating and the extent of corrosion deterioration of base metal. **Naval**

Ships Technical Manual Chapter 631, Preservation of Ships in Service (Surface Preparation and Painting) gives criteria for identifying coating failures.

090-1.56. Nondestructive testing to determine the extent of corrosion damage shall be performed where the visual examination indicates damage that could affect system operation. If nondestructive testing is required to support the visual inspection, consult NSTM Chapter 074 volume 2, Nondestructive Testing of Metals, Qualification and Certification Requirements for Naval Personnel, for general guidance on the extent of damage permitted before repair is required. The fact that inspected metal surfaces show indications of corrosion attack shall be cause for implementing corrosion control procedures as described in NSTM Chapter 631 or corrosion repairs in NSTM Chapter 074 volume 2, or both, as appropriate.

090-1.57. It is vital for inspection personnel to identify the type and extent of corrosion so that appropriate action can be taken to prevent catastrophic failure. Most ship corrosion is electrochemical and occurs in the presence of an electrolyte such as seawater. It is usually accelerated in areas where dissimilar metals are in proximity. Further information on characteristics of electrochemical corrosion are available in Chapter 633 (9190), Preservation of Ships in Service (Cathodic Protection). Categories of types of corrosion most common to naval ships are described in paragraphs 090-1.58 through 090-1.64.

090-1.58 General Corrosion Attack. General corrosion attack is usually associated with a uniform surface deterioration over an extensive area.

090-1.59 Pitting. Pitting attack on a metal surface takes the form of deep cavities of small diameter. It may be localized, or may cover larger areas. Pitting may be found on both ferrous and nonferrous metals and their alloys.

090-1.60 Exfoliation Attack. Exfoliation attack is a type of corrosion deterioration resulting in separation of a metal into thin layers or foils, which can usually be peeled from the surface.

090-1.61 Galvanic or Dissimilar Metal Corrosion Attack. When two dissimilar metals, such as aluminum and steel, are coupled together and subjected to a corrosive environment (such as water, salt spray, stack gas, or cleaning solutions), the more active metal (aluminum) becomes the anode and corrodes through exfoliation or pitting.

090-1.62 Stress Corrosion Cracking. Stress corrosion cracking results from the simultaneous action on a susceptible metal or alloy of a sustained static load and a corrosive environment. It is particularly characteristic of high strength aluminum alloys, certain low strength alloys, and high strength steels. Cracks may be intergranular (along grain boundaries) or transgranular (across grains).

090-1.63 Fretting Corrosion. Fretting corrosion (high impingement/abrasion) is a type of attack that takes place when two heavily loaded surfaces in contact with each other (usually machinery parts) are subjected to either slight vibration or oscillation. The small particles that are constantly being removed from the rubbing surfaces create the abrasive action responsible for the corrosion attack.

090-1.64 Crevice Corrosion. Crevice corrosion is usually a pitting attack caused by the greater concentration of dissolved oxygen in an electrolyte such as water, seawater, or cleaning solutions trapped in a crevice, compared to the concentration of dissolved oxygen in the rest of the electrolyte.

090-1.65 Detection of Corrosion Attack. The occurrence or frequent recurrence of electrochemical corrosion attack in any particular compartment or specific piece of equipment or hardware is generally attributable to the presence of an electrolytic solution (seawater). Corrosion inspection shall therefore be conducted with great care in those places where certain environmental or design characteristics aggravate the corrosion problem. Some adverse features of these design characteristics will usually involve:

1. Seawater splash
2. Sea (salt) spray
3. Poor drainage
4. High humidity/poor ventilation
5. Dissimilar metal connections
6. High impingement/abrasion.

090-1.66 Critical Inspection Areas. Examples of corrosion-susceptible areas are described in paragraphs 090-1.67 through 090-1.72. Not all shipboard areas with potential corrosion problems are included.

090-1.67 Bilges (Fire Rooms, Engine Rooms, Diesel Engine Rooms, Pumprooms). Because of high humidity, seawater, and corrosive solutions present in bilges, it is important that control inspections be made regularly. Components and equipment requiring careful attention include:

1. Suction Pumps
2. Foundations and machinery supports
3. Boiler air casings
4. Galvanic anodes

090-1.68 Galley and Scullery. Structures and equipment in galleys and sculleries are susceptible to electrochemical corrosion attack. Joined dissimilar metals, in particular, should be carefully inspected.

090-1.69 Tanks and Voids. Under ordinary conditions all voids, cofferdams, and double-bottom compartments, except those specially fitted or designated for carrying reserve feed, ballast water, fuel, diesel oil, or lubricating oils, shall be kept dry as much as practicable. These areas are normally protected by organic coatings and shall be inspected for paint failure such as flaking, blistering, peeling, and general lifting. The substrate metal surface shall also be inspected for corrosion. For this purpose, a knife or sharp instrument may be used to lift the paint to determine if the rate of corrosion attack on the underlying metal is accelerating.

090-1.70 Shaft Alley. Particular emphasis shall be placed during shaft alley inspections on:

1. Pump suction
2. Bearing and machinery foundations
3. Restricted and nondraining areas.

090-1.71 Oilers. In oilers, doublebottom compartments, except those designated for carrying reserve feed water, ballast water, fuel, diesel oil, or lubricating oils, shall routinely be kept dry. Use of these compartments for storage of additional fresh water or for seawater ballast for trimming purposes shall be avoided except in cases of necessity. Cofferdam compartments shall be kept dry except where directed and approved. Cofferdams adjacent to cargo gasoline tanks will be kept completely filled with fresh water; this water should be slightly alkaline to minimize corrosion. This prevents seepage of gasoline into the cofferdams when gasoline cargo is carried. It also prevents the accumulation of gasoline vapor in the cofferdam even when the tanks are empty. This precaution shall be taken whether the gasoline tanks are full or empty. The carrying of fresh water in the cofferdam between cargo fuel tanks and a fire room is permissible if necessary to prevent oil leakage or to enhance fire protection. The water shall be maintained at such height in cofferdams as the Commanding Officer deems necessary.

090-1.72 Miscellaneous Areas. In addition to the corrosion-susceptible areas listed, other spaces, areas, compartments, hardware, and equipment requiring critical scrutiny for corrosion attack include:
Aluminum bulkhead stiffeners
Aluminum and steel joints (interior wet spaces and exterior)
Aluminum decking (exterior and interior), fan rooms, and underneath deck tile
Pipe bulkhead penetrations
Pipe and wire clamps
Safety rail fittings
Helicopter deck tiedown fittings
Certain areas directly exposed to stack gases, such as radar supports.

090-1.73 Watertight Integrity Tests. A planned program for conducting watertight integrity tests and inspections shall be instituted so that all spaces are covered during an operating cycle, including a routine shipyard overhaul. Chapter 079 volume 4, (9880, Sect IV), Compartment Testing and Inspection, specifies types and cycles of testing. A mandatory schedule in the form of a plan of watertight integrity tests and inspections has been prepared by NAVSEA for most ships. A compartment shall not be air-tested unless specified in this schedule.

090-1.74 Inspection of Safety Devices. Mechanical, electrical, or electronic safety devices, installed for the protection of machinery equipment or personnel, shall be inspected at suitable regular intervals in accordance with PMS and whenever warranted by unusual circumstances or conditions. Whenever practicable, such inspection shall include operation of the safety device while the equipment or unit is in actual operation.

090-1.75 Inspection by a Shipyard. Examination of a structure by a shipyard, and the required reports, are to be in accordance with Chapter 100, Hull Structures. Materiel Inspections required during drydocking and the required reports are listed in Chapter 997, Docking Instructions and Routine Work in Drydock.

090-1.76 Inspection of Wood Hull Ships. Inspection of wood-hull ships is covered in Chapter 100, Hull Structures.

Naval Ship's Technical Manual Chapter 100, Hull Structures

100-2.21 Gun Foundations. After gun firing, gun foundations shall be examined to determine whether any or all of the following adverse effects have occurred:

1. Loosening of hold down bolts
2. Elongation of hold down bolts
3. Indication of excessive strain in foundation girders and connections, such as cracked paint or welds, or loose rivets
4. Indication of excessive strains on the stanchions and their connections

100-2.22 Any excessive vibration of gun foundations, which makes rapid firing of the guns either difficult or uncertain, shall be reported to NAVSEA on **Report of Equipment Failure**, Report Symbol 9120-1 (NAVSEA 3621).

100-2.23 No structural modification in way of or affecting the structural strength and rigidity of ordnance foundations shall be undertaken without NAVSEA approval.

100-2.24 Gun Director and Missile Launcher Foundations. Gun director and missile launcher foundations shall be inspected periodically for alignment to determine the following:

1. Foundation structure has not been distorted
2. Hold-down bolts have not loosened
3. Bolt holes have not become elongated
4. No excessive vibration exists

100-2.31 Shipyard Structural Examination

100-2.32 General. When a ship is assigned availability for repairs, the repair activity shall make an inspection of the ship's structure when evidence of severe deterioration has been reported by the Commanding Officer. Repairs shall be based on criteria that have been established for such examinations. These criteria are described in the following paragraphs.

100-2.33 General Criteria. Strength members of portion of strength members, which have suffered a reduction in cross sectional area of 25 percent of greater from their original, shall be cropped out and replaced. In cases where material deterioration is limited to small areas (less than two square feet), repairs may be accomplished by welding in lieu of replacement.

100-2.34 Scattered pits of depth at least 25 percent, but not greater than 45 percent, of original thickness may be repaired by welding. Repairs to restore thickness of existing structure by cladding or surfacing shall be accomplished by the metal arc welding process as set forth in Chapter 074, **Welding and Allied Processes.**

100-2.35 Where galvanized plating was installed, it must be replaced with galvanized plating, or coated, over abrasive blasted surfaces, with inorganic zinc type paint in accordance with MIL-P,23236, class 3 post-curing type.

100-2.36 Special Criteria. For certain ship classes, specific structural inspection and renewal criteria have been established. Check off lists also have been prepared for some of these ship classes and are available from the cognizant planning yards and Type Commanders.

Naval Ship's Technical Manual Chapter 631, Preservation of Ships in Service
Volume 1. General
Section 1. General Information

631–2.8.2 Safety Precautions and Requirements for Abrasive Blasting. The safety precautions and requirements that shall be taken to prevent introduction of abrasive-blasting materials into ship spaces and unprotected equipment, and to prevent injury to personnel and property damage, are described in the following paragraphs. These precautions apply to all abrasive blasting operations on or within the vicinity of naval ships undergoing any type of availability. The Commissioned Submarine and the Commissioned Surface Ship General Reactor Plant Overhaul and Repair Specifications (NAVSEA 0989–LP–037–2000 and 0989–LP–043–0000), respectively, shall be consulted for additional precautions before areas outboard of the reactor compartment or machinery spaces of nuclear powered ships are blasted with abrasives.

631–2.8.2.1.3. The entire area to be blasted shall be visually inspected. Heavily rusted or corroded areas, damaged metal, and holes in the structure or piping shall be checked to determine if the technical examination is warranted, and for possible repair prior to blasting. Abrasive blasting hoses routed through compartments shall be identified by an appropriately marked sign posted in each compartment, warning against damaging the hoses.

631–2.8.2.2 Postoperational Requirements. After any blasting or contamination of ship interior, the equipment or components blasted or contaminated by abrasive dust shall be cleaned and tested in accordance with the applicable NSTM chapter prior to being put into service. The entire area shall be visually inspected for pits, scabs, and scars. Suspected wall thickness reductions shall be reported for further technical examination in accordance with NSTM Chapter 100, Hull Structures, and NSTM Chapter 505, Piping Systems.

APPENDIX M

Underwater Ship Husbandry Manual
S0600-AA-PRO-010
0910-LP-018-0350, Revision 2
October 1, 1998

APPENDIX M

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Chapter 17 Underwater Ship Husbandry Inspection Procedures

Section 1 Introduction

17-1.2 Scope.

17-1.2.1 This chapter addresses the personnel, equipment, and documentation requirements for UWSH inspections, using non-invasive procedures and techniques. The term non-invasive means that the diver does not remove any cover plates or disassemble any portion of the system during the inspection. Non-invasive inspections are divided into two categories: Level 1 inspections and Level 2 inspections.

17-1.2.2 Level 1 inspections are stern-to-stem, non-invasive inspections of the entire hull and its appendages. Level 1 inspections are typically routine, scheduled inspections. These inspections may be performed for regularly scheduled maintenance assessment, post-deployment condition assessment, or damage assessment following a collision, grounding, or other suspected mishap. It is also used as a pre- and post-hull cleaning inspection.

17-1.2.3 Level 2 inspections are system-specific, non-invasive inspections. Level 2 inspections usually result from either a deficiency discovered during a Level 1 inspection or from a problem reported by the ship.

17-1.2.4 A third level of inspection, Level 3, are system-specific, invasive procedures requiring some amount of disassembly of the system or component to complete the inspection. Level 3 inspections are outside the scope of this chapter. Level 3 inspections are covered in system-specific chapters of this manual.

17-1.3 APPLICABILITY.

17-1.3.1 The Level 1 and 2 inspection procedures covered in this manual are applicable to all classes of active surface ships and submarines for which the procedures have been completed. A list of current inspection procedures can be found in the table of contents. As additional procedures are developed for other ship classes, this table will be revised.

17-1.3.2 The information and procedures contained in this chapter are not intended to duplicate or supersede information contained in various system technical manuals, the *U.S. Navy Diving Manual* or the *Naval Ship's Technical Manual* (NSTM).

17-1.3.3 Certification as a Level 1 or 2 Inspector under this chapter does not imply certification under other commercial or military standards (e.g., ASNT, MIL-STD-271).

17-1.4 MANUAL LAYOUT.

17-1.4.1 This chapter is intended to serve two distinct purposes: as a general information and training guide and as a collection of inspection procedures for specific ship classes. The general information section includes references and discusses inspection equipment, personnel requirements, inspection techniques, (e.g., tag outs, positioning and locating), the inspection process, post-inspection requirements, and safety. Each separate ship class section includes a general hull description, a description of major hull components pertinent to that class, and Level 1 and Level 2 inspection procedures.

17-1.4.2 Level 1 procedures are organized as follows.

17-1.4.2.1 Procedures are given in the order inspection items are found from stern to stem.

17-1.4.2.2 Each ship section contains a "Plan and Profile" drawing of the ship. This figure shows key inspection items and their approximate frame locations. Inspection items are numbered to correspond with an inspection checklist (discussed below).

17-1.4.2.3 Each ship section also includes a "Checklist of Major Hull Components," which can be used as an on-site reference. For each inspection item, the table lists the Plan and Profile drawing reference number, name of the item, system served, docking plan reference number, exact hull location (closest frame and distance from the centerline), and size of the opening. A space is also provided to record the condition found.

17-1.4.2.4 The Level 1 inspections and the checklists detailed in this manual were accurate at the time of publication for the lead ship in each class. However, SHIPALTs and other variations within any given ship class will require alterations and deletions to these procedures. Regular input from divers using these procedures will ensure that they are up to date.

17-1.4.2.5 The checklist presents hull components in the order in which they are found, beginning at the stern area and then moving to the port side, bow, and starboard. This order limits diver excursions under the keel, yet covers the entire hull surface. All hull openings listed on the docking drawing are also found on the checklist, even though some of them are located above the waterline. Items that appear above the waterline can be used to assist in the setup of the dive station and also can help the diver's orientation with the hull prior to descending below. The checklist and plan and profile figures can be photocopied for reference on the dive station during an inspection.

17-1.4.3 Level 2 procedures are given in order in which equipment is found, beginning at the stern.

Section 2 Personnel and Equipment Requirements

17-2.1 Personnel Requirements.

17-2.1.1 This section discusses the personnel qualifications and equipment requirements necessary to conduct quality UWSH inspections.

17-2.1.2 The qualifications of the divers conducting the UWSH inspection are the single most important factor impacting the quality of data collected. This section sets forth specific minimum diver qualification standards for UWSH Inspectors.

17-2.1.3 The types of UWSH inspectors are Trainee, Level 1 Inspector, Level 2 Inspector, and Level 3 Inspector.

17-2.1.4 Trainees are those personnel who are newly assigned to a diving locker and who have no UWSH experience. They may assist a Level 1 Inspector during a Level 1 inspection. Trainees must have, as a minimum, the following skills and knowledge: a. A thorough understanding of the terms and procedures of this chapter; b. The ability to track and locate their position on any area of the hull; and c. Training in the use of Diver's Underwater Color Television System (DUCTS)

17-2.1.5 Level 1 Inspectors are those personnel trained and qualified to perform non-invasive inspections. They may assist a Level 2 Inspector during a Level 2 inspection. Level 1 Inspectors must have, as a minimum, the following skills and knowledge:

a. A thorough understanding of the terms and procedures of this chapter;
b. The ability to track and locate their position on any area of the hull;
c. The ability to accurately report the size (area or percent) of damage, paint failure mode, and types of corrosion;
d. The ability to accurately determine Fouling Rating (FR) and Paint Deterioration Rating (PDR) in accordance with NSTM Chapter 081;
e. The ability to accurately measure clearances, including where and how to take measurements and how to use feeler gauges and inside and outside calipers;
f. Successful completion of U.S. Navy Training Course "Tools and Their Uses," NAVEDTRA No. 82085;
g. Demonstrated ability to accurately report propeller surface roughness using the Rupert Comparator;
h. Training in the use of the DUCTS; and
i. Training in the use of underwater 35mm photography equipment.

17-2.1.6 Level 2 Inspectors are those personnel trained and qualified to perform Level 2 inspections. They may assist a Level 3 Inspector during an invasive inspection. Level 2 Inspectors must have, as a minimum, the following skills and knowledge:

a. One year demonstrated experience as a Level 1 Inspector;
b. Successful completion of U.S. Navy Training Course "Blue Print Reading and Sketching," NAVEDTRA No. 82014;
c. The ability to read engineering drawings and plans; and

d. A functional understanding of the operation and purpose of the specific system being inspected.

17-2.1.7 Level 3 Inspectors are those personnel trained and qualified to perform both invasive and non-invasive inspections. Level 3 Inspectors must have, as a minimum, the following skills and knowledge:

a. One year demonstrated experience as a Level 2 Inspector; and
b. Knowledge and demonstrated experience following the procedures covered in system-specific chapters of this manual.

Chapter 17, Section 7
DDG 51 Class—Underwater Ship Husbandry Inspection Procedures

17-7.3 Level 1 Inspection Procedures.
17-7.3.1 Introduction.
17-7.3.1.1 This section contains Level 1 inspection procedures for the DDG 51 Class Guided Missile Destroyer. The Table 17-7.2 checklist presents components in the order in which the diver would find them when making a stern area, port side, bow, and starboard side inspection dive. Note that all hull openings included on the docking plan are listed in Figure 17-7.1 and Table 17-7.2. Depending on the ship's draft at the time of the inspection, some items may be above the waterline. The Dive Supervisor can refer to Figures 17-7.1 and 17-7.2 and Table 17-7.2 (found at the end of these Level 1 procedures) to pinpoint the exact location of a particular component. These tables and figures can be photocopied and used to document the reported condition of each component. In addition, the NAVSEA Diver Inspection Data Forms for the hull, Sonar Dome Rubber Window, ICCP, and propeller should be used to record the inspection results. These forms are included in Section 5 of this chapter. Underwater color photography should also be used to further depict the damage described in the report and in the forms.

17-7.3.2 Paint and Fouling Inspection.
NOTE
To accurately report the PDR and FR, the diver must be thoroughly familiar with NSTM Chapter 081, "Waterborne Underwater Hull Cleaning of Navy Ships."

17-7.3.2.1 One of the most important aspects of a Level 1 inspection is the assessment of the Fouling Rating (FR) and the Paint Deterioration Rating (PDR). Values for the FR and the PDR may vary widely along the length of a hull.

17-7.3.2.2 The diver should continuously report the condition of the paint using standard terms such as peeling, blistered (broken or intact), and missing antifouling or anticorrosive paint. Report the color of exposed paint. A diver's light is necessary to report color accurately. Use sections of hull plate to estimate the condition of small areas: flat and curved areas of plate, edges, welds, seams, rivets, and bolt heads. The Dive Supervisor maintains a running log of the conditions and records the FR and PDR for localized areas. This enables the Dive Supervisor to keep track of the total estimate for each section of the hull. These values are then summarized, yielding the overall condition for each area: bow, stern, flat bottom, and sides. Report the docking block areas separately from the flat bottom and sides. For docking block areas, report the average percent of block areas painted and the percent of base metal with pitting. Estimate the average diameter and depth of pitting. For a heavily fouled section of hull, only the FR can be reported since little or no hull paint will be visible.

17-7.3.2.3 This inspection procedure alerts the diver when the inspection process has been completed for each section of the hull to assist in summarizing the overall conditions.

a. Inspect and report the FR.

b. Inspect and report the PDR. Report localized areas of pitting, blisters, peeling, or missing paint.

c. Inspect and report the docking block FR and PDR.

17-7.3.3 General Hull Plate Inspection.

a. Carefully examine the hull plating. Look for areas of bare metal, bleeding rust, and large areas of pitting.

b. Inspect for holes, cracked weld seams, distorted hull plates, localized areas of pitting, corrosion, and any other apparent damage.

c. Estimate and report the extent and location of any damage; report length of cracks and average pit diameter and depth.

APPENDIX N

The Corrosion Control

Information Management System (CCIMS)

Inspection Manual

APPENDIX N

The Corrosion Control Information Management System (CCIMS) Inspection Manual

1 - Introduction

This manual is based on input from the Type Commanders, the Fleet, Carderock Division, Naval Surface Warfare Center (CDNSWC), NAVSEA, NAVAIR, and PERA-CV. It seeks to provide, at the deck plate level, a uniform set of inspection attributes and inspection criteria. This is done by comparing what is seen against the text and pictures in the manual and then appropriately marking the applicable Inspection Form.

Historically, slow to degrade systems inspection data was never rigorously stored in one place for easy access to aid in the planning process. The Corrosion Control Information Management System (CCIMS), whose data input screens duplicate the various Inspection Forms, accomplishes this task. Slow to degrade areas are defined as tanks, voids, sponson voids, aircraft electrical servicing station trunks (AESS), ventilation systems, bilges and non-skid.

2 - Purpose

The purpose of this manual is to provide standardized inspection and reporting procedures for slow to degrade systems as defined above.

3 - Scope

This manual establishes a standardized procedure for inspecting slow to degrade systems on an aircraft carrier and provides standard report forms for recording the inspection results. The objective of the inspection is to produce useful, accurate, and reproducible data about the condition of everything within the system. Where applicable, this includes coating condition, cathodic protection depletion, and the condition of tank internals such as ladders, tank level indicators, and piping. Maintenance planners will use the data to determine how much and what type of maintenance is needed in each system.

6 - Procedure

6.1 General

This document describes, in text and picture, the line by line procedures for completing the appropriate Inspection Form. It is expected that an inspector will take a copy of this manual and a blank Inspection Form into the tank. As experience is gained, only occasional reference to the manual should be required.

The inspector will need the following tools:

1. one appropriate Inspection Form for each area to be inspected,
2. a copy of this manual, or, as a minimum, a set of Coating Condition Reference Standards (Figure 11) and T-bar Coating Condition Reference Standards (Figure 12), or the Aircraft Carrier Tank and Void Inspection Hip Pocket Guide
3. a powerful flash light
4. a pocket knife
5. a small magnet
6. a rag

6.2 Tank and Void Inspection

The Tank and Void Inspection Form is divided into fourteen discrete areas. They are: General Data, Access Data, Ladder Data, Vent/Overflow Data, Tank Level Indicator (TLI) Data, Sounding Tube Data, Cathodic Protection Data, Coating Data, Structural Integrity Data, Seachest Data, Piping Data, Desiccant Data, Ship Defined Attributes, and Close-Out Inspection. A block for Additional Comments are available for explanation of problems found.

6.2.9 Structural Integrity Data

65. Structural Integrity Compromised by Corrosion: Indicate whether or not the structural integrity of the tank was compromised by corrosion (i.e., rust holes). If the structural integrity has been compromised, circle YES and provide amplifying information in the ADDITIONAL COMMENTS block. Otherwise, circle NO. NOTE: A compromise of the structural integrity of a tank requires immediate attention and a significant repair effort. Submit work request for emergent repairs. Additional inspections and data may be required by others. Include data from the additional inspection in the Additional Comments block or attach copy of inspection results to the report for this inspection.

APPENDIX O

United States Code
Title 10--Armed Forces

Subtitle C--Navy and Marine Corps

Part Iv--General Administration

Chapter 633--Naval Vessels

APPENDIX O

United States Code
Title 10--Armed Forces

Subtitle C--Navy and Marine Corps

Part Iv--General Administration

Chapter 633--Naval Vessels

Sec. 7304. Examination of vessels; striking of vessels from Naval Vessel Register

(a) Boards of Officers to Examine Naval Vessels. The Secretary of the Navy shall designate boards of naval officers to examine naval vessels, including unfinished vessels, for the purpose of making a recommendation to the Secretary as to which vessels, if any, should be stricken from the Naval Vessel Register. Each vessel shall be examined at least once every three years if practicable.
(b) Actions by Board. A board designated under subsection (a) shall submit to the Secretary in writing its recommendations as to which vessels, if any, among those it examined should be stricken from the Naval Vessel Register.
(c) Action by Secretary. If the Secretary concurs with a recommendation by a board that a vessel should be stricken from the Naval Vessel Register, the Secretary shall strike the name of that vessel from the Naval Vessel Register.