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SSC-380

SHIP STRUCTURAL INTEGRITY INFORMATION SYSTEM

SHIP STRUCTURE COMMITTEE

1995

SHIP STRUCTURE COMMITTEE

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Ship Structure Committee

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SHIP STRUCTURAL INTEGRITY INFORMATION SYSTEM

In 1992 the SSC published a report by Prof. Robert Bea of the University of California, Berkeley that introduced the need to tie together all of the failure information on the U.S. maritime fleet. A program was proposed to mirror that which is currently used in the airline and other industries. The system could be used to identify developing problems earlier and address them before they manifest themselves as a severe catastrophe.

This project develops the concept further by evaluating databases currently in use by ship operators to monitor their vessels. It then proposes a system to address the data capture needs for design, construction, inspection, maintenance, and operations. As one possible application of the program, it is used to develop Critical Area Inspections Plans (CAIPs) as required by the U.S. Coast Guard for some vessels. This project is being followed by a second phase for further investigation.

J. C. CARD
Rear Admiral, U.S. Coast Guard
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16. Abstract
This report marks the completion of the initial studies into a system to capture data necessary to perform analysis on failures in ship structures. It evaluates some existing ship database systems with the purpose to define guidelines for an improved, industry wide system. The system is anticipated to include information from design, construction, inspection, maintenance and operations. Particular emphasis has been placed on the capability of the system to produce Critical Area Inspection Plans (CAIPs) as defined by the U.S. Coast Guard. This report is the first year of what is intended to be a multi-year program.

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United States Department of Commerce
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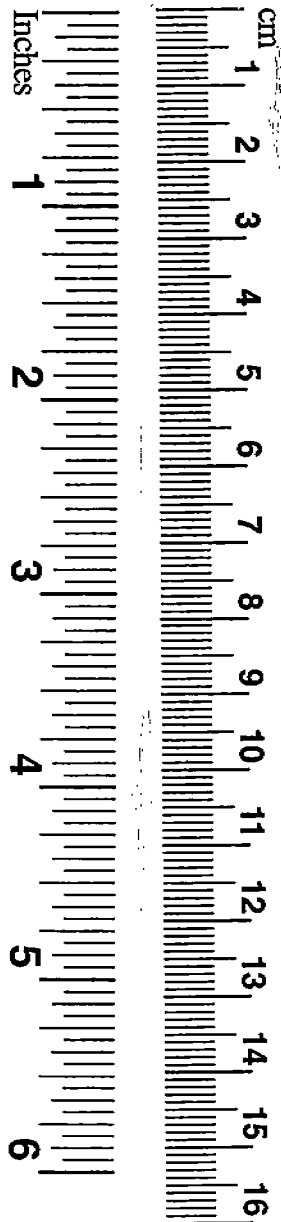
METRIC CONVERSION CARD

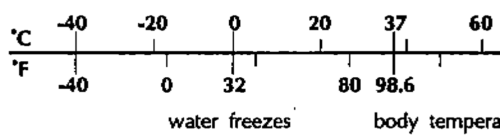
Approximate Conversions to Metric Measures

Symbol	*When You Know*	*Multiply by*	*To Find*	*Symbol*
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	metric ton	t
VOLUME				
tsp	teaspoons	5	milliliters	mL
Tbsp	tablespoons	15	milliliters	mL
in^3	cubic inches	16	milliliters	mL
fl oz	fluid ounces	30	milliliters	mL
c	cups	0.24	liters	L
pt	pints	0.47	liters	L
qt	quarts	0.95	liters	L
gal	gallons	3.8	liters	L
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
TEMPERATURE (exact)				
°F	degrees Fahrenheit	subtract 32, multiply by 5/9	degrees Celsius	°C



Approximate Conversions from Metri

Symbol	*When You Know*	*Multiply by*	*T*
LENGTH			
mm	millimeters	0.04	inches
cm	centimeters	0.4	inches
m	meters	3.3	feet
m	meters	1.1	yards
km	kilometers	0.6	miles
AREA			
cm^2	square centimeters	0.16	square
m^2	square meters	1.2	square
km^2	square kilometers	0.4	square
ha	hectares (10,000 m^2)	2.5	acres
MASS (weigh			
g	grams	0.035	ounces
kg	kilograms	2.2	pounds
t	metric ton (1,000 kg)	1.1	short to
VOLUME			
mL	milliliters	0.03	fluid o
mL	milliliters	0.06	cubic i
L	liters	2.1	pints
L	liters	1.06	quarts
L	liters	0.26	gallons
m^3	cubic meters	35	cubic f
m^3	cubic meters	1.3	cubic y
TEMPERATURE (			
°C	degrees Celsius	multiply by 9/5, add 32	de Fa



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Chapter 1

Introduction

This report documents the results of the SSIIS project (Ship Structural Integrity Information System) are documented. The SSIIS project is a one-year project sponsored by the U.S. Coast Guard Research & Development Center through the National Maritime Enhancement Institute of the Maritime Administration (MARAD). The SSIIS project was initiated by the Department of Naval Architecture & Offshore Engineering at the University of California at Berkeley in September 1993.

The SSIIS project had two main objectives:

- **Development and documentation of standards for the development of a computerized Ship Structural Integrity Information System for tank ships.**
- **Demonstration of the application of these standards with a prototype PC based database system.**

With the development of advanced database technology and the availability of powerful and economic computer systems and storage capacity it has become possible to develop an integrated database system for ships. Based on the structure and complexity of the task, it is necessary to use a modular concept that allows the individual development and implementation of each module.

The Ship Structure Committee has funded a study to establish a procedure for development of Marine Structural Integrity Programs (MSIP) for commercial ships, with particular focus given to tankers, [1]. The aim was to adopt a procedure similar to the Airframe Structural Integrity Program (ASIP) established by the U.S. Air Force and the Federal Aviation Agency.

As part of the MSIP study, the general information structure governing all aspects of tanker design, construction and operation has been outlined. This structure is shown in Fig. 1.1).

The SSIIS project uses this structure as a starting point for the development of a general ship information database system. The data contents of the different modules shown in Fig. 1.1) is defined in more detail. The main emphasis is given to the **Inspection** module. For this module, the necessary database structure is developed and used for the application prototype created as part of the SSIIS project.

Chapter 2 documents the need for a general ship information system and describes important components of this system.

Largely due to the U.S. Coast Guard requirement that makes it mandatory for tank ship operators to submit Critical Area Inspection Plans (CAIP) for each vessel based on the results of structural surveys, several database systems have been developed to archive and analyse the results of crack and corrosion surveys. The underlying concepts of these systems have to be evaluated in order to make recommendations for a more general system. In addition, based on the user experience with these database systems, it is possible to compare different data input and visual representation techniques. **Chapter 3** documents existing database systems, evaluates performance characteristics and makes recommendations for an improved system.

Aside from its use to store and document the inspection results, the Ship Structural Integrity Information System is intended to contain all relevant vessel information resulting from design, construction, inspection, maintenance and operations. This will allow it to use the SSIIS as the information source for different analysis applications, thus eliminating the need for multiple data entry. In addition, the information about vessel operations will give operators better flexibility in scheduling and can result in optimized performance characteristics. **Chapter 4** documents the information needs of different analysis applications, lists the information available from vessel operations and describes ongoing efforts for vessel computerization, vessel scheduling and data management by various operators.

Chapter 5 documents the CAIP requirements as defined by the U.S. Coast Guard. CAIP reports submitted to the U.S. Coast Guardby different operators have been analysed to determine the differences in format and information contents. Based on this analysis and on the experience of USCG inspectors a desired format is introduced that will be used as an output definition for the SSIIS prototype development.

In order to define the scope and information content of the system, it is necessary to determine the anticipated usage of the database. This decision involves the investigation of the data needs of operators, class societies and regulatory agencies. In addition, the information contents of various analysis software has to be recognized. **Chapter 6** outlines the characteristics of the Ship Structural Integrity Information System. This outline will be used to define the different data modules and develop the prototype application.

It is one of the objectives of the SSIIS project to design and implement an application prototype that can be used to store inspection and survey results and generate Critical Area Inspection Plans. The prototype will use the CAIP format developed based on the analysis of existing CAIP reports. **Chapter 7** documents the prototype development.

Chapter 8 concludes this report, summarizes the development and makes recommendations for future development.

Marine Structural Integrity Programs

MSIP

Information System

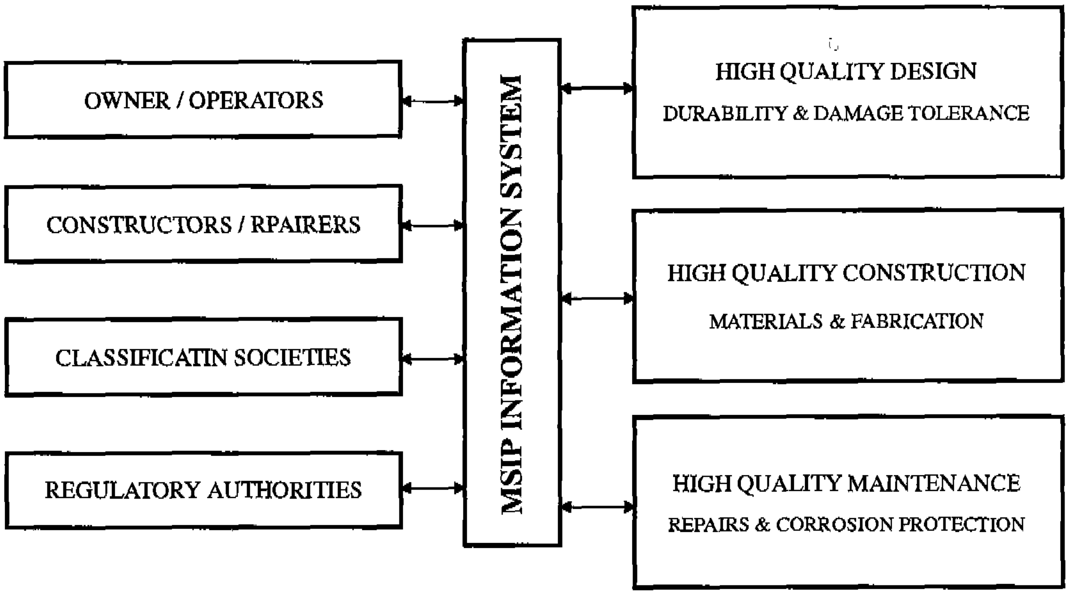


Figure 1.1: MSIP - Vessel Information Structure

Chapter 2

The Need for Integrated Ship Information Systems

2.1 Reasons for Vessel Information System

2.1.1 General Considerations

In recent years, several research efforts and development projects have been conducted with the aim to develop and implement database systems to store, manipulate and analyse the information that is gathered during the operating of commercial vessels. In particular, most of these efforts have concentrated on oil tankers due to regulatory requirements and the specific structural configurations that require periodic inspections resulting in large amounts of survey data.

In addition, it is important for tanker owners and operators to have immediate access to general ship specific information for both the day to day operations and repair and maintenance procedures.

Due to the disproportionally high number of fatigue cracks found in vessels operating on the Trans-Alaska Pipeline Service (TAPS) trade route, the U.S. Coast Guard requires a Critical Area Inspection Plan (CAIP) for these vessels. The CAIP for each vessel has to specify the methods used by vessel operators for the documentation and tracking of structural failures, [16].

Each CAIP will contain detailed information on the vessel's fracture history, corrosion control systems and previous repairs. In addition the CAIP requires operators to document trends in the occurence of fatigue and corrosion incidents. The plan has to be updated yearly to include the most recent survey data for the determination of the critical areas. These requirements will therefore result in a large amount of data that has to be managed, which is most easily done, if the vessel and survey information is contained in a database.

The *International Association of Classification Societies (IACS)* has recently published a set of rules governing the conduct of surveys for existing vessels, (*Enhanced Survey Rules for Existing Vessels*), [21]. The document is partly based on recommendations issued by the International Maritime Organization (IMO) and the guidance manuals for tanker inspections published by the Tanker Structure Cooperative Forum, [36], [37].

The IACS document requires shorter inspection intervals for uncoated ballast tanks and makes it the owners/operators responsibility to provide detailed information related to crack and corrosion survey results including trends and damage statistics. These guidelines are enforced by the American Bureau of Shipping (ABS) for U.S. flag vessels as of January 1, 1993.

2.2 The Fatigue Problem

Fig. (2.1) shows a schematic view of the *Fatigue Problem* and the related procedures necessary for an effective prevention and control of fatigue damage. In addition the possible data exchange between the different areas (`Information Management`, `Load Information` and `Analysis`) is shown.

In general, the storage of analysis results in databases and the retrieval of input parameters from databases is a very desirable development that will lead to more efficient software tools.

Regularly scheduled inspection and maintenance operations result in a large amount of survey data (both for corrosion and cracks). This data has to be managed efficiently. A database that contains general vessel information and the results from crack and corrosion surveys can be regarded as the most effective method of `Information Management`.

Systematic monitoring methods of vessel response quantities e.g. accelerations, stresses, are currently being developed. This information can result in improved estimates of the long-term loading. The estimates of the long-term loading introduces the largest uncertainties into the fatigue life evaluation procedure. It will therefore be extremely beneficial to develop improved estimates of the `Load Information`.

`Analysis` of fatigue damage has to be performed for two cases:

- **Design**: Modification of a CSD resulting in a reduced SCF value will improve the fatigue life of a CSD. Constraints due to manufacturing limitations and economic considerations will influence the design process.
- **Repair**: In general, several repair alternatives are available for cracks found in CSD. The possibilities range from simply re-welding to a complete re-design of the detail. The choice of the repair method can be based on an economic optimization approach.

The `Design` of CSD can be improved by using *Damage Statistics* based on the crack survey information contained in the database. The *Design SCF Values* that are calculated during the design of a CSD can be included in the database. This makes these SCF values directly available for the `Repair` case of a CSD.

Including the calculated SCF values in the database will gradually result in a catalog of SCF values reducing the number of finite element analyses to be performed for both the `Design` and the `Repair` case.

The linkage of the `Analysis` procedures to the `Information Management` will therefore result in a combination of the two traditional approaches to the estimation of fatigue life (SCF values from finite element analysis or SCF values from SCF table based on geometry parameters). In addition this information linkage is one of the requirements for the development of a knowledge based system for both the design and the repair of Critical Structural Details.

2.3 Research Efforts

Structural Maintenance Project (SMP)

The structure of the *Fatigue Problem* shown in Fig. (2.1) has been developed based on the experiences with the Structural Maintenance Project (SMP) [1] . Within this project, most aspects of the *Fatigue Problem* have been addressed.

The SMP project was a two-year international joint industry project with two technical goals:

- To develop practical tools and procedures for the analysis of proposed ship structural repairs in order to minimize time and materials within the constraints of regulatory and class requirements and prudent engineering practices.

[1] Structural Maintenance Project for New & Existing Ships, Department of Naval Architecture & Offshore Engineering, University of California at Berkeley. 1990 - 1992

- To equip operators, classification societies and shipyards with powerful, yet practical, analytical tools for the assessment of corrosion of ship critical structural components and the assessment of fatigue cracking useful for ship repair and maintenance.
- To prepare guidelines for the cost-effective design and construction of lower-maintenance ship structures which also facilitate future inspections and repairs.

The research efforts were organized into six studies:

Study 1 – Fatigue Damage Evaluations
Study 2 – Corrosion Damage Evaluations
Study 3 – Interaction of Details with Adjacent Structure
Study 4 – Fatigue and Corrosion Repair Assessments
Study 5 – Durability Considerations for New & Existing Ships
Study 6 – Development of Software and Applications Examples

The developed software consists of a ship information database system (SIMS), an interactive mesh generation module to develop FEM models of Critical Structural Details (CSD), an analysis module that calculates the hot-spot stresses based on a unit-load approach, a long-term load generation module based on travel route and ship characteristics and a fatigue life evaluation module that calculates fatigue damage and failure probabilities.

All modules are linked through a graphical user interface (GUI), which makes the software more suitable for standard design and repair operations.

By automating the mesh generation and FEM analysis of CSD it is possible to analyse different design alternatives and to evaluate the effect of different repair alternatives on the hot-spot stress and thus the calculated long-term loading and the resulting fatigue life.

The actual failure data contained in the database was used to obtain failure probabilities necessary to verify the fatigue analysis procedure.

2.4 Intended Information Contents

The developed database structure can be regarded as the core of this system that includes all areas of design, operation, inspection and repair for vessels. This system should, among others, contain the following information:

- The original vessel design parameters
- Offsets for all frames. This information is necessary input for ship motions programs and all stability calculations.
- Locations and specifications for all tanks
- An electronic description of the structural configuration. This should ideally be in a form suitable for direct use in a finite-element analysis.
- The results of all initial design calculations should be stored, especially with regard to the hot-spot stresses in structural details. This information is needed for subsequent fatigue life analyses and the comparison with repair alternatives.
- The vessel's voyage information. For each voyage the loading and ballast condition has to be included. In general, provisions have to be made to include all information contained in a vessel's deck log.
- Data obtained from the monitoring of the vessel's response characteristics. The amount and type of information has to be determined in a way that it is possible to extract the vessel's long-term loading from the database. The development of the database is therefore intrinsically connected to the design and implementation of ship monitoring systems.

- Results from crack and corrosion surveys. Location information has to be linked to the structural configuration.
- Repair information. The structural configuration of the vessel has to be updated in the case that a component is re-designed. The repair information should be linked to the observed and documented failures

The above system has to be developed in a fashion that it can be implemented in a modular way. This is necessary since not all possible users should have access to the complete system. A core system, very similar to the developed SIMS could be implemented as a requirement for vessel operators and could be used by classification societies and regulatory agencies as a data source for rule development and research.

A more complete system with some or all of the above outlined functions could be used internally by vessel operators to optimize vessel design, operation and maintenance.

Overall, the development of an electronic database system for the management of all information related to the operation, inspection, maintenance and repair of oil tankers will be beneficial in reducing costs and improving the quality of ship design and repair.

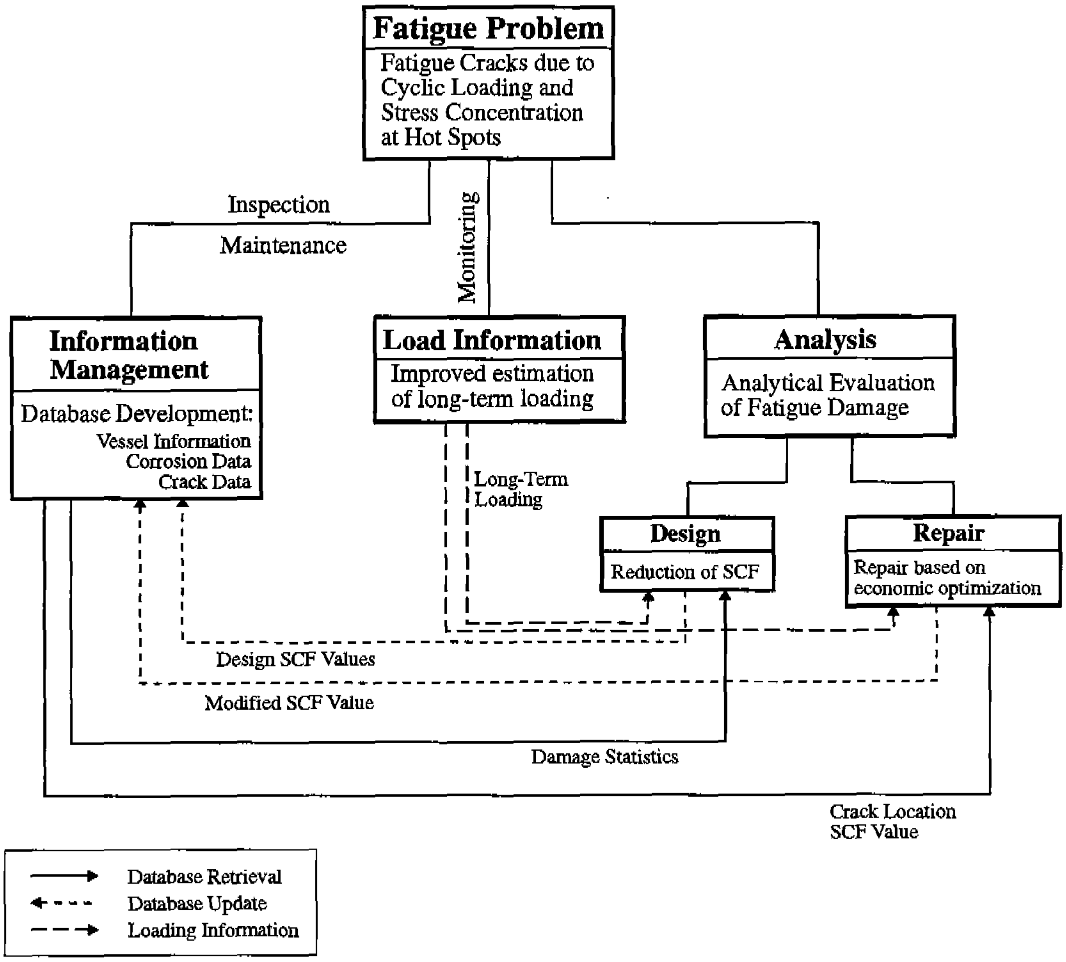


Figure 2.1: Schematic View of the Fatigue Problem

Chapter 3

Existing Ship Database Systems

3.1 Introduction

Partly due to the U.S. Coast Guard requirement of the implementation and maintenance of Critical Area Inspection Plans and also to facilitate inspection, maintenance and repair (IMR) operations, several database systems have been developed that store and evaluate general vessel information in conjunction with survey data. In the following, several of these systems are evaluated with the purpose to determine the general approach, the information contents and the overall effectiveness.

Special regard is given to the method used to determine and represent failure locations (cracks and corrosion) within a vessel. The use of graphical information is analysed to determine the relation between the cost for data input to the increase in information contents and overall usability.

The evaluated systems include the CATSIR database systems (developed by CHEVRON in cooperation with OCEANEERING), ARCO's Hull Fracture Database (HFDB), FracTrac (developed by MCA Engineering) and SID (Structural Inspection Database, developed by MIL Systems).

In addition, the SIMS (Ship Information Management System) developed as part of the Structural Maintenance Project for New & Existing Ships (SMP) project conducted at the Department of Naval Architecture & Offshore Engineering at UC Berkeley, is documented.

As part of a one-year research effort to *develop a rational basis for defining corrosion limits in tankers*, the structure of a support database system has been developed that contains ship specific data and inspection data. This database structure is documented in section 3.7.

It is the main purpose of this review of existing database systems to study the different approaches to archive and use ship information and survey results and to document the applicability of each system for a future SSIIS.

For each system, the projected usage and overall programm philosophy is described and a detailed description of the program structure is included. The benefits and disadvantages of each system are summarized with special regard to the requirements of a future SSIIS.

Additional information about current database efforts with respect to vessel reliability, availability and maintenance (RAM) databases can be found in [20]. The background and present status of RAM databanks is described. Various national and international RAM databanks are summarized with particular emphasis on the SRF data bank of Sweden and the SRIC data bank of Japan.

In a different database development, a selection guide for tankers of 10,000 deadweight tons or more has been developed and is updated and published annually, [35]. The guide is intended to aide tanker charterers, cargo owners and others involved with tankers in the selection of tankers that perform satisfactorily and pose a minimal risk of casualties.

A rating system has been developed that assigns a rating to each tanker based on a set of criteria, i.e. casualties, age, name changes, owner's total losses and oil spills, classification society, owner, flag of registry, etc..

Of particular importance is the inclusion of casualties and oil spills. Any future tanker database development has to evaluate the possible data format to identify causes for casualties and oil spills. This is particularly important to evaluate the extent of human and organizational error in tanker operations.

3.2 Database Theory

3.2.1 Introduction

The storage and management of information and operational data has always been one of the most important tasks for all types of organizations. Data is in general contained in a database. In [9], the term *database* is defined as

> A database is a collection of stored operational data used by the application systems of some particular enterprise

It has to be noted that the storage method for the data is not defined. In the following only the development of electronic database systems is outlined.

A database system is characterized by the data model it supports. Early systems were developed based on the established file system. These *hierarchical* or *network* models have in general low level data manipulation languages and require users to optimize the access to the data by carefully navigating in hierarchies or networks [13].

Almost all of the database systems developed over the past few years are based on the *relational* model. In addition, almost all current database research is also based on relational ideas. Many non-relational systems are often described, for commercial purposes, as supporting relational features. Currently, the *relational model* is the single most important development in the entire history of the database field, [9].

3.2.2 The Relational Model

The *relational model* was introduced by E.F. Codd in 1970, [4], including the following definition of the model's first objectives:

- To allow a high degree of data independence. The application programs must not be affected by modifications to the internal data representation, particularly by the changes to file organizations, record orderings, and access paths.
- To provide substantial grounds for dealing with data semantics, consistency, and redundancy problems.

In a relational system data is perceived by the user as two-dimensional tables or relations. A relation is defined in [13] as

> *Subset of the Cartesian product of a list of domains characterized by a name*

where a *domain* is the set of possible atomic data items. A relation contains a time-variant number of unique records. Each record is uniquely defined by a *primary key*, where the key can consist of a combination of several data items. An *atomic* data item is the smallest non-dividable piece of information.

Relations are manipulated by the use of a set of operators defined as *relational algebra* and an assignment operation. The most important property of each of the algebraic operations is the fact that the output of each operation results in another relation. In the original definition, Codd [6] defined eight operators, two groups of four each. One group contains the operations `union`, `intersection`, `difference` and `Cartesian product` and the other group consists of the special relational operations `select project`, `join` and `divide`.

The fundamental intent of *relational algebra* is to allow the *writing of expressions* for data retrieval, updating, the definition of access rights and many other possible applications.

3.2.3 Database Design: Normalization Theory

While the *relational model* has led to the development of powerful database systems, it does not free the user from the task of defining the database structure and organizing the required information content into different relations.

A badly designed database structure can lead to data inconsistencies due to data reduncancy, i.e. the same information is stored in several places.

Normalization Theory has been developed to formalize the requirements for an effective database design. Originally, Codd defined the first, second and third normal form (1NF, 2NF, 3NF), [5]. Later the third normal form was re-defined as the Boyce-Codd normal form (BCNF), [7] and a fourth (4NF) and fifth (5NF) normal form were proposed, [11],[12].

The definition of the different normal forms is intended to serve as guidelines for the design of efficient databases. A relation is only required to be in the first normal form (1NF). The first normal form (1NF) requires that a relation only contains atomic values.

Definitions for the higher normal forms are given in [13], [9]. In general it is desirable to develop relations that satisfy the conditions of the higher normal forms. However, for a particular database design it is possible that a relation that is not of a higher normal form can be advantagous.

3.3 CATSIR - Computer Aided Tanker Structures Inspection & Repair

3.3.1 Overview

Chevron Shipping Inc. in cooperation with OCEANEERING - Solus Schall has developed and implemented CATSIR, a database system for the data management of general vessel information in combination with the results from structural surveys, in particular crack and corrosion information. CATSIR (Computer Aided Tanker Structures Inspection & Repair) is described in [38].

CATSIR consists of two components, a database part and a customized AutoCad^{TM} drafting program.

- The database is used to store all relevant information. If it is used as a stand-alone application, the information related to the location of corrosion gaugings and crack occurrences and the description of the crack type are entered using the frame numbers and different code words.
- The AutoCad^{TM} part allows it to *post* the location information directly on the construction drawing. In addition the AutoCad^{TM} module is used to enter repair information such as areas for steel renewal and coatings. This information is transferred back into the database for processing.

3.3.2 Development History

CATSIR has been developed to be used for data storage and as a tool for the repair and maintenance process. The original development has been started in 1986. CATSIR 1.0 contained a database and an AutoCad^{TM} module and was intended to facilitate repair and maintenance procedures.

In the second version of CATSIR (CATSIR 2.0), the results of crack and corrosion susrveys were included in the database. The format for the database module that contains the crack information has been developed in cooperation with the *Structural Maintenance Project for New & Existing Ships (SMP)* conducted at the Department of Naval Architecture and Offshore Engineering at the University of California at Berkeley, [32].

The main focus of the cooperation was the representation of fatigue crack types and location without the use of graphical illustrations. This has resulted in a set of keywords that represent the crack location and the type of detail.

CATSIR 3.0 includes a modified *Defects* module. The crack and corrosion information that is entered in the database is directly transferred to the AutoCad^{TM} module. Only the location has to be entered using a pointing device (mouse). In addition, some data analysis capabilities are included that allow it to plot average corrosion rates and crack distributions.

3.3.3 CATSIR 3.0 - Program Capabilities

CATSIR (Computer Aided Tanker Structures Inspection and Repairs) is a program developed for recording and manipulating inspection and repair data for tanker structures. CATSIR links a database management system with a customized AutoCad^{TM} drafting program to allow users to display information either on drawings or in a report.

According to information provided by Solus Schall, [28] and based on the evaluation of the demonstration copy of CATSIR 3.00, the system is intended to

- **Improve gauging team efficiency** by eliminating manual drafting and field reports and by reducing preparation time for the final report
- **Enhance the efficiency and quality of inspections** through assistance with CAIP programs, improved communications between home office and gauging team and through quick identification of future trouble areas.
- **Improve repair planning productivity** by eliminating manual writing of steel specifications, manual calculations of steel weight and coating areas, manual drafting of repair drawings and through quick updates of repair specifications / drawings in the field.

According to Solus Schall, [28], CATSIR can be used in various stages of a vessel's maintenance cycle with the main applications identified as follows:

Recording of data during a voyage inspection and generating a survey report

No need for drafting of drawings since the structural AutoCad^{TM} files are always accessible in CATSIR. The use of CATSIR eliminates draft report production. The ability to send the CATSIR data electronically to the home office is possible on many ships and can considerably improve the information flow relating to an inspection.

Preparation of steel repair specifications for periodic overhauls

Steel and coatings can be specified on CATSIR drawings and steel weights and coating areas are calculated automatically. If the inspection information and maintenance history is stored in CATSIR, all information needed for preparing the specification is readily available. The CATSIR drawings and reports can then be produced and attached to the repair specification.

Reporting of inspection and repair data during a periodic overhaul

The steel repairs, coating work, and installed anodes can be directly entered in CATSIR which will automatically calculate total steel weights, coating areas, and the total number of anodes. This will greatly reduce the bookkeeping associated with structural repairs.

Preparation of U.S. Coast Guard Critical Area Inspection Plans (CAIP)

CATSIR offers an excellent means of storing and retrieving the data required by the U.S. Coast Guard for their Critical Area Inspection Plans (CAIP). CATSIR is able to record data on fractures and repairs and is easily updated after each inspection.

In order to use the graphical features of CATSIR it is necessary to implement all construction drawings in the form of AutoCad^{TM} drawings. For the case that the system is used for both data management and repair planning and documentation the considerable expense for the preparation of these AutCad drawing can be justified.

As a most recent development, EXXON has purchased the database part of CATSIR to be used for the documentation and management of vessel data and survey results.

3.3.4 CATSIR 3.0 - Program Structure

The CATSIR database system is menu-driven. The *Main Menu* contains the following five items.

1. **Vessel Information**
2. **T.I.P. (Technical Information Pool)**
3. **Tank Voyage Log**
4. **Library Maintenance**
5. **System Administration**

The functionality of each item is summarized in the following sections.

- **Vessel Information**: The vessel information module is the heart of the CATSIR program and is the access point to the twelve available CATSIR sub-modules:

Vessel Information
Vessel History
Tank Information
Drawing Log & AutoCad^{TM}
Survey (Inspection)
Anode Data
Coating Data
Crack Survey
Gauging - Wall Thickness
Photographic Log
Pitting Survey
Renewal Records

  The information contents for each of these sub-modules is listed in Appendix A.

- **T.I.P. (Technical Information Pool)**: The T.I.P. module is simply a user-defined help system designed to exist alongside the formal CATSIR help system. From this module any tip (typically relating to the system or the inspection control) may be entered thus allowing the users to share usage experience and improve overall system performance.

  Each entry in the T.I.P. contains the following information:

  - Keyword
  - Date
  - Author
  - Source
  - Comment (any length, contains the actual information

- **Tank Voyage Log**: The tank voyage log is an isolated module designed to store basic data on the conditions endured by any tank being monitored. The system provides data that may be used to predict the tank's condition based on its use.

  The information contained in the tank voyage log is listed in Appendix A.

- **Library Maintenance**: Many of the fields in the various categories in CATSIR are validated automatically, some fields are checked against standard user-defined validation libraries, thus enforcing consistent data entry. Library maintenance is the module where the system administrator controls these validation data-tables.

  The Library Maintenance module contains the following entries:

Vessel Owner Library
Ship Builder Library
Shipyard Library
Classification Society
Inspection Equipment
Inspection Company
U.T. Technicians
Steel Type
Product Number
Color
Coating Type
Surface Discontinuity
Member
IGS Source
Survey / Inspection Typ
Crack Cause
Zone Definition
Repair Type

- **System Administration**: All housekeeping tasks relating to the database management are undertaken in this module.

  The following tasks can be performed within the system administration module:

Exit
Password Maintenance
Regenerate System
Change to Multi/Single User
Printer Control
Print User Documentation

3.3.5 User Experience

The development of CATSIR has been sponsored by Chevron Shipping. The system has been used by Chevron as part of the vessel maintenance and repair operations. The experience of engineers and inspectors with CATSIR has strongly influenced the development of the most recent version, CATSIR 3.0.

Informative meetings at Chevron Shipping and the use of a demonstration copy of CATSIR 3.0 have resulted in the following information:

- Currently, 42 vessels are included in the database. About 500 AutoCad^{TM} drawings are available per vessel. A total of about **900 mB** of storage capacity is necessary for a total of 18800 AutoCad^{TM} drawings.

- Depending on the vessel class and the number of drawings per class, it costs between $15,000 and $20,000 to prepare the AutoCad^{TM} drawings for one vessel class and include them into CATSIR.
- At the present time, the AutoCad^{TM} drawings for the 42 vessels currently entered into CATSIR are stored on an optical disk and can be accessed through the implemented Local Area Network (LAN).
- CATSIR 3.0 contains some analysis capabilities that allow it to calculate and display average corrosion rates for different areas in the vessel. It is also possible to create charts that show the distribution of different crack types. However, these analysis and graphing capabilities are not flexible enough to accomodate both the day-to-day needs and more advanced research to determine trends and causes for failures.

3.3.6 CATSIR - Summary

CATSIR 3.0 is primarily designed to contain the results of structural surveys and to facilitate the repair and maintenance operations. It incorporates graphical representations of the ship structural components using AutoCad^{TM}.

The incorporation of the structural drawings in a vessel database can be used as an example for the future implementation of SSIIS. The necessary amount of storage space will make it, however, necessary to improve the data storage methods.

Presently, CATSIR can be easily improved to produce Critical Area Inspection Plans that meet the developed format. Additional data analysis routines have to be implemented that facilitate the observation of trends. In addition, the classification of critical inspection areas has to be included in CATSIR.

3.4 HFDB - Hull Fracture DataBase

3.4.1 Overview

A graphical database for hull fracture reports has been developed by Aerohydro, Inc. (AHI) for ARCO Marine, Inc. (AMI). The database is described in detail in [23]

The purpose of HFDB is the establishment, maintenance and utilization of a graphics-oriented database of structural fracture data from the AMI fleet of crude oil tankships. Using HFDB enables the user to discern and explore patterns of fracture experience, which may lead to improved design, maintenance, and inspection procedures and to reduced risk of structural failures in future vessel operations.

Data is entered graphically through the use of graphics tablets allowing fracture locations to be entered from fracture report sheets. The system uses a general coordinate system to represent fracture locations. For each vessel class the construction drawings of the different frames are stored in the database in a graphical format and are used to display the fracture information.

Due to the defined purpose of the database system the description of the location and the nature of the fracture incidents does not include a precise definition of the fracture location in the particular structural detail. The fracture information contained in the database can therefore not directly be used to verify or calibrate the results from fatigue damage or fracture mechanics calculations.

ARCO Marine Inc. is using HFDB to monitor and assess hull fractures in its fleet of ten crude oil tankers in the Alaska to West Coast trade. Use of the database focuses ARCO's fracture control efforts which include inspections, analyses, and modifications.

3.4.2 HFDB - Program Structure

A detailed summary of the program structure and the data input method used for HFDB can be found in [23] and is summarized in the following.

HFDB is a menu driven program. The main, top level menu provides access to the three principal functions:

- Data Entry
- Data Selection
- Display

The main menu also provides access to utility functions such a backing up and restoring the fracture database and deleting erroneous fracture records.

The system is implemented as a Paradox Application Language (PAL) program. This program calls compiled programs written in Microsoft© QuickBASIC to perform graphical functions not conductive to implementation with PAL.

3.4.2.1 Data Entry

Input to HFDB is initially entered by a shipyard surveyor on a paper form called a **Fracture Report Sheet (FRS)**. An FRS is an 8.5" x 11" form with a drawing of a particular structure in a particular class of ship. Five different types of FRS are currently implemented in the HFDB:

1. Bulkhead
2. Web Frame
3. Bulkhead / Web Frame
4. Centerline Girder
5. Longitudinal Girder (off-center)

A particular FRS may be *unique* or *generic*. Generic FRS's have a secondary, schematic drawing which allows the FRS to be located in the ship.

Fractures are marked on the appropriate FRS indicating the location and the severity (length). When a blank FRS has been filled out, it becomes a **Fracture Report**.

Fracture reports (FR) are entered into HFDB using a graphical tablet. For a given FR, the ship identification, date and the type of FRS is entered. To enter a fracture requires the following information:

1. A structural member selected from a list of structural members
2. A severity level
3. A location on the structural drawing

Optionally, a repair method (repair/modify/renew) and a comment can be entered.

3.4.2.2 Data Selection

Data analysis with HFDB requires the selection of data subsets. HFDB allows the selection of data based on ship, class, structure fractured, severity, and date. In addition it is also possible to select a particular FR or a specific type of structure.

For experienced Paradox users, there is a provision to enter Paradox, make a selection using all the capabilities of the Paradox query mechanism, return to HFDB, and display the selected subset.

3.4.2.3 Graphic Display

The selected data subsets can be displayed in one of three views. The *Time Plot* displays a histogram of the selected fracture records vs. time with the bars of the histogram color coded for severity.

The *Profile Display* shows a schematic profile of a ship below a stacked bar chart representing the longitudinal distribution of the selected fractures. Each bar is color coded to represent the occurrence of each severity.

In the *Section View* the location of the fractures in a selected section is shown. In addition the transverse and vertical distribution of the fractures is shown.

Each display option can be sent to an attached PostScript printer to produce presentation quality output.

3.4.3 Information in Fracture Database

The fracture database is the core of HFDB. It contains one record for each fracture. The following information is recorded for each fracture:

- Fracture Report serial number
- Fracture number - within fracture report
- FRS number - identifies the fracture repotrt sheet from wich the data was entered
- Ship
- Vessel Class
- X - location of fracture
- Y - location of fracture
- Z - location of fracture
- Severity
- Member - chosen from a defined list of structural members
- Disposition - Repair, Modify, Renew
- Year repaired
- Date entered

3.4.4 HFDB - Summary

The Hull Fracture DataBase that is currently used by ARCO has been specifically designed to facilitate the storage and analysis of fractures in tank vessels. It includes options to view the distribution of different crack types in the vessel.

Most interesting is the data input method used to enter crack locations into the database. Standardized templates are used to record the crack location in the vessel. Using a digitizing tablet, these location are then transferred to the database.

HFDB contains only fracture information. Additional general vessel data has to be included to make it fully compatible with the developed CAIP standards.

3.5 FracTrac

3.5.1 Overview

FracTrac is a database designed for the computerized tracking of vessel structural failures. It has been developed by MCA Engineering, Costa Mesa, CA 92626, to facilitate the input and storage of cracks in structural details.

In 1990 and 1991 the U.S. Coast Guard had individual meetings with tanker operators to determine and evaluate the different methods used to manage survey information related to vessel structural failures. Based on the outcome of this investigation, the U.S. Coast Guard decided to developed fracture histories for individual tankers.

In order to facilitate the development of these fracture histories, MCA Engineers initiated the development of an electronic database system that could be used to store and review vessel structural failures. After an initial development period of 1 year, the system was successfully used in a field test in Richmond, CA.

The initial development of FracTrac was supported by West Coast Shipping. In addition, BP Oil will be using FracTrac for its tanker fleet and has asked MCA Engineers to prepare the necessary input data for the vessels. This includes the development of AutoCad^{TM} drawings of the primary ship structure. An existing database that contains the fracture history for the 165,000 DWT Atigun Pass Class tankers will be converted to FracTrac in order to have the complete fracture histories of these vessels available in one database.

According to company information, FracTrac has been specifically designed to facilitate the preparation of Critical Area Inspection Plans (CAIP) as required by the U.S. Coast Guard. The possibility to have FracTrac installed onboard of a vessel makes it possible to review the fracture history and the distribution of fractures on the vessel prior to an inspection.

Based on the development and operational experience with FracTrac, MCA Engineers is currently developing additional modules that will allow it to enter and analyse thickness gaugings and calculate corrosion rates.

3.5.2 FracTrac - Program Structure

FracTrac has been developed for IBM PC compatible computers using the Microsoft© Windows^{TM} graphical user interface (GUI). The database has been built using FoxPro 2.5 database development system for Windows^{TM}.

FracTrac is intended to provide a graphical display of fractures in the ship structural details in conjunction with detailed information about the individual fractures. In order to achieve this goal, FracTrac consists of two inter-related modules:

- Graphical representation of vessel structural geometry using AutoCad^{TM} drawings of primary structural components.
- Fracture database

FracTrac has been developed as a one-vessel system. All data file and AutoCad^{TM} drawing naming conventions are designed to handle one individual vessel. In day-to-day operations, the information for one vessel is stored on an optical disk, which is loaded into the system before FracTrac is started.

If information for a different vessel is required, the *old* vessel data has to be removed and the *new* vessel data is read into the system from its optical disk.

This information structure severely limits the applicability of FracTrac for multiple vessel configurations. The need to physically remove data from the disk can result in a loss of data due to an operator error.

The data analysis capabilities are also limited due to this one-vessel configuration. It is not possible to investigate fractures in different vessels of the same class to identify trends and to evaluate pattern type failures.

3.5.2.1 FracTrac - AutoCad^{TM} Module

In order to get a clear understanding about the distribution of fractures in a vessel, it is necessary to use a graphical representation of the vessel geometry. FracTrac uses AutoCad^{TM} to visualize the ship structure, because of the wide acceptance of AutoCad^{TM} for Computer Aided Design purposes.

As part of the necessary input information for a vessel, it is therefore necessary to generate AutoCad^{TM} drawings of the ship structure. The level of visualization is dependent on the level of detail in the AutoCad^{TM} drawings.

In order to reduce data preparation costs, one operator has chosen to focus only on the cargo block and to prepare drawings only for primary structural components, i.e. webframes, longitudinal girders, bulkheads. As a result of this decision, it will not be possible to represent cracks in secondary or tertiary components. The location of a crack in a horizontal girder or a bracket connection can therefore be entered only approximately, which can result in a misleading graphical representation.

Depending on the purpose for the use of FracTrac, this loss of accuracy might be acceptable considering the significant cost benefits due to the reduced number of AutoCad^{TM} drawings.

The system is able to show a wireframe view of the vessel that includes the locations for all fractures that have been entered for the vessel. The wireframe view is created by using the outlines of all frames and transverse bulkheads.

Since the system uses a customized AutoCad^{TM} user interface, it is possible to show individual frames and structural components of the vessel. By selecting a specific fracture the structure that is linked to this fracture is displayed. This makes it possible to quickly identify problem areas and the associated structure.

A lookup table is created that specifies for each AutoCad^{TM} drawing the origin, the orientation and the location(s) within the ship. This makes it possible to have one drawing for several locations.

In general, the ability of FracTrac to include AutoCad^{TM} drawings to graphically represent the ship structure makes the program very useful to review and quickly identify problem areas. The flexibility in the level of detail in the AutoCad^{TM} drawings makes it possible to customize the display of the ship structure based on the preferences and objectives of the vessel owner. A limited representation of the vessel structure, e.g. the cargo block only, will significantly reduce the costs associated with the preparation of the AutoCad^{TM} drawings.

Fractures are entered directly into the structural drawings. Each fracture is represented graphically with a colored symbol indicating the fracture class. The fractures are directly linked to the database, where additional information for each fracture is entered. This includes the fracture location, the nature of the fracture, and additional photos and sketches.

Figs. (3.1, 3.2) show screen images of FracTrac's AutoCad^{TM} module. The figures show the different structural views and the representation of crack locations within the structure.

Fractures can only be entered for structural components that are represented in an AutoCad^{TM} drawing. In the case that a fracture is located in a component that is not represented, this fracture has to be entered in the closest structural component that is represented in an AutoCad^{TM} drawing. This procedure can therefore result in a graphical misrepresentation of fractures.

If, for example, fractures are found in horizontal girders, but no AutoCad^{TM} drawings for horizontal girders are available in FracTrac, these fractures have to be entered on the adjacent bulkhead and will therefore show in the display as bulkhead fractures. In the fracture database, however, these fractures can be identified correctly as being located in the horizontal girder. Unfortunately, it is not possible to determine, whether the AutoCad^{TM} location or the database location is the *correct* one.

3.5.2.2 FracTrac - Fracture Database

In conjunction with the graphical representation of the ship structure and the fracture location, a database is used in FracTrac to store and manipulate information related to the individual fractures.

The database has been developed using FOXPRO 2.5, a Windows^{TM}based database development system. The Windows^{TM}graphical user interface facilitates the use and display of sketches and photos and makes it possible to seamlessly integrate the AutoCad^{TM} environment for the graphical representation of the ship structure and the fracture location.

FracTrac organizes the fractures according to *Report #*, *Tag #* and *Code #*. This relates the fractures both to the AutoCad^{TM} drawing and to the survey report that has been used to enter the fracture into the database.

The fracture location is defined in two ways that are not directly related to each other. The fracture is first entered graphically in the AutoCad^{TM} drawing, which at the same time creates a record in the fracture database. Once a fracture is entered in an AutoCad^{TM} drawing, the fracture entry screen for this new record is opened to allow additional data input for the new record. Fig. (3.3) shows this data entry screen. The following information is used to represent the fracture location:

- **Tank #**: When the fracture record is first opened based on a fracture entry in an AutoCad^{TM} drawing, the **Tank #** defaults to the corresponding tank # in the AutoCad^{TM} drawing. It is, however, possible to change this entry, which in turn will destroy the link between the AutoCad^{TM} fracture location and the fracture record location. It is therefore solely the users responsibility to ensure data integrity.

- **Tank Location**: The tank location identifies the transverse location of a particular tank (port, center, starboard). This information is also by default obtained from the AutoCad^{TM} drawing, but can also be changed by the user.

- **From Frame # To Frame #**: The two frame #'s identify the longitudinal location of the fracture. The relative position of a fracture between two frames can not be accurately specified. The entry of the frame #'s is also independent from the location of the fracture in the AutoCad^{TM} drawing.

- **From Stiffener To Stiffener**: The two stiffener #'s identify the vertical location of the fracture. In praxis, this is only applicable for fractures in sideshell or longitudinal bulkhead details. The stiffener #'s are not linked to actual coordinates in a general coordinate system and can therefore not give an accurate definition of the vertical position. In addition, the relative location of a fracture between two stiffeners can not be specified.

- **Primary Member**: In addition to the geometric location, the fracture location is identified in terms of the structural components. The *primary* member details the main structural component in which the fracture is located. Primary members are: deck, bottom, sideshell, longitudinal bulkhead, transverse bulkhead, frame, center vertical keel.

- **Secondary Member**: This entry identifies the local structural component that is associated with the fracture. This makes it possible to classify fracture and perform search and analysis operations based on local structural components. Secondary members are: plating, stiffener, bracket, strut, horizontal girder.

- **Tertiary Member**: This entry is intended to identify the exact fracture location, or the fracture origin. Tertiary members are: web, flange.

- **Comment**: In the comment field, additional information about the fracture location, or origin can be entered as text.

In addition to the described information, the fracture location and type can also be identified through sketches and photos, which can be a more effective method to clearly document a specific fracture. The only drawback in the use of sketches or photos is the amount of storage space that is necessary. Sketches and photos are stored as bitmaps, which have a size of about 100 Kb. The use of sketches and photos will therefore significantly increase the size of the database.

After specifying the fracture location, the fracture characteristics are described in more detail. The following information is entered for each fracture:

- **Class**: Three classes of fractures can be entered. These classes correspond to the U.S. Coast Guard definition of fracture classes, see [15]. The USCG class definitions are summarized in section 5.2.1. This class definition is used to color-code the fracture locations in the AutoCad^{TM} drawing.
- **Size in inches**: The length of the fracture is entered here.
- **Repair Method**: In order to evaluate the effectiveness of different repairs, it is necessary to specify the repair method for a fracture. The following repair methods can be entered: re-weld, renew, modified.
- **Type**: The type information is intended to distinguish between new fractures and fractures in previously repaired locations. This information can help to identify unsuccessful repair solutions.
- **Previous Tag #, if repeated fracture**: For fractures in previously repaired locations, the tag # of the original fracture has to be entered to allow the construction of repair histories.
- **Comments**: Comments with regard to the fracture cause, or specific location or other more general remarks can be entered in text form.

The database module of FracTrac does not contain provisions to enter general vessel related information, i.e. LBP, LOA, breadth, draft, etc.. In addition, no tank specific information can be entered. This constitutes a significant drawback with regard to the preparation of Critical Area Inspection Plans (CAIP). As part of a CAIP, general vessel information is required. In order to develop an automated CAIP report generating module, it is necessary to have access to the general vessel information.

3.5.2.3 FracTrac - Reporting Module

A reporting module is currently being implemented by MCA Engineers. This module uses graphical displays to show the general vessel layout including tank locations and tank types. Fig. (3.4) shows this reporting screen. In addition to the tank locations, a pie-chart is shown that identifies the percentage of Class 1, 2 and 3 cracks found in the vessel.

In a second screen for the inspection summary, bar-charts show the number of cracks separately for port, center and starboard tanks. This FracTrac screen display is shown in Fig. (3.5). It is possible to select the display of all fracture classes or only one or two of the three classes. This makes it possible to clearly identify the more severe fracture classes.

The tank locations and the general arrangement are obtained from a general arrangement plan that is contained in FracTrac as an AutoCad^{TM} drawing. The different tank types are identified through the use of color-coding.

The distribution of fractures over the ship length can be customized using different search and selection criteria. It is possible to select all fracture classes or to show only one or two of the three classes. In addition fractures can be shown for individual tank types and tank locations.

The focus on the three fracture classes, as defined by the U.S. Coast Guard makes the reporting module very useful for the generation of Critical Area Inspection Plan (CAIP) reports. The use of color codes to identify the different fracture classes makes it possible to obtain a very informative overview over the general vessel condition.

3.5.3 FracTrac - Summary

FracTrac consists of a combination of a customized AutoCad^{TM} interface with a Windows^{TM}based database system. The software is intended for the computerized tracking of vessel structural failures. According to company information, FracTrac can be used for the generation of Critical Area Inspection Plan (CAIP) reports as required by the U.S. Coast Guard.

Based on this evaluation of FracTrac, it has to be concluded that the program can be very helpful in the generation of CAIP reports, but it misses some important information that is required as part of a CAIP report. In the following, some of the key features of FracTrac are commented:

- **Program Structure**: The configuration of FracTrac as a one-vessel application severely limits the program for general use. Reporting and analysis capabilities for multiple vessels of the same class are not possible. The manual replacement of data that is necessary in order to load a different vessel into FracTrac can result in data losses or data corruption due to an operator error.

- **AutoCad^{TM} graphical display**: The use of AutoCad^{TM} drawings to represent the ship structure results in a detailed representation of the structural configuration. Fracture location can be accurately defined, if the AutoCad^{TM} drawing of the relevant structural component has been included in the FracTrac drawing library.

  In cases were drawings of secondary or tertiary structural components have been ommitted due to economic considerations, fractures in these components can not be represented at the correct locations.

- **Fracture database**: The database is focused on the entry of fracture information only. No general ship information or tank information can be entered. This limits the database as a general tool for the storage of vessel information. In addition, necessary information for the generation of CAIP reports is not available.

  The focus on U.S. Coast Guard fracture classifications makes the database very useful for the documentation and tracking of fractures and the reporting to the USCG.

- **Reporting Module**: The graphical representation of fractures over the ship length and the ability to show different fracture classes separately makes the reporting capabilities of FracTrac very well suited for the generation of CAIP reports and the internal review of fatigue cracking in tankers.

3.6 Structural Inspection Database (SID)

3.6.1 SID - Overview

The **Structural Inspection Database (SID)** is a software program created to collate data on structural surveys, defects and repairs on Canadian Forces vessels, and assist in the assessment of structural integrity, the management of survey and repair strategy, and the pursuit of various related Research & Development initiatives.

SID has been developed by **MIL Systems Engineering Inc, Ottawa, Ontario, Canada**[1] on behalf of the Canadian Navy. The system has been developed with the purpose to automate the inspection data recording process and to facilitate the generation of structural integrity reports.

Although SID has been developed for the use with Navy vessels, it can easily be adapted to commercial vessels. SID is currently used by the Canadian Navy and has been licensed to the Royal Navy in the U.K. and to NWSC, the U.S. Navy ship research group.

SID is intended as a tool with which the entire structural inspection information base of the Canadian Forces maritime arm may be controlled and used to maximum effectiveness. SID has the capability to store information pertaining to every ship in the Forces.

Each ship is divided into its internal spaces (or compartments) and internal or external features such as masts (referred to as elements). In turn, every defect located in every compartment or element of every ship is also stored within SID.

In Canada, the program is used by surveyors at the two designated survey and maintenance centers, Halifax on the Atlantic side and Esquimalt on the Pacific side. Data analysis and evaluation

[1] Complete address in appendix F

is performed at the Navy headquarters in Ontario, Canada. The headquarter also provides the basic setup information required by SID for surveyor use (i.e. ship information).

3.6.2 SID - Program Structure

The information with regard to the program structure has been obtained from the SID User Manual, [17], that has been supplied together with a demonstration copy of the program to the SSIIS project.

The program uses the Windows^{TM}graphical user interface. The software is menu based and uses a pointer-type approach, in which the current ship, deck, compartment, and defect remain in effect as the current selections until a different configuration is selected.

Structural defects are specified for a specified ship, compartment and deck. The currently selected ship, compartment and deck are shown on three buttons on the `Main Menu Screen`. The buttons may be used to select the current ship, compartment or deck.

The ship and compartment button bring up the ship or compartment browse screens, respectively. The deck button activates the deck plan screen, from which the current deck can be selected. These screens are described in the following sections in more detail.

The SID menu consists of the following eight items:

- **Administration**: The administrative items in this menu selection are intended primarily for the system administration for maintenance tasks.
- **Input**: Allows the input of ship, compartment and defects information. Special editing permission is required to enter ship and compartment information.
- **Edit**: Allows the editing of ship, compartment and defects information. In addition, it is possible to edit the `Statement of Structural Integrity`. Special editing permission is required to edit ship and compartment information.
- **Browse**: The browse screens allow it to view listings of available ships, compartments/elements and defects. These screens are used to select the current ship, compartment or defect. Special editing permission is required to delete data items from the browse screens.
- **DeckPlan**: The DeckPlan menu item activates the graphical deck plan display of SID. The graphical deck plan display makes it possible to choose decks, compartments and defects without using the actual `Main Menu`.
- **Reports**: Three types of reports can be generated. A printout of the DND 1754 form, a listing of all of the compartments requiring inspections, and a custom query feature to provide user-specified information.
- **Exit**: Exit SID.
- **Help**: Opens a customized help system.

Several of the system features of SID require special editing permissions granted through the use of different passwords and user definitions. This guarantees that the sensitive system data, i.e. ship and compartment information cannot be changed by unauthorized users.

SID uses a system of part hierarchies and defect types to clearly identify defects in structural components. Using a part hierarchy makes it possible to store the exact defect location without the use of a graphical representation of the structural geometry.

The following sections describe some of the key features of SID in more detail. This includes among others the ship data entry, the compartment selection and the defects classifications.

3.6.2.1 SID - Ship Data Entry

The definition of a ship for later compartmentation and defect input is the necessary first step in the entire SID recording process. The basic vessel related information is entered on the ship data entry screen. This screen is shown in Fig. (3.6).

This entry screen is used to enter general vessel information (name, class, home port, etc.), and inspection history (including inspection dates and caveats on ship operations). Special edit permission is required to enter ship information.

As part of the vessel information it is necessary to enter the frame location on the ship. Surveyors enter defects with respect to frame numbers, and it is therefore necessary to provide information that links the frame numbers to the geometric location within the vessel.

Deck names have to be entered for all decks. Deck names are limited to two characters and should be entered from top to bottom in order. Decks should be entered as they appear on the ship's drawings.

In order to create the graphical ship deck plan it is necessary to enter geometrical information about the ship's compartments and elements. A compartment is a normal interior space on the vessel (i.e., enclosed in all three dimensions by decks and/or bulkheads. An element is an item which is subject to structural inspection but which cannot be classed as a compartment, such as masts and appendages.

The compartment information is entered on the *compartment data entry screen*, shown in Fig. (3.7). The compartments are defined for the individual decks. Compartments and elements are defined using what is known as a *bounding box*, which consists of a rectangular box at the extrem extents of the compartment or element, or portion thereof. In general, each compartment or element is defined by a single bounding box within SID.

Compartments and elements are specified only once in a given ship, so that those compartments which extend through more than one deck in the vertical direction are defined as part of the lowest deck upon which they appear. Compartments, tanks, and voids which have the bottom of the ship as a boundary are normally placed at the lowest deck level of the model.

If a ship of the same class has been previously entered, all of the geometric information of that vessel can be copied to a new vessel. This includes the frame locations, the decks, and the compartment/element definitions. In SID this process is referred to as *cloning*.

3.6.2.2 SID - Defects Entry

The defects entry is the core of the Structural Inspection Database. Fig. (3.8) shows the *Defects Entry screen*. The defect entry screen is similar in layout to the Canadian Forces form DND-1756, the *Hull Survey Record Sheet*. The DND-1756 entries for ship name and class, deck, compartment name, and frame number correspond to the values entered in the defect entry screen. Defect type and affected part and the detail location can be entered in SID directly based on information in DND-1756.

The current ship name, deck, and compartment are displayed. A sequential defect number is assigned and displayed. The surveyor name and a check to indicate if the entire compartment was surveyed have to be entered. In addition, the date, when the defect was identified, has to be specified.

The defect location is defined by the frame number, where the defect is located and the height of the defect above the deck (entered as a percentage of the distance between the deck and the deckhead). The transverse location of the defect is defined either by the longitudinal number (including P or S, to indicate Port or Starboard location) or as a *distance from the compartment centreline* (also including P or S). Only one of these transverse location definitions can be entered to avoid data corruption.

Other information about the defect and repair are entered as free format text in the *Additional Details*, *Proposed Repair* and *Action Taken* boxes.

The defect type is specified in a pop-up dialogue, shown in Fig. (3.9). Several standard defect types have been pre-defined, along with the possibility to enter *Other* non-standard defects. For each defect type, additional, more specific information is required. In the following, the different defect types are listed:

- cracking
  - mode: brittle, ductile, fatigue or unknown
  - length: numeric
- corrosion
  - general or pitting
  - depth: surface ($\leq 10\%$), moderate ($\leq 25\%$), deep ($\leq 50\%$), or excessive ($> 50\%$)
  - localized ($<$ % of total area of structural part), scattered ($< 25\%$), or extensive ($> 25\%$)
- deformation
  - tripped, torn, bent, wrinkled, dished, or *other*
  - span
  - depth
  - description recommended for type *other*
- other
  - description

After specifying the defect type, it is necessary to define the *affected part*. This definition is also performed using a pre-defined hierarchy. This procedure facilitates the grouping and sorting of defects for analysis by standardizing the identification procedure for defective parts.

The hierarchy is organized as a tree structure, where each branch of the tree becomes more specific about the defect. The tree structure has been implemented through the use of list boxes, each corresponding to a level in the parts hierarchy. Fig. (3.10) shows the data entry screen used to identify the affected part. The tree structure is shown for a sideshell detail.

3.6.2.3 SID - Deck Plan View

The *Deck Plan View* shows the graphical representation of the deck plan. Fig. (3.11) shows part of the deck plan for a navy fuel supply vessel. The deck plan shows the compartments that have been entered for a given deck.

The deck plan can be used to choose decks, compartments, and defects, moving within the SID menu structure without using the actual main menu. Decks are selected using a *Deck* list box. Once a deck is selected, a graphical representation of the spaces on that deck are displayed. The *bounding boxes* of all compartments on the selected deck are shown.

3.6.2.4 SID - Reports

The *Reports* menu item in SID is used to generate listings of data from the information stored in the database. Three types of reports are available:

- **DND-1754 form**: A printout of Part 3 of the process involved in documenting a whole ship survey is generated, including
  - The HMC *Ships Survey Compartment Listing* for the ship
  - HMC *Ships Survey Compartment Listing Continuation Sheets*
  - the *Hull Survey Record Sheets* for each defect on the ship
  - the *Hull Survey Record Continuation Sheets*

- **Compartments requiring survey**: A list is generated containing all compartments or elements that have not been inspected since a user-specified date
- **Custom query results**: SID uses a query feature that makes it possible to extract customized information from the database. Selected fields can be chosen from the database using a query mechanism. For a selected set of fields, the scope of the retrieval and the report format can be defined. This makes it possible to generate customized reports for specific purposes.

3.6.3 SID - Summary

SID is a database system to document inspection results and structural failures, originally developed for use by the Canadian Navy. The software is intended to collate data on structural surveys, defects and repairs of vessels, and to assist in the assessment of structural integrity, the management of survey and repair strategy, and the pursuit of various R&D initiatives.

The vessel structure is defined by frames, decks and compartments. Compartments are entered for each deck. The *bounding box* for each compartment is used to create a graphical display of the compartments for each deck. This graphical view can be used to select compartments and access defects information.

No graphical representation of the structural geometry is used in SID. This has the advantage that the required initial input for a vessel is substantially reduced. It is, however, not possible to show the defect location in a structural component. For a database system, that is designed for a large number of different ship types, the decision not to use a graphical representation of the structural geometry, greatly reduces the setup costs and the necessary data storage capacities.

Defects are defined by the defect location (frame #, transverse position with respect to the current deck, transverse position), the affected part, and the type of defect. A *tree structure* approach is used to identify the affected part. This method makes it possible to precisely identify a defect location and to perform database searches for a particular location or detail component. Especially important for fatigue cracks is the ability to identify the local component in which the crack originated. Due to the importance of the *tree structure* for the identification of the exact defect location and the detail configuration, the complete *tree structure* is shown in Appendix B.

SID contains report generating options that are tailored to the need of the Canadian Navy. The inclusion of these report generation options greatly enhances the usefulness of the database system and can serve as a guideline for the design of the CAIP report implementation in SSIIS.

Overall, the Structural Inspection Database (SID), developed by MIL Systems, Ontario, CANADA, is a very powerful database system for the recording and analysis of structural failures in ships. The system contains most of the necessary information to generate CAIP reports. The use of a *tree structure* to identify the geometric configuration of the defect location provides a suitable alternative to the graphical representation of defect locations and can also be used for detailed database analyses.

3.7 Definition of Corrosion Limits (DCL)

3.7.1 Overview

A research project has been conducted at the Department of Naval Architecture & Offshore Engineering at the University of California at Berkeley[2] titled *Development of a Rational Basis for Defining Corrosion Limits in Tankers*. This project has been a continuation of the Structural Maintenance Project for New & Existing Ships (SMP) conducted at Berkeley in 1990 - 1992.

It was the objective of the DCL project to make advances in the area of setting allowable limits for the wastage of tanker structures based on a procedure involving rational analytical techniques as an adjunct to the traditional, experience based approaches.

[2]Complete address in appendix F

Current practice in the definition of corrosion is based on a unified hull girder longitudinal strength standard as defined by the International Association of Classification Societies (IACS). The standard is based on the aquired experience with successful designs and is well established for traditional design and construction concepts. A safety margin is included in the formulae for longitudinal strength to account for the corrosion wastage.

In the DCL project, the definition of corrosion limits is viewed as only one component of an overall Life Assessment procedure. Corrosion wastage is only one of the possible failure modes for a vessel. In order to develop a system that can be used for all of the possible failure modes, a database system is used to contain all the necessary input information. This includes the general vessel and structural geometry description, vessel survey information and historic performance data.

As an application example, the life assessment procedure is implemented for the failure modes of buckling instability of the ships structural components. A database system is used to store and manage all necessary input data and intermediate results.

3.7.2 Program Structure

The general approach and the program structure are documented in detail in [24]. The DCL project uses a life assessment procedure developed by Nippon Kaiji-Kyokai for ships and offshore structures. This procedure describes the reliability of a vessel in terms of the *availability* of the vessel, where *availability* is defined as the percentage of time that the vessel *must* be in service.

A vessel is in general out of service due to inspections or repairs. These *outages* can be attributed to three major categories of events:

1. Planned Inspection and Maintenance Routines (IMR)
2. Repair of structural failures that are due to a weakness in the ship's structure.
3. Repair of structural failures following accidents that are caused by unforeseen extreme loading conditions and/or human and organizational error (HOE).

A numerical quantity called *un*availability can be defined as that fraction of time that the vessel is out of service (years-per-year) due to each of the above three categories. Respectively, these components of the total unavailability, U, can be designated as U_{PL}, U_{SF}, U_{OT}. the availability, Av, is expressed as:

$$Av = 1 - U = 1 - (U_{PL} + U_{SF} + U_{OT})$$

In order to support the types of analyses involved in the assessment of the *availability* it is necessary to create a database system. This database system has to contain the following three major components:

- A preliminary survey database that would contain, among other things, information concerning the vessels particulars, its cargo, its route, its corrosion protection system, its inspection and maintenance routine, its intended service life, and its prescribed availability.
- A database of records and statistics of unforeseen accidents, instances of human error resulting in accidents.
- A database containing referential data such as gauging reports, crack inspections, the location and nature of structural failures, the time it took to repair them, etc..

A database management system is necessary to maintain the data and control the flow of information. Fig. (3.15) shows a data flow diagram (DFD) depicting the role of the database management system within the context of the DCL project.

In order to calculate the unavailability due to structural failures, U_{SF}, it is necessary to classify

- Yield failure due to bending of the ship
- Compression instability buckling
- Brittle fracture
- Fatigue fracture
- Ultimate plastic collapse

In the DCL project, only the two failure modes *compression instability buckling* and *ultimate plastic collapse* are treated. For each failure mode, the Mean Time Between Failures (MTBF) and the Mean Time to Repair (MTTR) have to be calculated.

3.7.2.1 Evaluation of Structural Failures, U_{SF}

The unavailability due to year-to-year type structural failures, U_{SF}, is defined as a function of the mean time between failure incidents and the mean time that the vessel is unavailable while the failure is being repaired. U_{SF} is a function of time and has to be calculated for all failure modes.

The general procedure for the calculation of U_{SF} for a specific vessel involves the evaluation of the loading effects based on the specific vessel geometry and loading environment. After calculating the capacity of the vessel structure, a reliability based analysis is performed to estimate the probability of failure for the particular failure mode based on the calculated loading and capacity. This then leads to the calculation of U_{SF} for a given time step.

Using corrosion data obtained from the referential database, the corrosion wastage for each element in the section is calculated and U_{SF} is calculated for the next time step. This process is repeated until U_{SF} is defined over the entire design life of the vessel.

The necessary vessel information is obtained from the *preliminary* database, described in section 3.7.2.2. In addition, the necessary vessel sections are defined using the notation of *elements*.

The demand, or loading, is based on a probabilistic model of the extreme vertical bending moment for a specific vessel. This model uses a spectral representation of the wave environment on a vessel route specified by the time spent in different Marsden zones. The extreme total vertical bending moment is comprised of the still water bending moment and the wave bending moment. Both are considered to be random variables.

The capacity of a vessel's structure to resist the different failure modes is represented by probability distributions. The capacity can generally be described in terms of load/displacement curves for both local and ultimate failure modes.

3.7.2.2 DCL - Database System

The three different database modules that are controlled by the database management system are used for the general life assessment analyses. This relationship is shown in Fig. (3.16). The *referential* database contains fleet-wide general data, vessel routes and inspection data. The *preliminary* database contains vessel specific data, vessel structural information and mission profiles. The *accident record* database contains data related to human & organizational errors (HOE) and other accident data.

The *referential* database that is used for this project, contains mainly inspection results (gauging reports) that are necessary to determine the corrosion rates for particular locations in a vessel. In addition, it is intended to contain data related to the location and nature of structural failures, including the time it took to repair particular failures.

The *preliminary* database is intended to provide all of the vessel specific information that is needed as input for the different analysis modules. A hierarchic definition of the vessel's internal arrangement is used. This definition is shown in Fig. (3.17). It shows the hierarchy as a one-to-many relationship. For every vessel there are many section separated by transverse bulkheads, and for every section there are a number of deck levels separated by decks and inner bottoms, and, finally, for every deck level there are a number of transverse compartments separated by longitudinal bulkheads. Although simple, this model is considered to allow a realistic description of the internal arrangement of a vessel.

For load calculations, such as the vertical wave bending moment, the hull geometry has to be available. For this purpose, the vessel is subdivided longitudinally into a number of stations. For each station the weight and the hull form is needed. Fig. (3.18) shows the station description for the purpose of load calculations. For each station the *half breadth*, the *height*, and the *girth distance* are entered for a sufficient number of points. This information in conjunction with *curve fitting* procedures is sufficient to describe the hull geometry.

In addition to the hull description contained in the *preliminary* database, information with respect to the mission profile of each vessel is included. This information is necessary to calculate the long-term loading based on the wave environment encountered by the vessel.

3.7.3 DCL - Summary

The DCL project uses a database to contain and handle all of the information requirements for the probabilistic analysis of the *unavailability* of a vessel. The project demonstrates the need for and the advantage of a general database system for vessel information. The integration of the information in a relational database makes it possible to develop the analysis procedures in a modular fashion.

The developed database structure is not detailed enough to serve as a prototype for the SSIIS database structure. However, it can be used as a good example for the benefits of a vessel information database.

3.8 The Ship Information Management System (SIMS)

3.8.1 Overview

The *Ship Information Management System* has been developed as part of the Structural Maintenance Project for New & Existing Ships (SMP) at the Department of Naval Architecture & Offshore Engineering at the University of California at Berkeley[3] .

The objective of the development was to create a database system that combined all relevant information regarding the operation of oil tankers including the results of all surveys that are performed during the lifetime of a vessel. The project participants (tanker operators, classification societies, shipyards) would thus obtain a common database system that allows data storage and management. Within the SMP project the database served the following purposes:

- Definition and calculation of average corrosion rates based on gauging information contained in the database.
- Definition of data structures suitable to document crack incidents detected in vessel surveys.
- Development of a sufficiently large data sample to calculate target failure probabilities based on actual failure data. This information was necessary for the verification and calibration of the developed fatigue life evaluation software.

During the first year of the SMP project two separate database systems have been developed, one for corrosion data and one for crack data. A corrosion database has been developed to contain the results of gauging reports. A large amount of survey data has been included in this database. Software has been developed to calculate the *average corrosion rates* for different ship details, locations and cargo. This development has been extensively documented in [29] and [3] and [2].

Parallel a database system has been developed to contain of crack surveys. This development of the database format has been closely related to the development of the CATSIR database system.

[3]Complete address in appendix F

Survey results for several ships has been included in the *crack* database. These survey results have been used to perform a set of preliminary data analyses. The development of the *crack* database and the results of the analyses have been documented in [32].

The experience that has been gained through the development of the two database systems and the need to develop a combined, integrated database system that contains both the corrosion and the crack information have let to the development of an improved database format. The comparison with several existing *crack* databases that have been supplied by participants of the SMP project has also been a great help for the definition of the database structure.

3.8.2 Summary of the Corrosion Database Development

One main objective of the Structural Maintenance Project for New and Existing Ships (SMP) was to study the effects of corrosion on internal tanks on ocean going oil tankers and product carriers. This includes the study of the primary corrosion effects, the evaluation of the different corrosion protection systems and the development of a database system with the main goal to determine corrosion rates for various types of tanks and conditions within tanks.

The results of the corrosion part of the SMP project are documented in [29]. This report contains the following topics:

- Summary of Literature Review
- Basic Corrosion Mechanisms in Ships
- Corrosion Protection Systems
- Summary of Data Analysis Method
- Summary of Corrosion Rates obtained from Analysis
- Conclusions and Recommendations

In the appendix of [29] a method is outlined that uses a reliability format to determine average corrosion rates and to define wastage limits.

In addition Corrosion questionnaires that have been sent to project participants are documented. Sample data sheets from corrosion surveys that have been used for the data input are also documented.

In the following section the material in the corrosion report that is related to the development of the corrosion database format is summarized. This will help to document the changes that have been made in the database format to both improve the database and to develop an integrated database format containing crack and corrosion data.

3.8.2.1 Development of Corrosion Database Format

The corrosion database format has been designed to include the data that is found in a gauging report. This data is usually obtained using an ultrasonic thickness (UT) device. It is the intent of gauging surveys to determine the average corrosion rate in a plate. For this purpose several measurements are taken that are assumed to be representative of the corrosion in the plate. Using statistical analysis procedures the mean or average corrosion can be determined.

In general, the corrosion rate is influenced by the environment the element is exposed to. This includes the type of tank (ballast or cargo), the chemical composition of the tank contents, the type of structural member, etc. .

The database has to be capable to include all these influencing factors in order to be a valuable source of information. Based on a questionnaire that has been sent out to the project participants, a list of important influence factors for which reasonable amounts of quality data exist, has been compiled. This list is summarized in the following table.

Ship Size	Tank Type	Cargo Sulfur (%)
Delivery Date	Time in Cargo	Cargo Water (%)
Cargo Type	Time in Ballast	Wax in Cargo
Double Bottom	Corrosion Protection System	Heated Cargo
Double Side	Ballast Type	Tank Washing
Class Society	Tank Temperature	Corrosion Type
Trade Route	Tank Humidity	Corroded Detail
Tank Location	Inert Gas	Location

The factors were separated into three main types: Ship specific data, Tank specific data, and Incident specific data. Ship specific data are those data which are assumed to apply to all gaugings in all tanks for all surveys of a single ship. They include: ship size, date of build, cargo type (crude or product), double side, double bottom, class society, trade route.

The tank specific data include: tank type, time in ballast (for ballast tanks), corrosion protection system, fresh or salt water ballast, clean or dirty ballast, sulfur, water, and wax content of cargo, presence of heated cargo, IGS gas quality, method of tank washing. Just as in the ship specific data, this will be assumed to remain constant over the life of the ship.

The incident data was taken for every incident of corrosion included in the database. An incident of corrosion is defined as a location where a gauging was taken. Thus every gauging represents a corrosion incident, and every gauging from the survey is included in the database. The incident data includes: ship age at survey, the type of corrosion, the type of detail the corrosion is gauged at, and some relative location in the tank of the gauging.

3.8.2.2 Representation of Detail Types

The types of details that were included in the corrosion database are represented by code words. These code words, based on the set of details used by the Tanker Structure Cooperative Forum (TSCF), are compatible with the code words used in the crack database. The details for the corrosion database do not have the same level of sophistication, e.g. brackets of any type are not included in the corrosion database. It was felt that the large increase in the degrees of freedom (and so a diminished sample size for each of the details) implied by the larger list would yield a unnecessarily diminished confidence in the results. It is important in a statistical study, because of the variable nature of corrosion, to obtain a sufficiently large sample size, so that any statistical characterization developed at least approaches reality. The TSCF list of basic details was chosen as a basis which would satisfy both the requirements of brief generality, as well as compatibility with the fatigue database.

3.8.2.3 Incident Location

The location of the gauging is given simply in the longitudinal, and vertical frames as either forward-middle-aft third of the tank or upper-middle-lower third of the tank respectively. A similar format is used in the crack database. Any more detailed, or rather specific, manner of identifying location would have meant the same increase in degrees of freedom as discussed above.

3.8.3 Summary of the Crack Database Development

3.8.3.1 Field Trips

Several Members of the project team have visited tankers during special surveys or other opportunities. These visits were intended to provide insights into survey methods and procedures and to observe inspection evaluations, repair design and repair fabrication associated with cracking and corrosion in structural components of tankers. The impressions developed from these field trips have been documented in the fatigue database report [32].

3.8.3.2 Location Representation

The definition of the location of a crack in a ship and the representation of this location proved to be a very complex problem. This problem arises due to the fact that it was not possible to link the crack data to graphic representations of the ship geometry.

Economic considerations requiring a minimum of data input had to be balanced with the need for an accurate representation of the location and the crack geometry. Since it is important to understand the original representation that has been developed in order to appreciate the modifications made in the development of the *Ship Maintenance Information System (SMIS)*, this original representation of the location, as documented in [32], is repeated in the following:

3.8.4 Combined Database Structure for SIMS

Two database formats have been developed as part of the Structural Maintenance Project. One to document and archive the results of gauging surveys i.e. corrosion, the other one to document and archive the results of structural surveys, i.e. cracks and other structural damage. These database formats had to be combined in order to create a versatile database management system. In order to reduce the amount of redundant information and to provide a means to prohibit illegal input a relational database format has been used. A short description of relational database theory is given in section 3.2.

Based on the experience from using the database formats that have been developed earlier for the crack and corrosion databases, several improvements have been made to these formats. These improvements and reasons for it are outlined in the following.

The combined database has to be able to contain all the ship relevant information. In addition all survey results have to be stored and have to be easily accessible. The database has to be detailed enough to allow scientific analysis of the data.

The *crack* and *corrosion* databases both require that ship specific information is available, such as tank numbers, longitudinal numbers, etc. . In addition it is desirable to use the same method of identifying the detail by using a set of code words defining principal location and detail components.

Most data items that are included in the database consist of some form of code word. For each item there is in general only a limited number of possible code words.

In the originally developed database formats most code words were defined only in the respective reports. One example of this procedure is the definition of the *side*. The crack database format defines the *side* by three code words (**P, C, S**) for port, center and starboard, respectively. The three code words are only defined in the database report.

The database management system then has to be developed specifically according to the written definitions. This is a severe limitation since the change of a code word requires the change of the database management software.

The limitations of this procedure have been experienced during the data input and the data analysis. The modified database format therefore uses a different procedure. For all information that is input using code words, these code words have to be defined in the database. This is done by using a data relation that contains all available code words for one data item together with a description of the code word. This allows it to easily add code words and also to change the description of one code word.

The database management system then simply links the input of one data item to the data relation containing the list of available code words. This procedure makes it impossible to enter invalid information. The database management system also does not have to be changed, if the list of code words is changed.

The above example of the *side* would be implemented by providing an additional relation for the *side* code words. This relation has three entries. Each entry contains the code word and a description, e.g. the code word **P** and the description **port**. The actual implementation is slightly different. Here the *side* is defined by five different code words. The exact format is described in section 7.3.9.

The database structure has been developed to include all ship specific information and the corrosion and crack related survey results. The overall database format is shown in Fig. (3.12). The figure shows the overall data structure. Only the name of each relation is displayed.

The data structure is primarily subdivided in two parts, the vessel description and the survey results. The vessel description is contained in the *class*, the *vessel* and the *tank* relations. Each of these relations has several other relations associated with it that contain secondary information and assure data integrity.

The *corrosion* and *crack* relations use the same definitions to describe the detail configuration. Each of the two relations also has associated secondary relations that assure data integrity and supply necessary data definitions.

3.8.5 Data Analysis

As part of the database development process, extensive data analysis has been performed using data from original survey reports and data obtained from other crack databases. The data analysis was performed for two main reasons:

- To show possible applications for the developed database
- To determine the areas and types of structural details that are most likely to be subject to fatigue damage

Fig. (3.13) shows the distribution of sideshell cracks over the shiplength, which is represented by the frame numbers. Most sideshell cracks are concentrated in two areas of the ship, *frames 29 - 35* and *frames 53 - 57*.

For each tank the distribution of the sideshell longitudinal cracks over the ship height has been plotted. The ship height is represented by the longitudinal #. Fig. (3.14) shows the crack distribution over the ship height for one tank 4. A total of 212 cracks were found in this tank. About 90% of these cracks occurred in *longitudinals 30 - 36*. These two figures give a good example for the possible use and the benefits of a vessel database that contains the results of structural surveys.

3.8.6 SIMS - Summary

The original database formats that have been developed to contain the survey results for crack and corrosion inspections have been combined and improved to create the *Ship Maintenance Information System (SMIS)*. This development has been based on experiences gained through the data analyses that have been performed and on comparisons with existing ship databases.

The developed system uses the concept of relational database theory. This has several important benefits, such as data integrity and a minimization of data redundancy.

The database structure does not rely on a graphical representation of the vessel geometry to represent crack and corrosion locations. It is therefore not necessary to include hull offsets and structural drawings in the database. This makes the system more usable for a wide variety of possible users. It requires less time to include additional ship classes and is therefore much less man-power intensive than most other system. The structure is set up in a way that allows it to non-dimensionalize locations in a ship, which makes it possible to compare data for different classes of ships in a realistic manner.

3.9 Database Usage for Research Purposes

The increased occurence of fatigue cracks in oil tankers has resulted in several research efforts to develop or improve fatigue life analysis procedures. Due to the complexity of both the long-term loading and the representation of fatigue strength of ship structural details the calculated fatigue life can vary considerably.

It is therefore desirable to use actual damage statistics to calibrate the analysis procedures. This can be accomplished through the use of database systems. One of the reasons to develop a database system as part of the SMP project was the need to obtain damage statistics for cracks in oil tankers. Survey results for several tankers have been included in the database. In addition data from existing databases maintained by tanker operators has been included in the SMP database. This process is described in detail in [32].

The data contained in the first version of the SMP database has been used by other researchers for verification purposes. In [39] a realistic wave model has been developed to calculate the fatigue damage in the side shell longitudinals of ships. The model has been used to analyse a segregated ballast tanker, and the results are compared to previously registered fatigue cracks that are included in the SMP database.

In a research project sponsored by the SNAME Technical and Research Committee crack data for a class of vessels contained in the SMP database has been used to validate analysis results. The project is described in [19].

3.10 Conclusions

Several existing database systems for the storage and analysis of structural survey results of ships have been evaluated to determine abilities of each system to generate CAIP reports and to gain experience for the development of a general Ship Structural Integrity Information System (SSIIS).

None of the database systems contains sufficient information to generate CAIP reports that are fully compatible with the developed CAIP reporting format, see chapter 5.7.

Different strategies have been used to represent failure locations and to describe the structural configurations. The use of AutoCad^{TM} drawings results in a large amount af data that needs to be stored, but has the advantage that graphical representations of failure locations are readily available. None of the systems that use AutoCad^{TM} have solved the problem of linking the failure locations on a drawing directly to a failure incident in the database in a fashions that prevents possible data corruption.

The data analysis capabilities of the different database systems have to be improved to generate meaningful CAIP reports that clearly document trends and show critical failure areas.

Overall, the evaluation of existing databases has been very important for the development of the SSIIS database structure. Additional user experience with the different database systems has to be gathered to aid in the final definition of a future SSIIS.

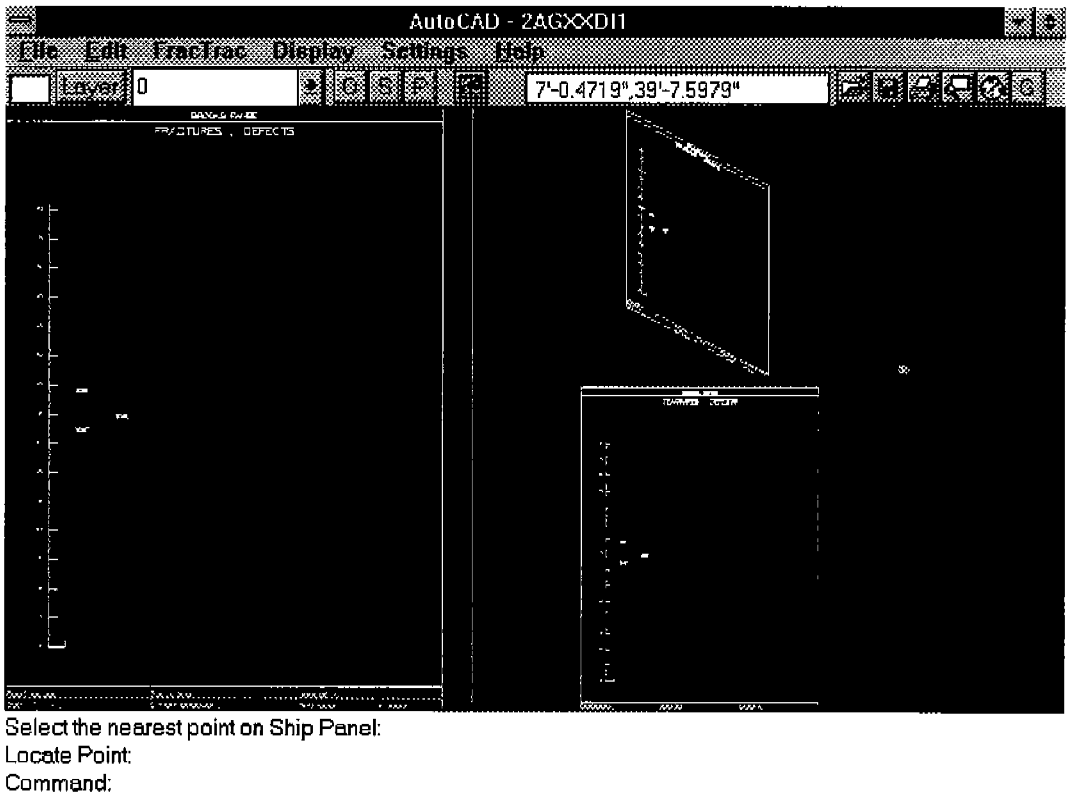


Figure 3.1: FracTrac - AutoCad^{TM} Screen View

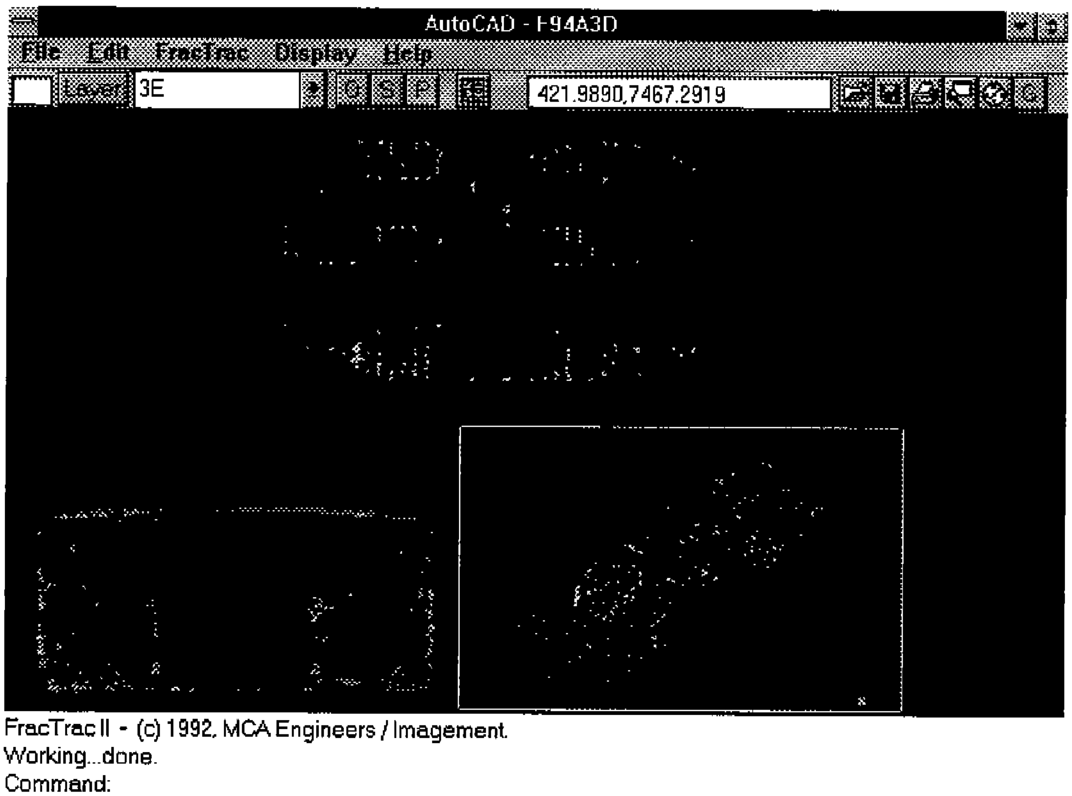


Figure 3.2: FracTrac - AutoCad^{TM} Fracture View

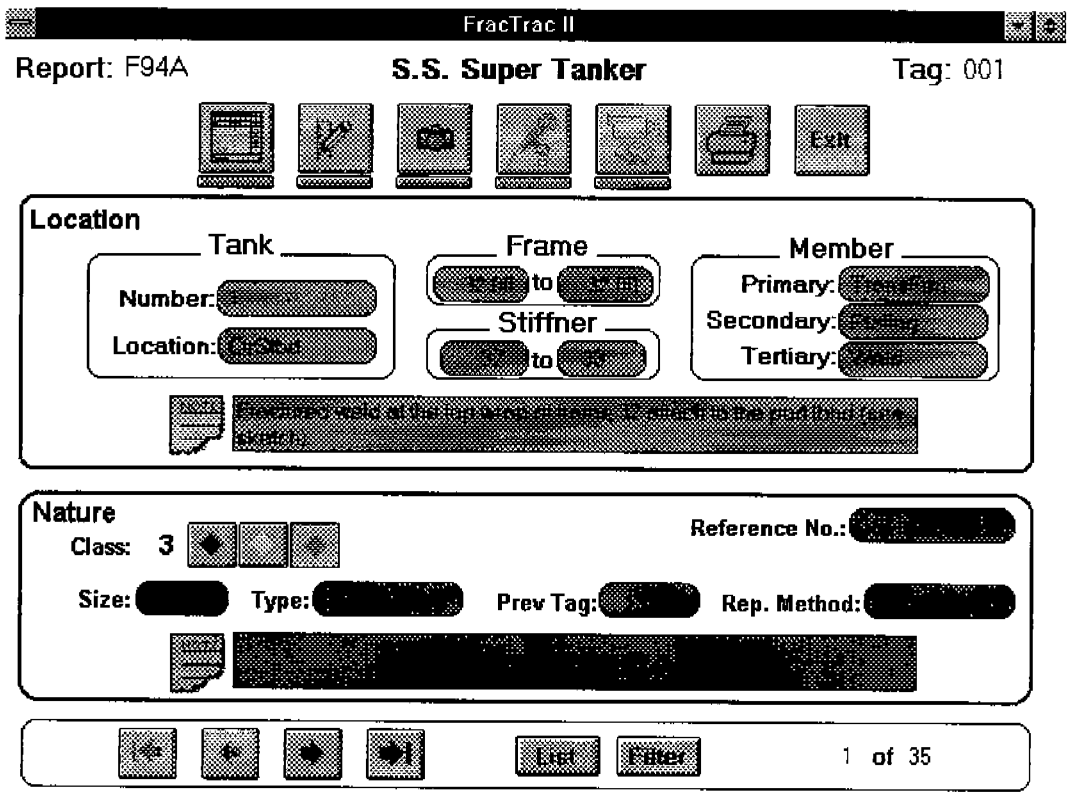


Figure 3.3: FracTrac - Fracture Input Screen

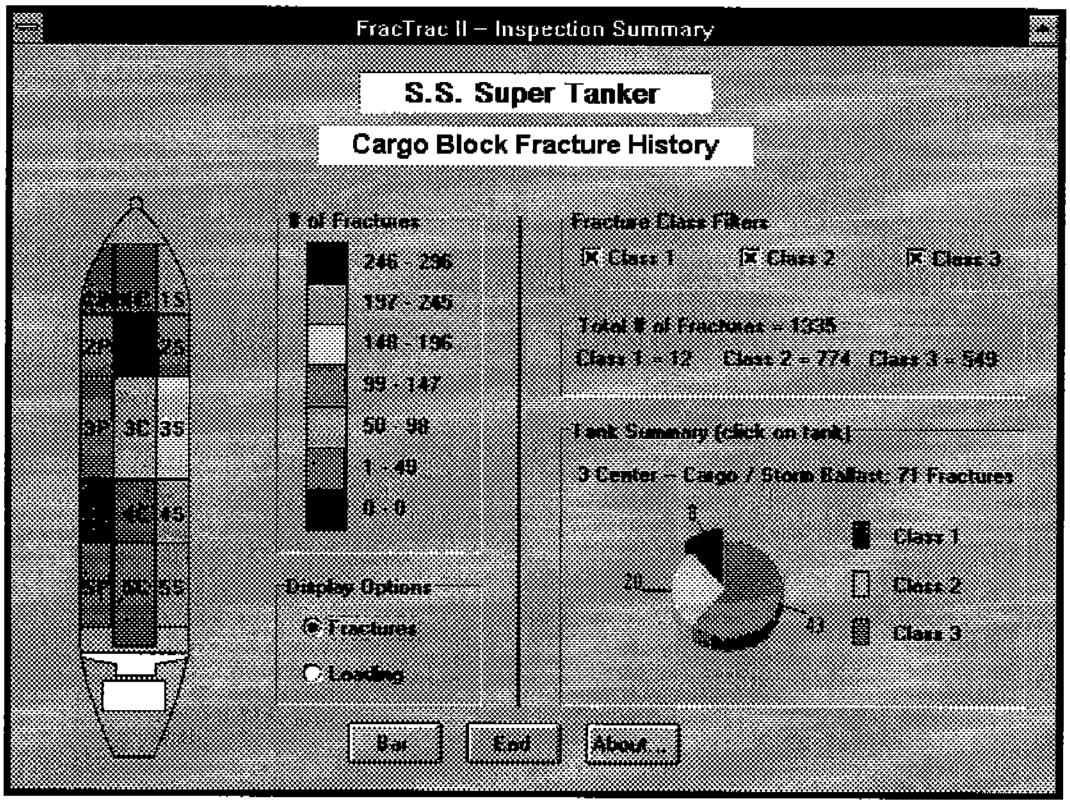


Figure 3.4: FracTrac - Cargo Block Fracture History Screen

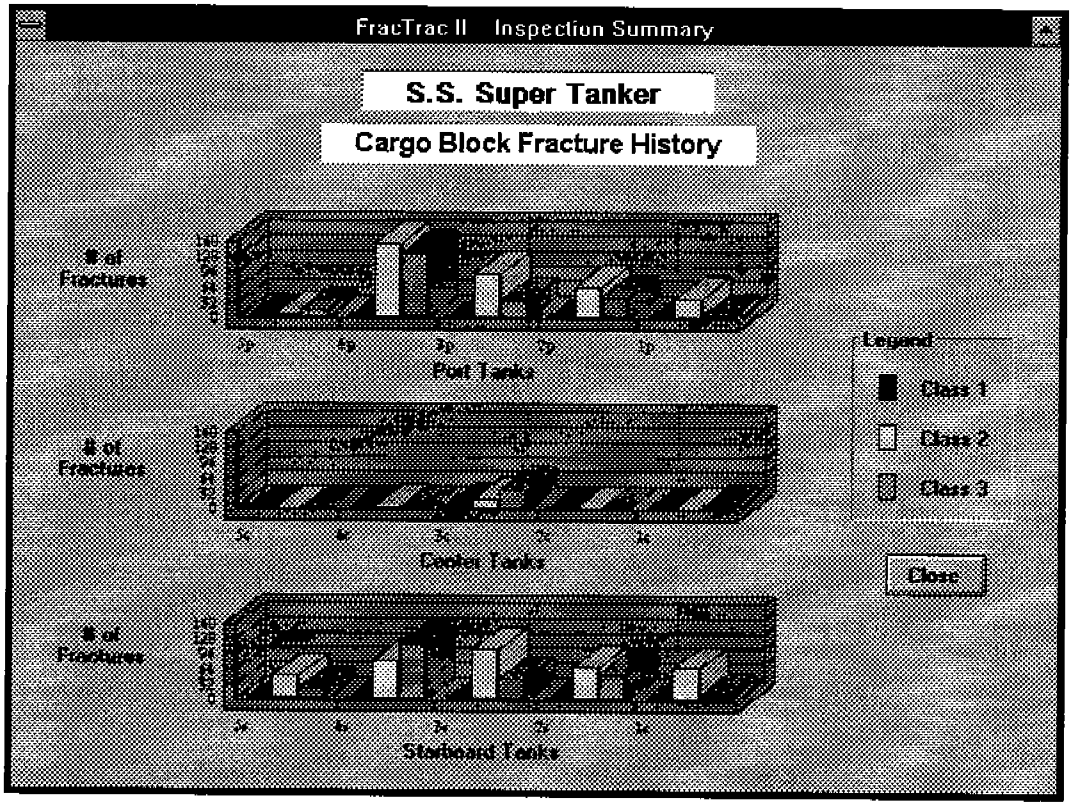


Figure 3.5: FracTrac - Fracture Distribution Screen

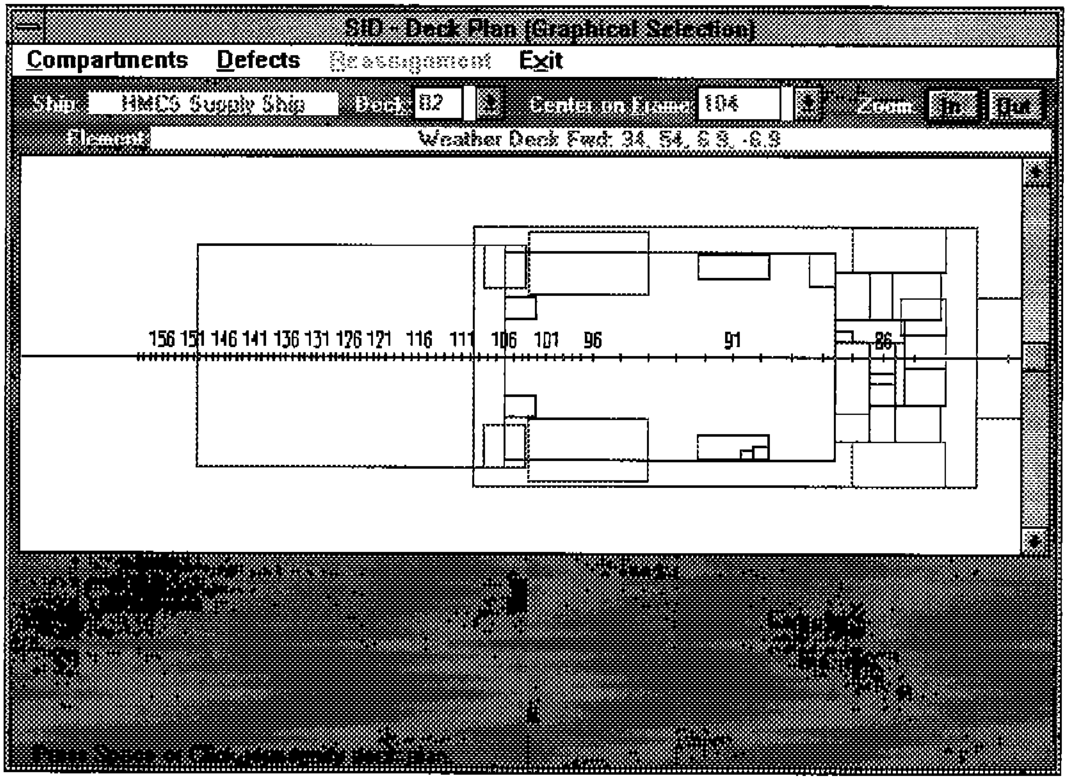


Figure 3.6: SID - Ship Data Entry Screen

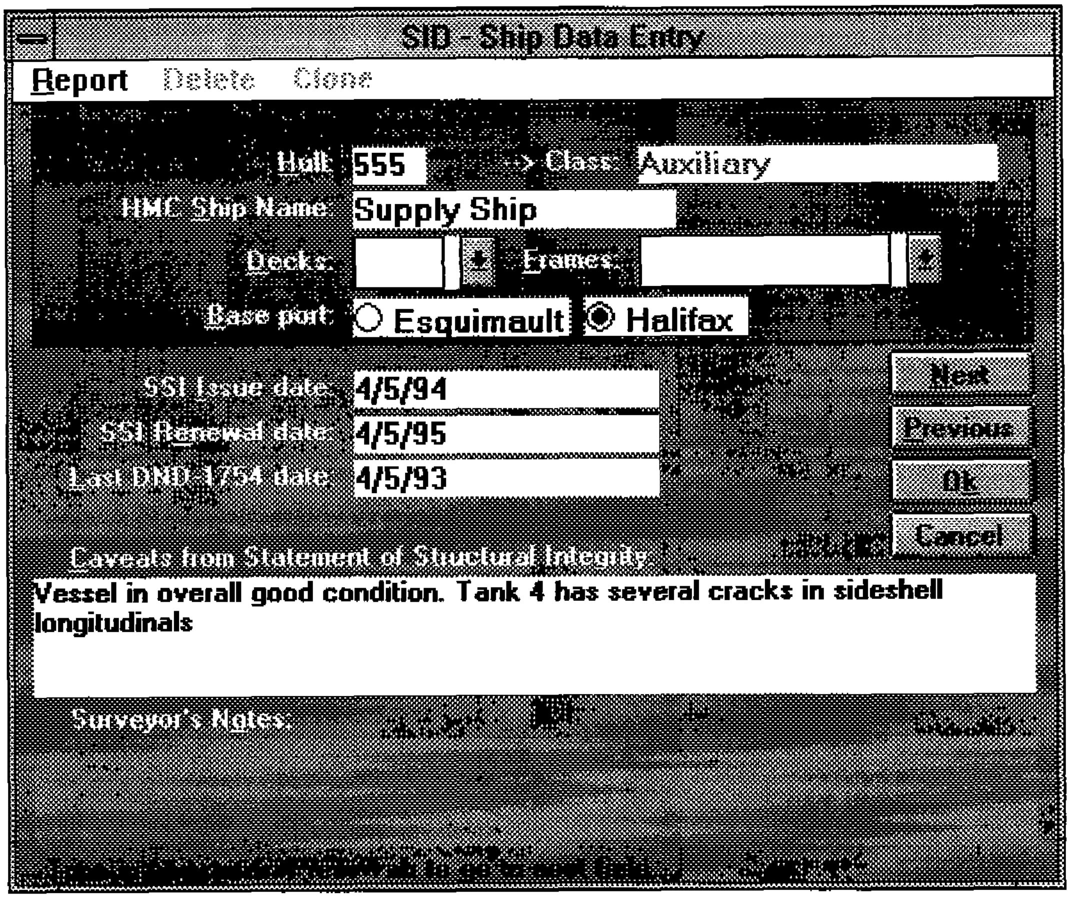


Figure 3.7: SID - Compartment/Element Data Entry Screen

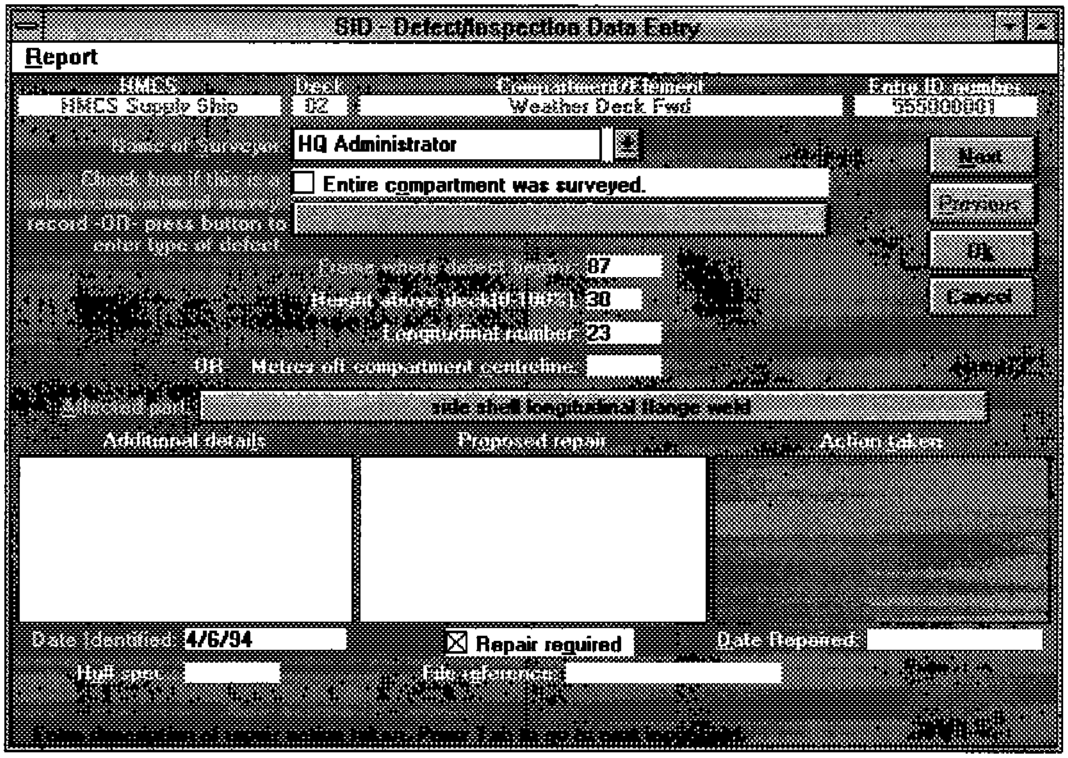


Figure 3.8: SID - Defects Entry Screen

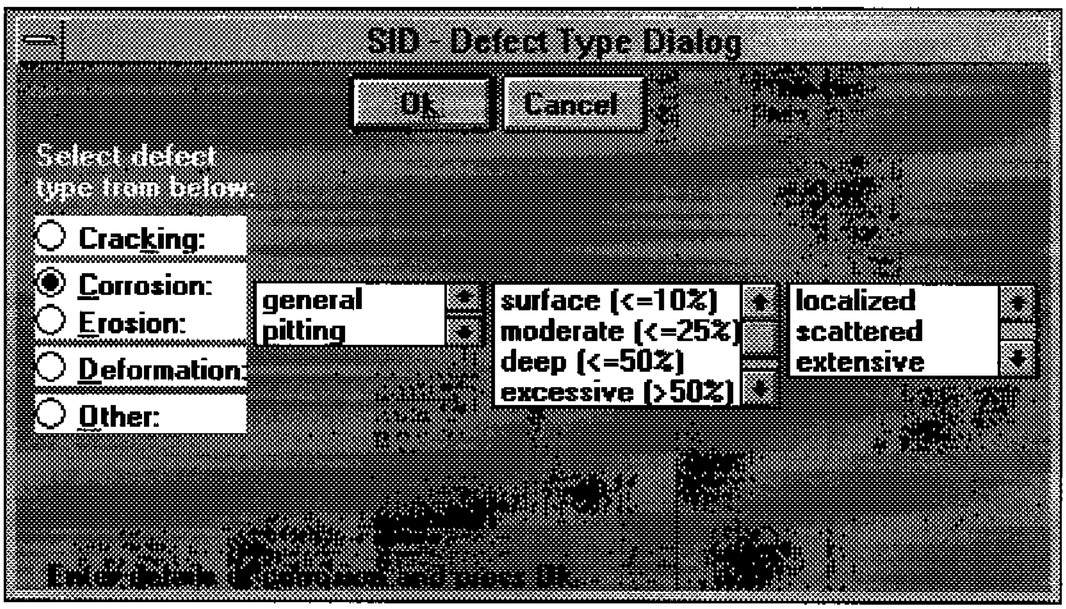


Figure 3.9: SID - Defects Type Entry Screen

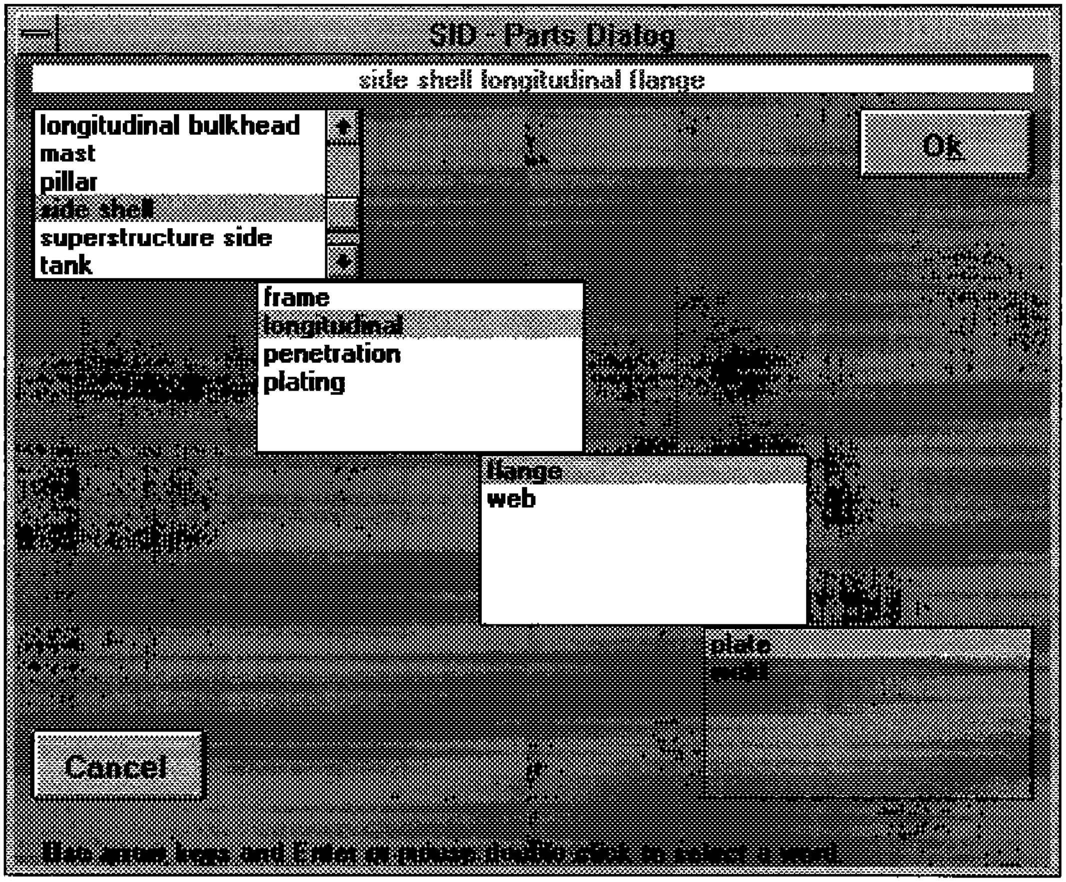


Figure 3.10: SID - Affected Part Entry Screen

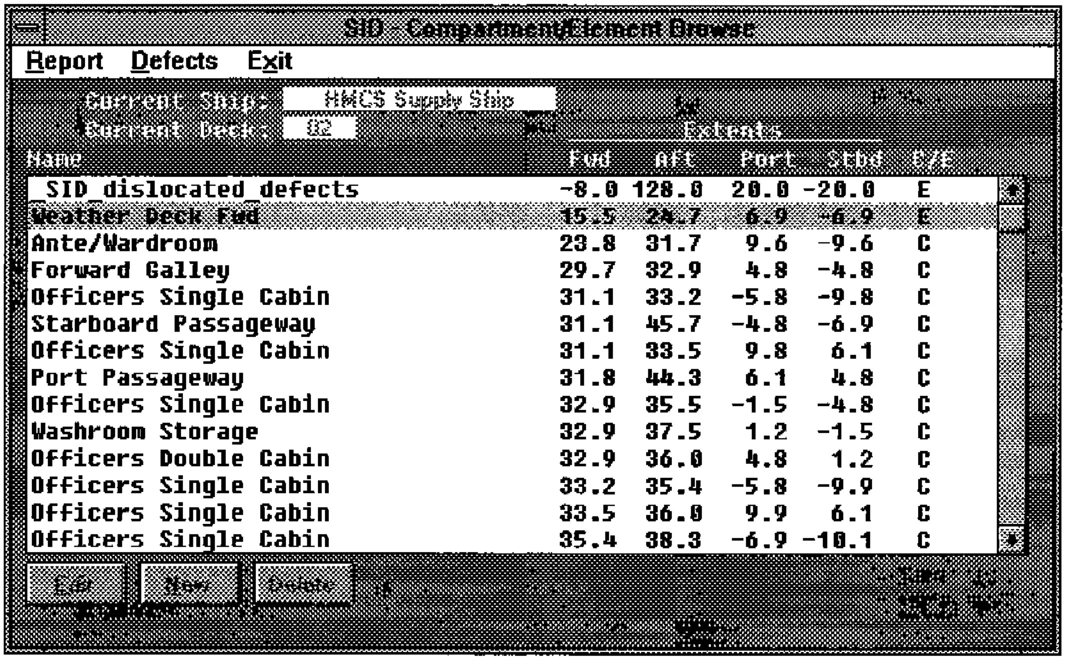


Figure 3.11: SID - Deck Plan View Screen

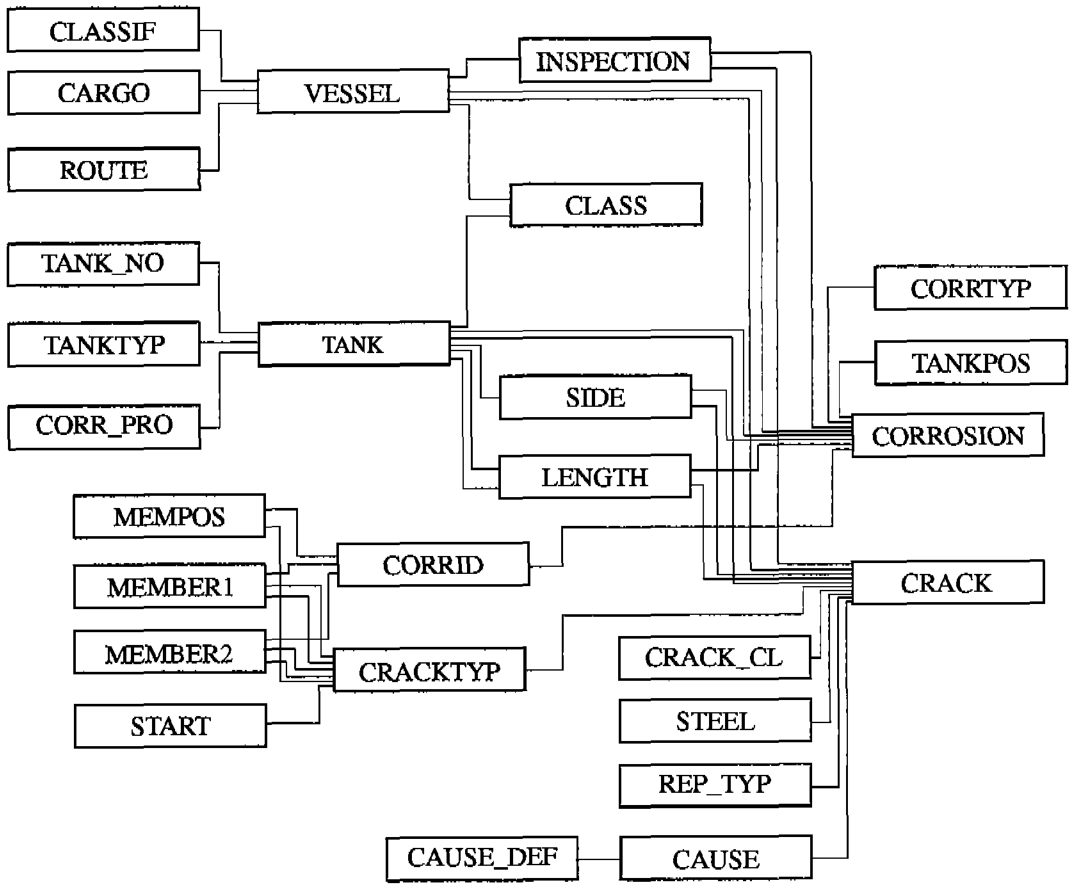


Figure 3.12: SMP Tanker Database: Overall Structure

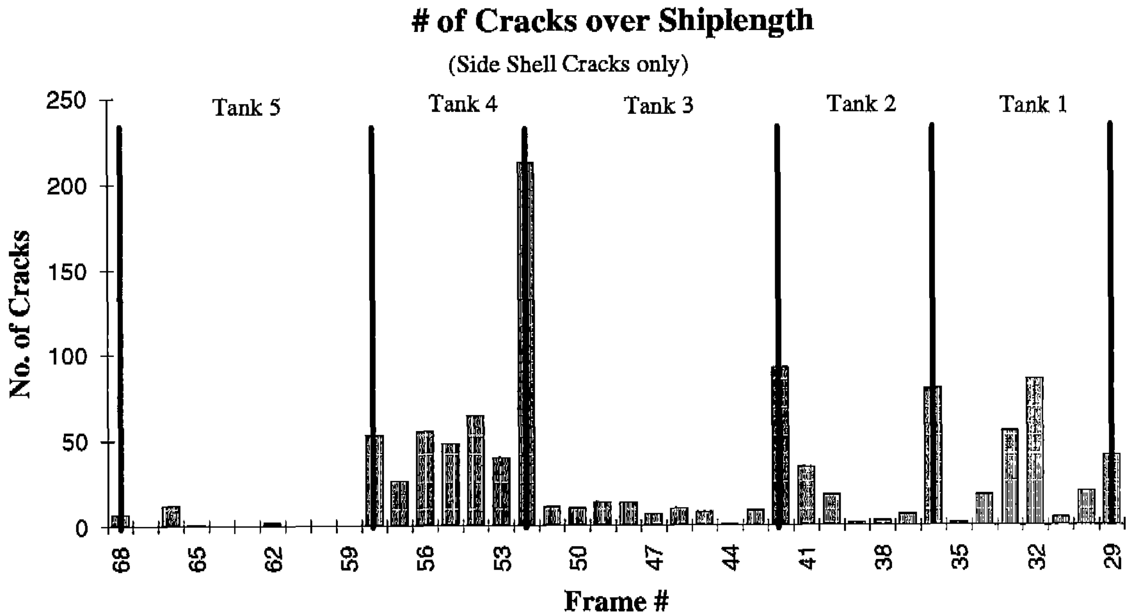


Figure 3.13: Number of Sideshell Cracks over Shiplength

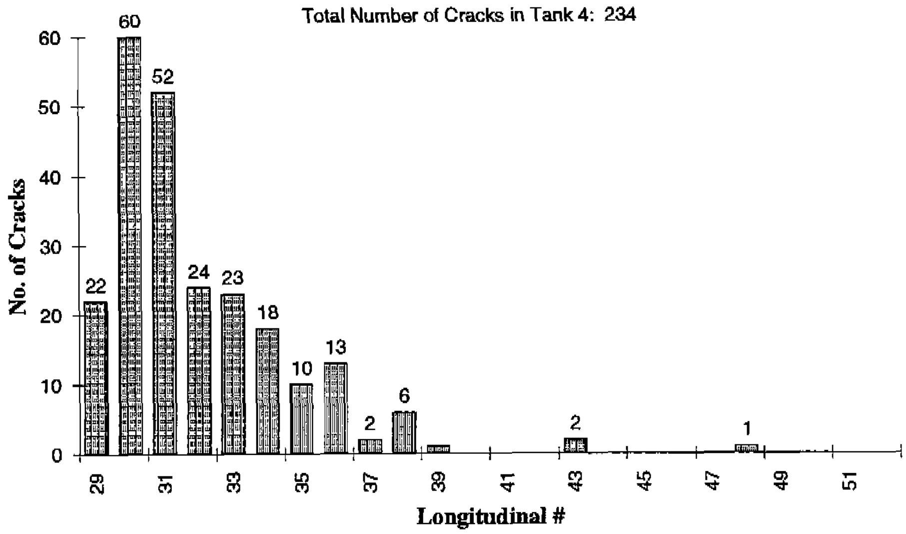


Figure 3.14: Side Shell Longitudinal Cracks in Tank 4

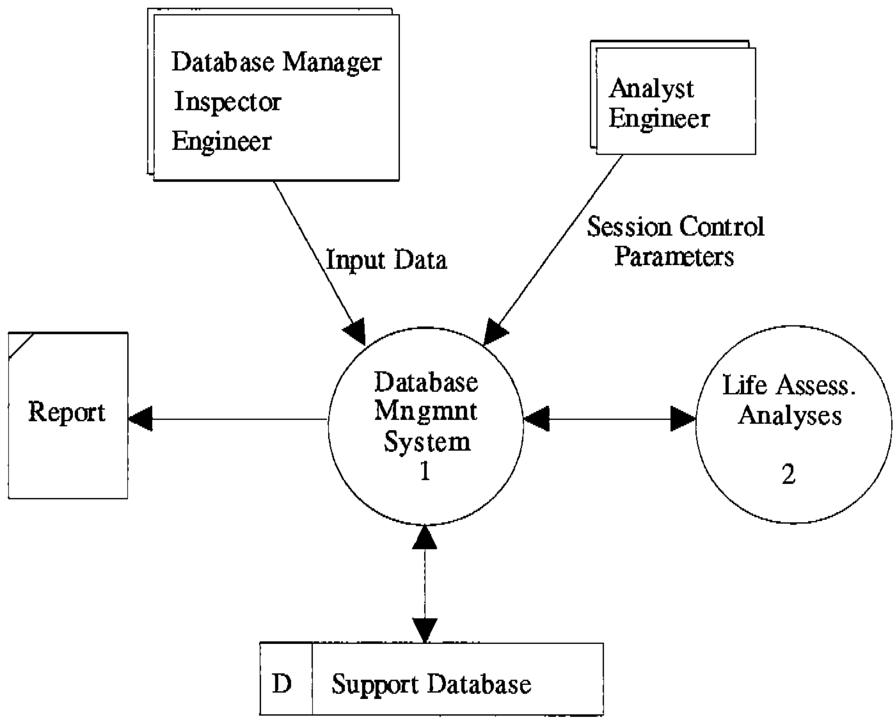


Figure 3.15: Database Management System in DCL

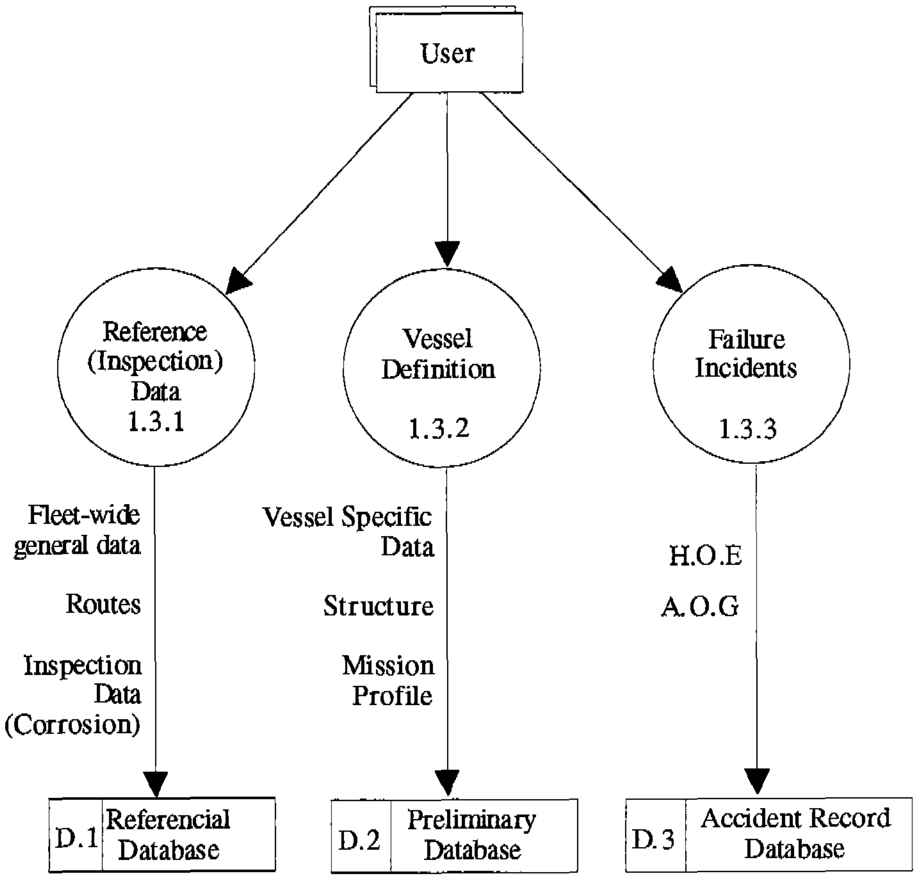
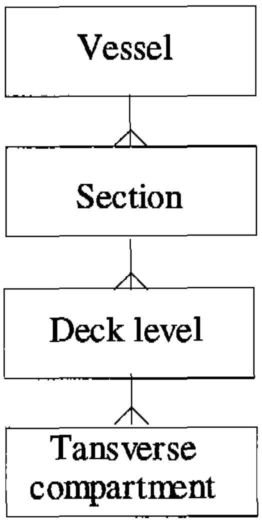


Figure 3.16: Database Use for Life Assessment Analyses



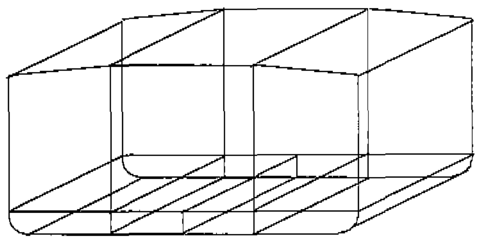


Figure 3.17: DCL - Vessel Internal Arrangement Hierarchy

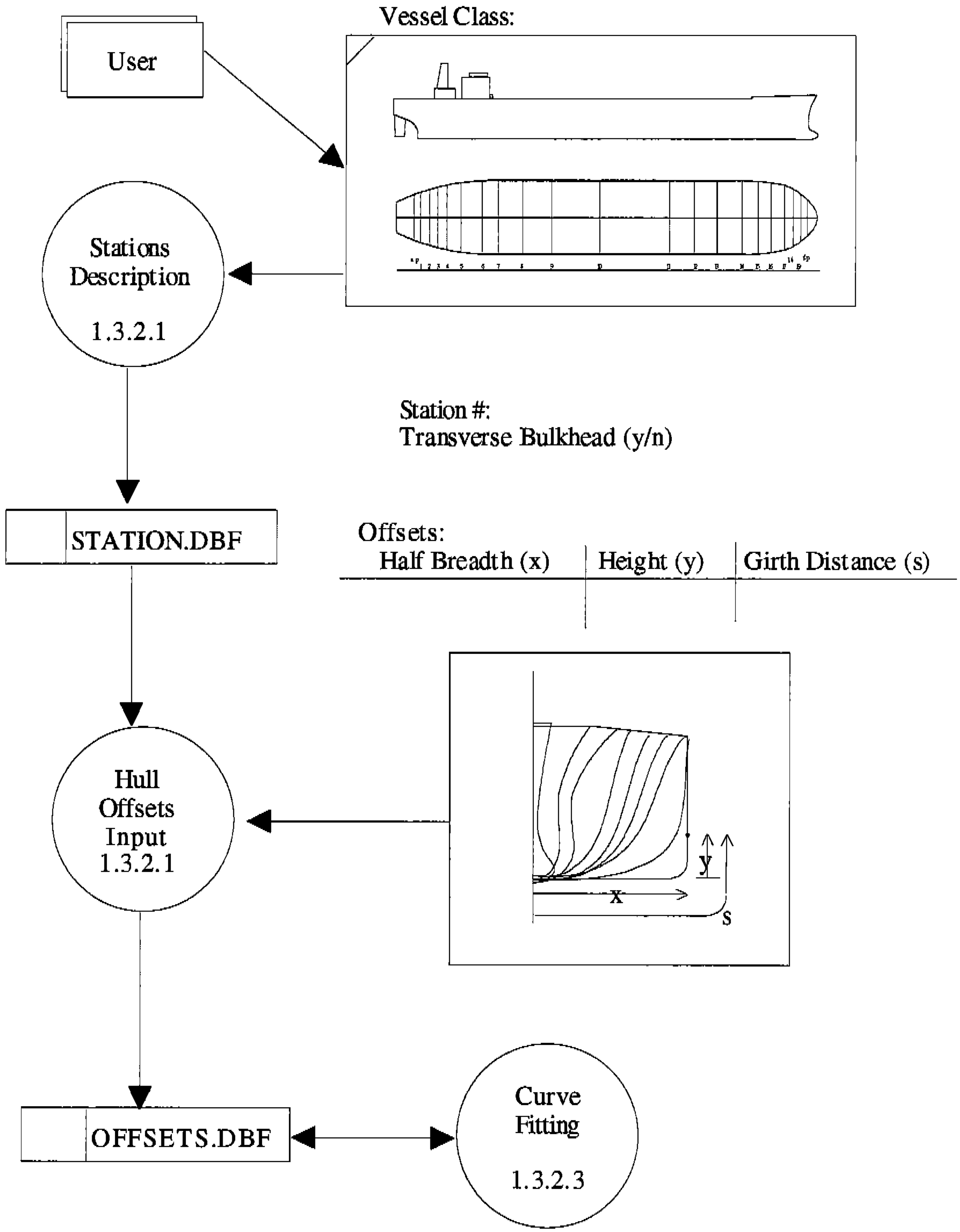


Figure 3.18: DCL - Hull Geometry Description

Chapter 4

Information Requirements for Analysis Applications

During design, construction, maintenance and operations of an oil tanker a large number of software programs are used to perform structural analysis, cargo scheduling, loading procedures, vessel routing, etc. In general, these programs have individual, proprietary input file formats. In many cases, the preparation of the input files requires a substantial amount of time. This is especially true for programs that require the input of the ship's hull and compartments.

With the advent of powerful, relational database systems and the increase in storage capacities of desktop computers, it has become possible to develop ship database systems that contain most of the information needed to use these analysis, scheduling, loading or vessel routing programs.

A general ship database can therefore be the information source for all ship related information. Software programs can either be re-structured to use database query techniques to retrieve information, or the database can be designed to produce the required input files.

The use of a general ship database will result in a reduction of data input and will reduce input errors. It also ensures that up-to-date information is used by all users.

In order to design the database system, it is necessary to evaluate the information needs of some of the more important software programs. This will ensure that the database contains sufficient information to be used as the information source for these prorgrams.

The following software programs are described and evaluated in this chapter:

- **HECSALV**: Ship Salvage Engineering Software. Herbert Engineering Corporation, San Francisco, CA 94111
- **CARGOMAX**: Tanker Loading Software. Herbert Engineering Corporation, San Francisco, CA 94111
- **TACTICS**: Tactical Stowage and Yard Control Planning. Ship Research Inc., Oakland, CA 94612
- **VISTA**: Vessel Schedule Tracking and Analysis. Ship Research Inc., Oakland, CA 94612
- **VMS (Vessel Management System)**: Vessel Scheduling and General Information. Chevron Shipping, San Francisco, CA 94105
- **Henry Chen**: Vessel Routing, Ocean Systems Inc., Oakland, CA

Each program is described outlining the program capabilities and the program structure. The necessary input information is documented.

4.1 HECSALV

The **HEC Salvage Engineering Software (HECSALV)** is an integrated system of programs for quick salvage response. The software makes it possible to quickly evaluate damaged conditions of a vessel. This includes ground reaction and strength calculations for grounding scenarios and collision cases.

The software requires the input of the vessel hull and compartment information together with the midship section, stability and loading information, the lightship weight distribution and down-flooding locations.

4.1.1 History

Herbert Engineering Corporation (HEC) is a naval architecture and marine transportation consulting company performing a variety of tasks including ship design, structural analysis and salvage response. In order to facilitate ship design contract work, several computer programs have been written that perform standard naval architecture calculations, i.e. hydrostatics, intact and damage stability, etc. In 1986, these programs have been combined to form the `Ship Design Software (SDS)`.

In 1988, the U.S. Navy decided to enhance their in-house salvage calculation capabilities. Based on an evaluation of existing software packages, the U.S. Navy selected SDS (developed by Herbert Engineering) as the basis for the improved salvage software. The U.S. Navy provided funding to improve the user interface of SDS and to add additional features such as strength calculations based on beam theory and the ability to analyse simple grounding cases.

The funding provided by the U.S. Navy initiated the development that led to the present version of HECSALV. At the present time, HECSALV is used by the USCG and the US Navy for their salvage response activities. In addition, HECSALV has been successfully used by commercial and military interests in actual salvage situations.

Some of the Companies and organizations that have purchased HECSALV include:

- Classification Societies - ABS, Lloyd's Register, Germanischer Lloyd
- Oil Companies - Amoco, BP Chevron, Conoco, Exxon, Mobil, Shell, UNOCAL,
- Organizations - David Taylor Research Center, National Transportation Safety Board, UC Berkeley, USCG Marine Safety Center, USCG Vessel Engineering, USCG Naval Academy, U.S. Navy Supervisor of Salvage, Webb Institute of Naval Architecture

4.1.2 Program Description

The HECSALV software is an integrated system of programs designed for quick salvage response. It enables a naval architect or salvage engineer to rapidly evaluate damaged conditions of a ship. Features include the ability to analyze the intact condition, free-floating damage cases, and various types of stranding. The program provides estimates of damage dependent projected oil outflow, tidal and weather effects on the damaged condition, and damaged hull girder strength and deflections.

The stranding module computes ground reaction and strength calculations for various grounding scenarios, including the effects due to waves and tidal changes. The section modulus editor provides for the efficient entry of the hull structure, in addition to calculations based on reduced strength from damage or corrosion to individual elements.

The software has the ability to compute the actual oil outflow based on hydrostatic balance methodology for both damage stability and stranding calculations. This feature has been used in a study for the U.S. Coast Guard to evaluate different tanker designs in terms of the projected oil outflow resulting from collisions and groundings, [8].

The software has the following main features:

- single and double pinnacle and shelf grounding analysis
- strength and deflection analysis for flooded or grounded cases
- damaged or corroded strength analysis based on actual section properties
- tidal variation analysis for grounded cases
- actual oil outflow based on vertical extent of damage
- specification of partially flooded tanks in the damaged condition
- specification of internal pressurization for damaged compartments

In addition, HECSALV includes programs for standard naval architecture data entry and calculations. These programs facilitate the entry of the necessary ship information for performing salvage calculations. Program functions include:

- Hull offset entry
- Hydrostatics, Bonjeans, and Cross Curve calculations
- Compartment definition
- Compartment volumes and centers calculations
- Intact trim and stability calculations
- Shear force and bending moment calculations

4.1.3 Program Structure

The HECSALV software consists of nine separate programs. The programs interact by passing data files back and forth. Understanding of interdepence of the various programs and the overall data flow is critical to the effective use of the HECSALV software. Not all nine programs are required for every design evaluation or salvage situation. A detailed description of the different programs and the common user interface can be found in [27].

Program usage can be divided into three broad categories:

- Development of data files for future use
- Analysis (Data files previously developed)
- Analysis (Data files not previously developed)

The Hull Offset Entry, Compartment Entry, Ship Data Entry, Section Modulus Editor, Hydrostatic and Bonjean, and Cross Curve Programs all create data files used in the analysis programs. If this data has been previously developed, it greatly reduces the response time required to assess a salvage operation or perform design calculations.

4.1.4 Data Requirements for HECSALV

The following information has to be provided to use HECSALV.

1. General Arrangement
2. Table of Offsets or Lines Plan (or Frame Scantling drawings if offsets and lines are not available)
3. Midship Section, Construction Profile and Plan and Shell Expansion for structural sections fore and aft of midships
4. Loading Manual and Trim and Stability Booklet

5. Longitudinal Strength Verification Calculations
6. Lightship Weight Distribution Table (or Curve)
7. Downflooding Locations
8. Draft Mark Locations
9. Allowable Shear Force and Bending Moments - Class approved for AT-SEA and IN-HARBOR

HECSALV uses a number of data files to pass information between the different program modules. In Appendix C, the contents of the main data files is described.

4.2 CARGOMAX

The **CARGOMAX** software is a computerized system for planning and evaluating ship loading. It quickly and precisely calculates ship stability and stress characteristics based on specified loading conditions.

The program is developed from technical information that reflects the physical characteristics of a ship or class of ships. This information includes hydrostatic data, tankage data, allowable shear forces and bending moments, and light ship weight distribution. This information is used to develop customized input screens that support quick and efficient entry of ship loading data.

4.2.1 History

In order to facilitate ship design contract work, software has been developed by Herbert Engineering to calculate the intact stability and stress characteristics for different loading scenarios.

User experience and interest from various clients indicated the need for an on-board system to monitor ship loading based on stability and stress criteria. This has led to the development of the CARGOMAX software in 1978.

The original software was developed for HP-85 desktop computers and was subsequently re-written for IBM Personal Computers (PC). Currently version 3.0 of CARGOMAX is commercially available.

CARGOMAX is mainly used by vessel operators to monitor the actual loading process in order to meet stability and strength requirements. CHEVRON Shipping uses the CARGOMAX load cases as input to the developed `Vessel Management System (VMS)`, see section 4.4.

4.2.2 Program Description

The CARGOMAX software is a software system to evaluate the intact stability and stress characteristics for different loading conditions. The program uses a menu system that provides access to all program functions with simple cursor control. These functions can be grouped into four broad categories:

- **File Manipulation**
- **Tank Data and Weight Entry**
- **Calculations**
- **Display and Printing**

A detailed description of all menu options and data entry procedures is given in [18]. This manual also describes the damage stability calculations that can be performed using the CARGOMAX software.

4.2.3 Data Requirements for CARGOMAX

In order to use CARGOMAX to evaluate different loading conditions for a vessel, hull offsets and compartment information for the vessel has to be available. This information follows the format used by HECSALV, described in section 4.1.4. The program uses the following data files

- Load Case Data `.LC`. This file is prepared based on data entry performed in CARGOMAX
- Hull Offsets `.HUL`. This file is prepared using HECSALV.
- Compartment Offsets `.CMP` & `CMA`. These files are prepared using HECSALV.
- Compartment Listing `.CML`. This file is prepared using HECSALV.

4.3 TACTICS

The **TACTICS** program is a workstation based computer system designed to support tactical stowage and yard control planning. *Tactical* planning is the day-to-day planning used to solve local problems, like what to do with 200 unexpected rolls in a nearly full yard. It differs from *strategic* planning which is planning used to solve global problems. The name **TACTICS** is an acronym for TActical Container Terminal Information Control System.

4.3.1 History

TACTICS has been developed by Ship Research Inc., Oakland, CA for American President Lines. The program is used for *tactical* stowage and yard control planning. The development of the TACTICS Pilot program was begun in June 1987, and the first version was installed in Kaohsiung in February/March 1988.

The TACTICS Pilot program was designed to serve two purposes:

- provide a tool to ease operational problems
- serve as a test bed to establish the feasibility and appropriateness of the TACTICS philosophy for improving APC's operations.

TACTICS is currently used by American President Lines for tactical stowage and yard control planning. Vessel schedule tracking and analysis is performed using VISTA, a subsystem of CAPS.

4.3.2 Program Description

TACTICS has been developed for the Apple Macintosh computer. The program therefore uses the Graphical User Interface of the Macintosh. Data entry is performed in dialog boxes. The program is distributed on a Local Area Network. General program information is stored on the file server, whereas ship information is stored on the individual computers.

The program consists of three main functions:

- Vessel information and port calls
- Yard layout and container storage
- Planning and recording of container movement

The different program functions are described in detail in [34] and are summarized in the subsequent sections.

4.3.2.1 Vessel Information and Port Calls

In order to plan stowage, calculate stability, etc., it is necessary to define the vessel, voyage and port call. This information is included in the vessel-voyage-port call (VVP). A VVP can either be downloaded from the mainframe or created directly. It contains the vessel name, the voyage number and the port call number.

As part of the vessel information, a hydrostatic table and the lightship weight distribution has to be entered. In order to calculate the changes in the weight distribution due to container storage, the center of gravity of each container row has to be entered.

Tank information includes the weight, the tank type (ballast, fuel, fresh water, other) and tank geometry (lcg, vcg, tcg). For each tank the weight of the contents has to be entered.

Ship and tank information in conjunction with the container loading is used to perform stability and strength calculations. Results of these calculations are displayed. The stability display includes the GM value, strength information, drafts and attitude. The strength display shows a graph of the vessel's shear and bending moment distribution.

The inbound stow plan for a vessel is downloaded from the ETC and the CAPS program. Both programs are operated on the mainframe. The ETC provides the inbound stow plan and CAPS provides the pre-plan and inbound vessel tankage to TACTICS.

Once a stowage plan has been completed and conformed in TACTICS it has in general to be uploaded to the mainframe systems ETC and CAPS.

4.3.2.2 Yard Layout and Stowage Plan

The container yard is the central feature of TACTICS. TACTICS provides a means of keeping track of all containers within the yard. It allows it to plan and track movements of containers between yard areas, from the yard to the ship, and in and out of the gate.

The yard overview shows an overhead or plan view of the yard, identifying different *physical* yard areas (Transtainer, Parking, Pile-type) and logical yard areas (Enroute, outgate, maintenance & repair, unknown). For each area type, an input window allows it to specify the container location for each specific container.

The yard space can be organized in different areas. A display window shows the occupied and the available space for each yard period. The space allocations can be changed using a *set layout* command.

4.3.2.3 Planning and Recording of Container Movements

The main purpose of TACTICS is to assist in planning and recording the movement of containers. In TACTICS containers can be moved from vessel to yard, yard to vessel, within the yard and vessel to vessel in a number of ways. Containers can be moved individually or as a group. They can be moved to assigned slot positions or put in a yard area without a specific slot location.

Containers are selected using the mouse by either clicking on one or mor containers or selecting a group of containers using a selection rectangle. The selected containers are moved by either clicking on the desired new location or by dragging the selected containers to the new position.

4.3.2.4 Container Attributes

A container's attributes are its various properties, like length, height, weight, routing, etc. The task of vessel and yard planning amounts to deciding where to put each container based on some or all its attributes.

On screen, it is possible to control the display of the container attributes based on the actual task. This reduces the amount of un-necessary information on the screen and enhances the planning procedure.

4.3.2.5 Searching and Operation Planning

The use of search lists in TACTICS makes it possible to find containers based on on or many of their attributes. This enables the user to find out information about containers in the system as well as to arrange selected containers in special ways to arrange their stowing.

All of the container attributes can be used to direct or limit a search. This includes container type, dimensions, status, owner, location, load vessel, etc.. The search will display a search list window that contains all the containers that satisfy the search criteria. The appearance and sorting of the search list can be changed by selecting the fields to be displayed and a specific sorting order.

Operation planning uses the notion of *events* to plan future operations. An *event* in TACTICS consists of a group of planned container movements. Using *events* makes it possible to specify a whole sequence of movements for a container.

For each *event* an event name, a start date & time and an event type are specified. The event type distinguishes between `Vessel Activity`, (discharge and load) and `Yard and General Activity`, (Shuffle and General).

4.4 The Vessel Management System (VMS)

As part of an ongoing effort to computerize ship operations to improve and optimize information flow between the vessels and the shore facilities, a *Vessel Management System (VMS)* is currently being developed by Chevron Shipping.

The system is intended to gather vessel specific information, improve the vessel scheduling and optimize performance by implementing a better information flow to and from the vessel.

4.4.1 History

The development of the *Vessel Management System* that contains both vessel and shore modules is based on the general strategy to improve the use of computers onboard ships.

As the first step in this program, Personal Computers (PC's) were installed on each vessel. Each PC contains a word processor, a spreadsheet and technical manuals. It was intended that the availability of computers would be an incentive for the vessel crew to independently develop computer skills. As a result of this project phase, it was concluded that workshops and specific computer training courses are necessary to develop computer skills.

In the second phase of the development, more specific, ship oriented software was installed on the computers. The installed software was a commercial package intended to document engine history and maintenance and contained a spare parts inventory.

Based on this system, a database system was developed for the documentation of vessel operations. Data originating on a vessel was transferred electronically to shore and stored in a central database.

In addition to this **vessel** module, a **shore** module is included in the present version of the *Vessel Management System*. The main purpose for this system is to improve and optimize vessel scheduling, i.e. matching vessels to cargo. In the following, the information flow for the vessel scheduling procedure is outlined:

- **Voyage Order**: In the home office, a preliminary voyage order is prepared using input from `Operations`, `Accounting` and `Scheduling`. The `Planning Group` reviews this voyage order to ensure that sufficient bunker capacities are available and that possible crew changes are arranged. The final voyage order is sent to the vessel using e-mail.
- **Voyage Module**: The voyage module contains information related to the planned and actual vessel route, the cargo data and voyage economics contained in the following sub-modules:
  - `Voyage Plan`: Lists way point chains and the current sea leg plan.

- `Voyage Orders`: Lists the itinerary, the cargo orders, the bunker orders, the charter party information and port/canal fees.
- `Voyage Monitor`: Lists noon position report, maneuvering report, operational activities, plan variance analysis and the upload of CargoMax data.
- `Voyage Analysis`: List the plan variance log and the plan variance analysis.
- `Upload CargoMax`: Lists fuel oil data for engine log.
- `Voyage Economics`: Lists estimated voyage profits and losses.

The voyage module interacts with the cargo module by sharing cargo and voyage information.

- **Cargo Module**: The cargo module lists details about the cargo handling, bunker activities, operational activities. This information is contained in several sub-modules:
  - `Demurrage & Port Activities`: Contains port activities details and demurrage calculations
  - `Deadfreight Statement`
  - `Cargo Reconcillation`: List B/L cargo figures, ship/shore differences, VEF qualifications and cargo reconcillations.
  - `Operational Activities`: Lists operating delays.
  - `Bunker Activities`: Lists bunker reconcillations, fuel cost by voyage, fuel cost by date and the bunker history.
  - `Upload CargoMax Data`
- **Vessel Reporting Module**: Using e-mail, the shipboard data is sent to the shoreside system where it is included in the Vessel Reporting System to generate reports and input for the voyage accounting system.
  - `Vessel Reporting System`: Contains Master Data updates, port/terminal activities, operations activities, deadweight/deadfreight, demurrage calculations, cargo summaries, voyage summaries, voyage analyses.
  - `Voyage Accounting System`: Contains freight revenue, demurrage revenue, voyage costs and bunker inventories.

In addition to the vessel scheduling, the VMS is also intended to provide more detailed information to the vessel crew. This includes information about the revenue basis for the vessel operations, the daily operating costs and port call costs.

Previously, the vessel crew was not informed about the economic aspects of ship operations. It is anticipated that the increased level of information will motivate the vessel crew to reduce delays and reduce the overall operating expenses. This strategy is in accordance with ongoing efforts for an overall quality improvement at Chevron.

The Vessel Management System is also used to improve the management of the vessel's operating expenses. Responsibility for the operating expense budget is given to the vessel. Cost estimates for each aquisition are entered into the system, thus creating an approximately accurate and up-to-date operational expense budget.

Many of the forms that have to be filled out to document vessel operations have been prepared for electronic input. This has significantly improved efficiency.

VMS data is sent to the home offics using electronic mail (e-mail). The following information can be sent:

1. Noon position report - 3 day report
2. Maneuvering - end of port call

3. Port Activity	-	end of port call
4. Port Delays	-	end of port call
5. Deadweight/deadfreight calc	-	end of loading
6. Ship/Shore differences	-	end of load/discharge
7. Measurement info load/discharge	-	end of last discharge
8. Plan variance	-	end of voyage
9. Bunker reconciliation	-	after bunkering
10. Operational Activity	-	end of voyage

The information is appended to a regular e-mail message. At the home office the message is automatically detected, converted to a suitable file format and included into VMS.

4.4.2 Operational Experiences

At the present time, the Vessel Management System is installed on about 2/3 of Chevron's tanker fleet. The installation process consists largely of crew training. According to the VMS project management, the implementation and crew training phase of the project by far exceeds the actual software development.

Originally, the crew training was performed in compact, on-shore workshops combined with on-board tutorials. The training courses were scheduled as part of the crew's vacation time, resulting in significant time gaps between the training courses and the practical application during vessel operations.

In a modified procedure, the computer training is conducted on-board of the vessel during a voyage. Individual training sessions are scheduled with crew members during the off-duty hours. This approach is judged to be more effective than the on-shore workshops. However, it is crucial to coordinate vacation schedules with the on-board training courses. Vacation time for a crew member directly following a training course will prevent the application of the gained computer skills. Short (3 day), on-shore seminars have been implemented for crew members returning from a vacation to refresh the computer skills and the knowledge of the Vessel Management System (VMS).

4.4.3 Information Contents of VMS

Data entry screens have been developed for the Vessel Management System. Some data is entered only once for each vessel, other data is entered after each port call, etc. The information that needs to be entered for each screen is listed in Appendix D.

Chapter 5

Development of CAIP Format

5.1 Introduction

One of the main reasons that has lead to the development of several ship information databases designed to contain the results of vessel structural surveys has been the introduction of Critical Area Inspection Plans (CAIP). The requirement for operators to document structural failures and to clearly identify problem areas and trends has led to an increased use of electronic databases.

This chapter documents the process resulting in a preferred format for Critical Area Inspection Plans that will be used as the output definition of the SSIIS prototype CAIP reporting module . In order to develop a clear understanding of Critical Area Inspection Plans, the background for the definition of the CAIP and the format and information contents as defined by the U.S. Coast Guard in [15] are documented.

The format and structure of several Critical Area Inspection Plans submitted to the U.S. Coast Guard by various operators are evaluated. Based on this evaluation and on the experience made by Coast Guard inspectors in using the Critical Area Inspection Plans a detailed CAIP format is described that is intended to improve the overall usefulness of Critical Area Inspection Plans.

5.2 U.S. Coast Guard Definition of Critical Area Inspection Plans (CAIP)

This section documents the contents of the *Navigation and Vessel Inspection Circular No. 15-91*, [15], issued by the U.S. Coast Guard in Oct. 1991. It is the purpose of this Circular to provide guidance to the marine industry for the development, use, and implementation of CAIP's. The Circular is intended to provide a performance standard for CAIP's rather than detailed instructions for the development of these plans.

Background

The following points document the background and intentions of CAIP's as outlined in [15]:

- 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 preparation of a CAIP is the primary responsibility of the vessel owner or operator. The CAIP is part of an integrated management plan for achieving an adequate level of structural monitoring, maintenance, and repair.

- The decision to require a CAIP on a single vessel or on an entire class of vessels may be based on the vessel's history, its service, or even the climatology of the trade route.
- The development and maintenance of a CAIP is intended to result in an increased involvment of the vessel's management in the processe of finding a solution to identified structural and/or maintenance problems. It is the ultimate goal of a CAIP to address the **cause** of problems, not merely the **symptoms**.
- Definition of terms used in CAIP's:
    1. **Active repair areas**: areas that continue to experience active or recurring cracking in the oil/watertight envelope or that affect the structural integrity of the vessel.
    2. **Critical inspection areas**: areas that incorporate all present and previous active repair areas including past active areas that require continued monitoring. Other areas may be deemed critical based on class problems or assessment of the structure through appropriate calculations and analysis.

Discussion

In [15] the intended purpose, expectations of the U.S. Coast Guard based on the implementation of the CAIP requirement, the CAIP development process and guidelines for CAIP surveys are discussed. In the following, these points are summarized:

- The cause of all structural failures must be addressed. Determining the causes of Class 1 structural failures, and other structural failures, as defined in enclosure(1) of [15], is critical to the correct selection of an appropriate repair methodology.
- CAIP's are intended to be the method used by vessel management to document and track structural failures. In this capacity, CAIP's will assist surveyors, inspectors and the vessel's crew in ensuring the vessel is properly inspected and maintained. Within the CAIP, the surveyor, inspector, or crew will be able to find detailed information on the vessel's fracture history, corrosion control systems, and previous repairs. The CAIP will also contain a record and evaluation of repairs to the vessel's fractures. It is critical to know what temporary or permanent repairs have been successful in the past. The evaluation of *permanent* repairs and/or design modifications is important to the vessel's overall fitness.
- The CAIP format presentation is at the discretion of the company's management. The information in the CAIP should be clear, up-to-date, and easy for someone not familiar with the vessel to understand.
- CAIP's will be developed by the vessel's owner or operator when required in writing by the appropriate Coast Guard authority. The designated authority will outline the existing or potential problem that necessitates a CAIP being developed. In addition, an appropriate policy letter will be promulgated, if necessary.

  CAIP's will be reviewed when they are initially developed. The review process will be specified in the implementing letter.

  CAIP's should be updated anytime the vessel experiences a new Class 1 or 2 fracture, a recurrence of the original problem, a modification, or a survey.

  In order to remove areas from active monitoring, the owner or operator has to submit a letter request together with the documentation contained in the vessel's CAIP supporting the change.
- Surveys are an integral part of the CAIP. Survey reports should include the basic information listed in enclosure (4) contained in [15].

Implementation

The implementation of a CAIP requirement for a vessel is to be closely monitored. OCMI's (Officer in Charge of Marine Inspections) are encouraged to take a very restrictive position regarding whether to issue a Certificate of Inspection to a vessel that has not complied with a requirement for a CAIP.

CAIP's have applicability for use on all vessels as a means of tracking and recording structural history. Even when not required, all owners and operators should be advised to incorporate the principles of CAIP's into their management philosophy.

5.2.1 Enclosure (1) to NVIC-15-91

Classification of Structural Failures

Definitions

1. Oil/watertight envelope - the strength deck, side shell and bottom plating of a vessel, including the bow and stern rakes of barges.
2. Internal strength members - the center vertical keel; deep web frames and girders; transverse bulkheads and girders; side, bottom and underdeck lognitudinals; longitudinal bulkheads; and bilge keels.
3. Buckle - any deformation in the oil/watertight envelope whereby the adjoining internal structural members are also bent to such an extent that structural strength has been lost.

Classifications

Three classes of structural failures are defined:

- **Class 1 Structural Failure**:
  A fracture that occurs during normal operating conditions (i.e., not as the result of a grounding, collision, or other casualty damage), that is
  1. A fracture of the oil/watertight envelope that is visible and of *any* length, or a buckle, that has either initiated in or has propagated into the oil/watertight envelope of a vessel; or
  2. a fracture 10 feet or longer in length that has either initiated in or has propagated into an internal strength member.
- **Class 2 Structural Failure**:
  A fracture less than 10 feet in length, or a buckle, that has either initiated in or has propagated into an internal strength member during normal operating conditions.
- **Class 3 Structural Failure**:
  A fracture or buckle that occurs under normal operating condition that does not otherwise meet the defintion of either a Class 1 or Class 2 structural failure.

5.2.2 Enclosure (2) to NVIC-15-91

Critical Areas Inspection Plans Performance Elements

1. Executive Summary - this overview should be easy to read and give an overall outlook on the vessel and the remainder of the plan. This summary should include a list of the designated crtical inspection areas.

2. Vessel Particulars

   a. Name, Official Number

   b. Vessel Design Class
      All other vessel particular information can be found on the Certificate of Inspection (COI).

3. Historical Information.

   a. Structural Failures

      (a) Type
      (b) Location
      (c) Method of repair

   b. Vessel Structural Modifications

      (a) Major structural modifications
      (b) Detail modifications

      This section is intended to be for those areas where the repair has been successful with no recurrence.

4. Active Repair Areas.

   a. Structural Failures

      (a) Type
      (b) Location
      (c) Method of repair
      (d) Number of occurrences
      (e) Date of most recent repair

   b. Vessel Structural Modifications

      (a) Major structural modifications
      (b) Detail modifications

   c. Structural Analyses Completed/Pending

      (a) Results of completed analyses kept on board
      (b) Implementation plan for recommended corrective action

   d. Trends

      (a) Description of method used to determine trends, i.e., gaugings, renewals, coating and anode systems, etc.
      (b) Results

Sections 3 and 4 above may be organized in many different ways depending on the volume of the information and the availability of other data management systems. It is important that the information be presented so it can be easily interpreted by company maintenance representatives, classification society surveyors, and Coast Guard inspectors.

5. Structural Inspections

    a. Critical Area Inspection Intervals

        (a) Annual/semi-annual

    b. Records of Inspections

        (a) Internal

            (a) Tank
            (b) Date
            (c) Method
            (d) Inspected by (USCG, ABS, Company)
            (e) Previous inspection date
            (f) Problems noted

        (b) A vessel log should be maintained indicating the person or persons who performed the inspection

        (c) External surveys (hull, bilge keels, etc.)

            (a) Date
            (b) Inspection method, i.e., drydock, underwater survey
            (c) Inspected by (USCG, ABS, Company)
            (d) Previous inspection date
            (e) Problems noted

6. Tank Coating Systems.

    a. Type

    b. Last Renewed

    c. Planned Renewal

    d. Present Condition and Percent Failure

7. Critical Areas Inspection Plan Update

    a. Internal Company Review

        (a) Frequency

The use of diagrams and vessel plans to illustrate fractures and problem areas is highly encouraged.

5.2.3 Enclosure (4) to NVIC-15-91

Critical Areas Inspection Plans Performance Elements

Survey reports should contain the following information:

1. Survey Particulars

    a. Vessel name

    b. Scope of survey

        (a) Yearly cargo block (entire or partial)
        (b) Active repair area
        (c) Any other area required to be inspected

    c. Local OCMI notified

    (a) MSO
    (b) Date of letter

2. Survey Participants
    a. Names
    b. Organizations
    c. Qualifications

3. Survey Results
    a. Tanks entered (or critical area checked)
    b. Tank cleanliness
    c. Method of inspection
    d. Comment of overall condition of the tanks
    e. If coated, percent of coating breakdown (if applicable)
    f. Fractures noted
        (a) Location
        (b) Dimensions
        (c) Suspected cause
        (d) Class/USCG notified
    g. Other damage/conditions noted
        (a) Deformations
        (b) Wastage

For tank vessels the *Guidance Manual for the Inspection and Condition Assessment of Tanker Structures*, [36], contains sample forms that, if properly filled out, could constitute the survey report.

A similar document has been published by the International Association of Classification Societies (IACS) for Bulk Carriers, [22]. The assessment and repair of the hull structure of bulk carriers is outlined in detail including sketches of frequent failures and possible repair solution. This information can be used to help in the development of repair representations in a future SSIIS.

5.3 Structural Failures Reporting Requirements

Chapter 5 of the Marine Safety Manual (MSM) contains classifications and definitions of structural failures, describes the notification procedures for the different failure classes and outlines the documentation requirements for structural failures, [14].

For Class 1 structural failures on U.S. Flag vessels the vessel's operator is required to submit to the classification society and to the OCMI (Officer in Charge of Marine Inspection) a detailed description of the failure and a proposal for both temporary and permanent repairs. In addition, the operator has to provide the past history of similar failure and the results of any past studies related to the type of failure that has occured. If this information is not available, the company is required to perform an analysis of the failure and submit the results to the OCMI.

The submitted information including recommendations from the respective classification society is evaluated by the OCMI to determine an appropriate repair.

Operational restrictions may be placed on a tank vessel pending the completion of the required permanent repair. For any temporary repair, the operator is required to submit calculations that show that the vessel can: 1) safely load other intact cargo tanks and 2) safely operate with the affected cargo tank either ballasted or empty.

Vessels with Significant Structural Problems may be subjected to operating restrictions, required to change service to a more moderate climate or phased out of service. A list of these *Special Attention Vessels* is maintained and provided to the field.

For Class 2 and Class 3 Structural Failures permanent repairs of non-critical failures can be delayed until the next scheduled shipyard repair period provided the operator provides sufficient information to demonstrate that the failures are not critical and will not propagate.

Fig. (5.1) shows a flow chart for the documentation of structural failures and the submission of reports. The chart shows the different procedures depending on the classification of the structural failure. In addition the different Coast Guard divisions involved in the process are clearly identified.

5.4 Evaluation of CAIP Report Examples

CAIP reports are routinely sent to the U.S. Coast Guard headquarters. Several reports from different companies are reviewed. This review is intended to document the differences and common elements of present Critical Area Inspection Plans and to develop improved format recommendation for CAIP reports.

For each reviewed CAIP report, a general description is given, outlining the approach, information contents and structure of the CAIP report. Then, the report is evaluated for its compliance with the list of Critical Area Inspection Plans Performance Elements outlined in enclosure (2) of the Navigation and Vessel Inspection Circular (NVIC) No. 15-91, [15].

The CAIP report review are intended to:

- determine the information content of each CAIP report
- evaluate the adherence of each report to the list of performance elements stated in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91, [15].
- conclude on the effectiveness of each CAIP report to achieve the goals that have led to the implementation of the Critical Area Inspection Plan requirement, as stated in the Navigation and Vessel Inspection Circular 15-91, [15].

5.4.1 Vessel A

5.4.1.1 Description

The Critical Area Inspection Plan for the *Vessel A* follows the NVIC format very closely. The vessel particulars are listed including a general arrangement drawing, a list of tanks, a machinery description and international load lines.

A summary of past structural failures is given. For Class 1, Class 2 and pattern type Class 3 failures, the fracture locations, repair information is listed indicating repair success where applicable.

A detailed table of structural failures is listed, documenting for each tank the failure type, location, class, repair/modification and the number of cracks in two successive structural surveys. Representative fracture types and fracture locations are shown on attached drawings. Reference is made to the individual inspection reports for additional information. A nomenclature for the keywords used in the failure table is provided.

Present and past Active Repair Areas are listed. The areas are listed by tanks and a short description of the location is given. A list of structural inspections, including the next scheduled drydock survey, is given. Inspection reports and inspection companies are listed.

The tank coating system is summarized, describing the original coating system and coating repair. In addition, a coating maintenance plan is summarized.

Attachment 1 of the Critical Area Inspection Plan for the *Vessel A* includes any revisions or additions deemed necessary following the April 1992 Visual Survey of the Vessel A.

The format of the table, describing the structural failures and the repair plan, has been changed. For each tank the location, a description of the failure, the size, the class and the repair plan is listed.

An updated summary of the inspection schedule and the coating system is listed.

5.4.1.2 CAIP Performance Elements Evaluation

Executive Summary

No Executive Summary included.

Vessel Particulars

General Arrangement, tank description, Machinery and load lines are summarized. The list of vessel particulars includes the following information:

- Name
- Hull No.
- Coast Guard ID
- ABS ID
- Vessel Class
- Builder
- Delivery
- DWT
- Presence of SBT
- Presence of IGS
- Presence of COW
- Presence of Heating Coils
- Cargo Type

Historical Information

Summary of Class 1, Class 2 and Class 3 failures. For Class 1, Class 2 and pattern type Class 3 failures, a short summary of the cracking problem, the repair solution and an assessment of the repair success is given. No graphical representation is available.

The tabular listing of failures lists failure types, location, class, repair/modification and the number of cracks found in different surveys for the individual tanks. Due to the lack of a graphical representation, this information is not very informative.

Vessel structural modifications are not listed separately and no drawings for detail modifications are presented.

Active Repair Areas

The report lists the active repair areas for each relevant tank. It does not document individual structural failures for these areas. This constitutes a significant difference from the NVIC format. No graphical representation of the active repair areas is given.

No structural modifications for the active repair areas are listed. No mention is made of completed or pending structural analysis. No trends for the structural failures in the active repair areas are documented.

Structural Inspections

The documentation of structural inspections states the inspection schedule for drydock surveys, structural surveys by ABS and USCG and owner's inspections. In addition, the date and inspection company for each inspection report are listed. No summary of the inspections is presented.

Tank Coating Systems

The original coating system is summarized and coating repairs are documented. A coating maintenance plan outlines the planned renewal. No summary of present condition and coating failure percentage is given.

Critical Areas Inspection Plan Update

A CAIP attachment is included that documents revisions and additions to the original CAIP based on the April 1992 Visual Survey. The attachment uses a modified format for the tabular representation of failures that improves the description of the failure. No graphical representation of the failure distribution on the vessel in given.

5.4.1.3 Summary

The Critical Area Inspection Plan for the *Vessel A* follows in its structure very closely the format outlined in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91, [15]. The lack of graphical representations of failure distributions in the vessel and the minimal documentation of failures in active repair areas constitute a significant limit in the usefulness of this CAIP.

5.4.2 Vessel B

5.4.2.1 Description

The Critical Area Inspection Plan for the *Vessel B* contains a very short description of the vessel indicating the name the class and the number of cargo tanks. In addition a general arrangement plan is shown that contains the main vessel dimensions and additional information.

A summary of the structural history with respect to each critical inspection area is given. Sketches of typical fractures are included. A list of Critical Areas is included. For each area the failures and the repair and modifications are described.

An inspection and repair summary is presented and the as-built and current tank coating systems are described. The inspections/surveys used for the Critical Area Inspection Program are listed and the means for tracking trends are summarized.

5.4.2.2 CAIP Performance Elements Evaluation

Executive Summary The plan summary lists the critical inspection areas and summarizes the most recent inspection findings.

Vessel Particulars

In a general description the vessel name, the Official Number, the class, the type of framing, the number of cargo and ballast tanks are summarized. In addition, a general arrangement plan is provided that lists the following information:

- LOA, LBP
- Molded Beam
- Depth, Molded to Main Deck at Side
- Current Summer Load Line Draft
- Current Summer Deadweight

- Lightship Weight
- Gross Registered Tonnage
- Net Registered Tonnage
- Builder
- Hull Number
- Year of Delivery
- Official Number

Historical Information

The structural history is provided with respect to each crictical inspection area. For each area the failures are described including sketches of typical failures. In most cases, the repair method is described and un-successful repairs are identified.

Active Repair Areas

A summary of the Critical Area Inspection Plan for the *Vessel B* is presented that lists for each critical area the location, the inspection procedure and the inspection frequency.

Structural Inspections

The inspection history is documented, listing the inspection date, the location, a description of the survey and repairs and a reference report for each inspection.

Tank Coating Systems

The as-built and current tank coating systems are listed. For each tank the tank type (cargo or ballast or both), the as-built coating systems, the current coating system and the last coating data are summarized.

Critical Areas Inspection Plan Update

It is stated that the results of periodic surveys will be used to update the CAIP report.

5.4.2.3 Summary

The Critical Area Inspection Plan report for the *Vessel B* follows in its structure very closely the format outlined in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91, [15]. The representation of the structural history is detailed and includes sketches of typical failures. A graphical representation of the failure distribution in the vessel would add clarity.

The documentation of the critical inspection areas is not sufficient. The critical inspection areas are listed, but no failure information or documentation of repairs/modifications is provided.

5.4.3 Vessel C

5.4.3.1 Description

The Critical Area Inspection Plan report for the *Vessel C* contains a short description of the main vessel particulars. A top view of the vessel shows the location of all tanks.

As part of the description of the vessel's structural history, plans are provided that indicate areas of high stress concentrations that are most likely to show fatigue failures.

The summary of the fracture history contains graphical output from ARCO's proprietary fracture database showing the longitudinal and transverse distribution of fractures for different inspections. The most common fractures are shown in several illustrations. The type of repair is described. Some structural modifications are illustrated.

A summary of fractures categorized according to severity and structural member shows that most fractures occur in longitudinals.

The tank coating history is documented. For each tank the tank protection system, the coating condition, the last inspection date and the last renewal date are listed.

The external surveys that have taken place since the CAIP requirement for the *Vessel C* was issued are summarized. The Inspection and CAIP update schedule conclude the Critical Area Inspection Plan report for the *Vessel C*. Appendix I contains a sample of a typical survey report. Appendix II explains how to record fractures and contains the Fracture Record Sheets that are used to report the fractures and to update the Hull Fracture Database. Additional appendixes contain the survey reports that have taken place since the plan was issued.

5.4.3.2 CAIP Performance Elements Evaluation

Executive Summary

No executive summary is contained in the Critical Area Inspection Plan report for the *Vessel C*.

Vessel Particulars

The location of all tanks is shown in a top view. In addition, the following vessel particulars are listed:

- Builder
- Delivery Date
- Hull No.
- Class
- LOA
- LBP
- SLL
- Beam, molded, MS
- Depth, molded
- Summer DWT

Historical Information

A short summary of the vessel history is provided indicating that no major structural modifications have been made to the vessel during its sailing life.

The results of a structural study to determine details with high stress concentrations are included as part of the structural history. Illustrations of these details indicating the problem areas are provided. These illustrations are very informative and document possible crack locations.

As part of the documentation of the fracture history, the longitudinal and transverse distribution of fractures in the hull is shown for the different surveys. In addition, the main fractures are described and are shown in detail drawings. The repair method is stated. Examples of detail modifications to reduce stress concentrations are included.

In order to summarize the fracture history, the failures are listed according to the structural member and the severity. This information is also presented graphically.

Active Repair Areas

No active repair areas are mentioned. No information identifying problems in active repair areas is included in the report.

Structural Inspections

A short list, indicating the external surveys performed since the CAIP requirement for the *Vessel C* was issued, is presented showing the survey date, the inspection method, the inspectors names and remarks about the survey findings and work performed.

Tank Coating Systems

The tank coating history lists for each tank the tank protection, the coating condition (new, good, fair, poor), the last inspection date, remarks and the last renewal date.

Critical Areas Inspection Plan Update

The CAIP report indicates the intention to provide updates of the fracture history after the biennial shipyard overhaul. In addition, a complete report of the fractures detected, along with repairs and/or structural modifications will be incorporated in an appendix to the CAIP.

5.4.3.3 Summary

The Critical Area Inspection Plan report for the *Vessel C* contains a short, informative summary of the vessel particulars. The documentation of the vessel's structural history is very helpful. Especially the illustrations of the structural details with high stress concentrations indicating the possible crack locations are valuable information.

The complete lack of information with regard to the critical inspection areas constitutes a significant flaw in the CAIP report for the *Vessel C*.

The inclusion of actual survey reports as appendices increases the volume of the report and is detrimental to the stated objective of Critical Area Inspection Plans to be used as a concise summary of the vessel's history and present status with respect to structural failures.

5.4.4 Vessel D

5.4.4.1 Description

The Critical Area Inspection Plan report for the *Vessel D* contains a short description of the main vessel particulars. A top view of the vessel shows the location of all tanks. A short description of the vessel's travel history is included.

As part of the description of the vessel's structural history, plans are provided that indicate areas of high stress concentrations that are most likely to show fatigue failures.

The summary of the fracture history contains graphical output from ARCO's proprietary fracture database showing the longitudinal and transverse distribution of fractures for different inspections. A detailed description of the Hull Fracture Database (HFDB) is included.

The results of a study titled *Structural Fatigue Damage Assessment of ARCO 120,000 deadweight Tankers* are documented including illustrations of finite element models for several local models.

The fracture history is documented showing the original and the modified design for the three most frequent fractures. Based on the database analysis it is concluded that the number of fractures for these details has decreased.

A summary of fractures categorized according to severity and structural member shows that most fractures occur in longitudinals. A graphical summary of the longitudinal and transverse distribution of fractures found between 1990 and 1993 is given. From a pie-chart representation showing the percentage of fractures per severity category it can be seen that 81 % of the fractures are under 12 inches in length.

The tank coating history is documented. For each tank the tank protection system, the coating condition, the last inspection date and the last renewal date are listed.

The external surveys that have taken place since the CAIP requirement for the *Vessel D* was issued are summarized.

Appendix I contains a sample of a typical survey report. Appendix II explains how to record fractures and contains the Fracture Record Sheets that are used to report the fractures and to update the Hull Fracture Database. Additional appendixes contain the survey reports that have taken place since the plan was issued. In appendix III the survey report of the cargo block inspection performed in May 1990 is included.

5.4.4.2 CAIP Performance Elements Evaluation

Executive Summary

No executive summary is contained in the Critical Area Inspection Plan report for the *Vessel D*.

Vessel Particulars

The location of all tanks is shown in a top view. In addition, the following vessel particulars are listed:

- Builder
- Delivery Date
- Hull No.
- Class
- LOA
- LBP
- SLL
- Beam, molded, MS
- Depth, molded
- Summer DWT

Historical Information

A short summary of the vessel history is provided indicating that no major structural modifications have been made to the vessel during its sailing life.

The results of a structural study to determine details with high stress concentrations are included as part of the structural history. Illustrations of these details indicating the problem areas are provided. These illustrations are very informative and document possible crack locations.

The results of a study titled *Structural Fatigue Damage Assessment of ARCO 120,000 deadweight Tankers* are documented including illustrations of finite element models for several local models. This study uses the original vessel log entries to determine the cyclic loading for the vessel during its service life. Using these loads in conjunction with global and local finite element models, the fatigue life for several critical detail locations is analysed. The results of these analyses are included in the CAIP report.

The fracture history is documented showing the original and the modified design for the three most frequent fractures. Based on the database analysis it is concluded that the number of fractures for these details has decreased.

As part of the documentation of the fracture history, the longitudinal and transverse distribution of fractures in the hull is shown for the different surveys. In addition, the main fractures are described and are shown in detail drawings. The repair method is stated. Examples of detail modifications to reduce stress concentrations are included.

In order to summarize the fracture history, the failures are listed according to the structural member and the severity. This information is also presented graphically.

Active Repair Areas

No active repair areas are mentioned. No information identifying problems in active repair areas is included in the report.

Structural Inspections

A short list, indicating the external surveys performed since the CAIP requirement for the *Vessel D* was issued, is presented showing the survey date, the inspection method, the inspectors names and remarks about the survey findings and work performed.

Tank Coating Systems

The tank coating history lists for each tank the tank protection, the coating condition (new, good, fair, poor), the last inspection date, remarks and the last renewal date.

Critical Areas Inspection Plan Update

The CAIP report indicates the intention to provide updates of the fracture history after the biennial shipyard overhaul. In addition, a complete report of the fractures detected, along with repairs and/or structural modifications will be incorporated in an appendix to the CAIP.

5.4.4.3 Summary

The Critical Area Inspection Plan report for the *Vessel D* contains a short, informative summary of the vessel particulars. The documentation of the vessel's structural history is very helpful. Especially the illustrations of the structural details with high stress concentrations indicating the possible crack locations are valuable information.

The reference to the fatigue life evaluation study is helpful, although the documentation is too extensive for the purpose of the Critical Area Inspection Plan report.

The complete lack of information with regard to the critical inspection areas constitutes a significant flaw in the CAIP report for the *Vessel D*.

The inclusion of actual survey reports as appendices increases the volume of the report and is detrimental to the stated objective of Critical Area Inspection Plans to be used as a concise summary of the vessel's history and present status with respect to structural failures.

5.4.5 Vessel E

5.4.5.1 Description

The Critical Area Inspection Plan for the *Vessel E* follows the NVIC format very closely. The vessel particulars are listed including a general arrangement drawing, a list of tanks, a machinery description and international load lines.

A summary of past structural failures is given. For Class 1, Class 2 and pattern type Class 3 failures, the fracture locations, repair information is listed indicating repair success where applicable.

A table of structural failures is listed, documenting tank, the tank type, the location the failure type, the repair/modification, the survey date, the failure class and comments for each failure. Reference is made to the individual inspection reports for additional information. A nomenclature for the keywords used in the failure table is provided.

A list of structural inspections, including the next scheduled drydock survey, is given. Inspection reports and inspection companies are listed.

The tank coating system is summarized, describing the original coating system and coating repair. In addition, a coating maintenance plan is summarized.

5.4.5.2 CAIP Performance Elements Evaluation

Executive Summary

No Executive Summary included.

Vessel Particulars

General Arrangement, tank description, Machinery and load lines are summarized. The list of vessel particulars includes the following information:

- Name
- Hull No.
- Coast Guard ID
- ABS ID
- Vessel Class
- Builder
- Delivery
- DWT
- Presence of SBT
- Presence of IGS
- Presence of COW
- Presence of Heating Coils

Historical Information

Summary of Class 1, Class 2 and Class 3 failures. For Class 1, Class 2 and pattern type Class 3 failures, a short summary of the cracking problem, the repair solution and an assessment of the repair success is given. No graphical representation is available.

The tabular listing of failures lists tank no., tank type, failure location, failure type, repair method, survey date, failure class and comments. Due to the lack of a graphical representation, this information is not very informative.

Vessel structural modifications are listed separately. No drawings for detail modifications are presented. References for structural surveys and structural analysis are included.

The coating systems summary contains a description of the original coating system, coating repairs and a coating maintenance plan.

Active Repair Areas

The report states that the *Vessel E* has no active repair areas.

Structural Inspections

The documentation of structural inspections states the inspection schedule for drydock surveys, structural surveys by ABS and USCG and owner's inspections. In addition the date and inspection company for each inspection report are listed. No summary of the inspections is presented.

Tank Coating Systems

The original coating system is summarized and coating repairs are documented. A coating maintenance plan outlines the planned renewal. No summary of present condition and coating failure percentage is given.

Critical Areas Inspection Plan Update

The report states that information from 1991 periodic overhaul and all structural information thereafter will be entered in CATSIR database which will form an update for the Critical Area Inspection Plan. CAIP will be automatically updated after each inspection and repair.

5.4.5.3 Summary

The Critical Area Inspection Plan for the *Vessel E* follows in its structure very closely the format outlined in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91, [15]. The lack of graphical representations of failure distributions in the vessel and the minimal documentation of failures in active repair areas constitute a significant limit in the usefulness of this CAIP.

5.4.6 Vessel F

5.4.6.1 Description

The Vessel F is a 255,350 dwt steam powered crude oil tanker engaged in worldwide trade. The vessel is owned by the Swansea Corporation which is wholly owned subsidiary of the Amerada Hess Corporation.

The CAIP report for the *Vessel F* contains an executive summary describing the vessel and its trade route and summarizing the contents of the CAIP report without presenting specific information.

A general vessel description contains the main vessel particulars, the builder and the vessel classification. The cargo tank arrangement is described and a capacity plan and a midship section drawing are attached.

A detailed summary of the typical full load and arrival ballast patterns is presented including cargo distribution and shear and bending moment distributions.

As part of the historical information consists, particulars of the most recent surveys are summarized. During these surveys only cracks in welds and brackets have been found. Due to the small number of cracks found, no major structural modifications have been necessary. The CAIP report summarizes the structural repairs in a very detailed fashion and provides sketches of these repairs. Modifications of structural details are summarized extensively using lists of modified details and detail drawings.

The tank protection systems of the *Vessel F* are described. The installation of anode systems in areas where increased corrosion rates have been experienced is summarized.

A very detailed set of guidelines for tank inspections is included in the CAIP report. These guidelines include rafting guidelines, safety requirements, information about orientation in tanks and sample tank information sheets.

Copies of the survey reports of the most recent structural surveys have been submitted as an addendum to this CAIP report.

5.4.6.2 CAIP Performance Elements Evaluation

Executive Summary

The executive summary identifies the vessel owner and the main trade route. In addition, the summary states the purpose of the CAIP report. No details about critical inspection areas or specific failures are provided.

Vessel Particulars

The vessel history (builder, delivery, original owner, classification society) is stated. The following vessel information is listed:

- Length Overall

- Length Between PP
- Breadth Molded
- Depth Molded
- Draft
- SDWT
- LTWT
- Installed Power

The cargo tank arrangement is described and documented with a copy of the Capacity Plan. In addition, a midship section drawing is provided. Information about the crude oil washing and inert gas systems is included.

Typical full load and arrival ballast patterns are summarized. For each load case the cargo distribution and shear and bending moment characteristics are shown.

Historical Information

A short summary of the past structural performance is provided. Structural repairs are documented in detail, including size and locations for additional brackets, repair sketches and steel renewal information.

Modifications were developed in areas where previous repairs (re-welding or replacement) have been unsuccessful. These modifications are documented using sketches, descriptions of the repair locations and detailed summaries of the modification process.

Active Repair Areas

No active repair areas are mentioned in the CAIP report for the *Vessel F.*

Structural Inspections

Information about structural inspections has been provided as part of the historical information. For the four most recent surveys, the following information is listed:

- Inspection Date
- Inspection Company
- Inspector
- Instrument
- Transducer

Detailed guidelines for tank inspections are included in the report. The guidelines include rafting guidelines, safety regulations, tank orientation requirements and tank inspection sheets.

Tank Coating Systems

The original anode system and an additionally installed bottom founded anode system are described in the CAIP. Coating materials used in the most recent docking period are listed. Coating procedures and specific coating locations are documented.

Critical Areas Inspection Plan Update

No specific provisions for an update of the Critical Area Inspection Plan are given.

5.4.6.3 Summary

The CAIP report for the *Vessel F* contains most of the elements listed in the format outlined in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91, [15]. The lack of graphical representations of failure distributions in the vessel and the missing documentation of failures in active repair areas constitute a significant limit in the usefulness of this CAIP.

The use of actual survey reports as an addendum to the CAIP report increases the volume of the CAIP report and is contrary to the stated objective of Critical Area Inspection Plans as a short, informative summary of the general vessel status and of the status of critical inspection areas.

5.4.7 Conclusions based on CAIP Report Evaluation

Six Critical Area Inspection Plan reports from four different operators have been analysed. This analysis was intended to :

- determine the information content of the CAIP reports.
- evaluate the adherence of the reports to the list of performance elements stated in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91, [15].
- conclude on the effectiveness of the CAIP reports to achieve the goals that have led to the implementation of the Critical Area Inspection Plan requirement, as stated in the Navigation and Vessel Inspection Circular 15-91, [15].

As stated in the NVIC 15-91, [15], a CAIP report 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 ultimate goal of a CAIP is to address the* cause *of problems, not merely the* **symptoms**...
... *Within the CAIP the surveyor, inspector, or vessel crew will be able to find detailed information on the vessel's fracture history, corrosion control systems, and previous repairs. The CAIP will also contain a record and evaluation of repairs to the vessel's fractures.*
... *The evaluation of permanent repairs and/or design modifications is important to the vessel's overall fitness.*

These excerpts from NVIC 15-91 summarize the underlying goals that have led to the implementation of the CAIP requirement. It has to be evaluated whether the existing CAIP reports meet these goals.

5.4.7.1 Information Contents

Several of the CAIP reports do not include an *executive summary*. In other cases, the *executive summaries* do not list the designated critical inspection areas.

Large discrepancies are found between the different CAIP reports. All reports focus on the illustration of the vessel's failure history. However, only the ARCO reports illustrate general trends with the help of graphical illustrations of the failure distributions. In all cases, the documentation of detail failures does not provide sufficient information about the cause of the failure and the type and effectiveness of repairs.

The documentation of the *active repair areas*, one of the main goals of the CAIP requirement, is not implemented by the majority of the CAIP reports. The CAIP reports for the two CHEVRON vessels list the critical repair areas, but fail to include detailed failure and repair information.

In most cases, the summary of structural inspections is limited to the inspection date, inspection company and location. Some CAIP reports include the actual inspection reports as an addendum, which significantly increases the volume of the CAIP report.

The documentation of the tank coating systems has been included with sufficient detail. The representation of the coating systems separately for each tank conveys the information in the most convenient way.

5.4.7.2 Adherence to Performance Elements of NVIC 15-91

All reviewed CAIP reports follow in general the list of performance elements outlined in enclosure 2 of NVIC 15-91, [15]. The majority of the CAIP reports do not provide sufficient information with respect to the *critical repair areas*, one of the main concerns of the Critical Area Inspection Plan requirement. The description of trends and causes for failures is also not addressed adequately.

5.4.7.3 Effectiveness of CAIP Reports

Based on the information contents and the representation style of the six CAIP reports that have been reviewed, it has to be concluded that none of the reports completely satisfies the goals and purpose that are inherent in the Critical Area Inspection Plan requirement.

The lack of graphical representations of failure trends makes it difficult to anticipate possible critical areas. Finding trends in the failure data is also an important method to determine causes for failures. The lack of trend information is therefore detrimental to the goals of the CAIP requirement.

In general, most CAIP reports include additional information (survey reports, sample inspection sheets, surveying guidelines, etc.). This additional information reduces the effectiveness of the CAIP reports due to the increased volume of the report. CAIP reports are intended to be short and concise summaries of a vessel's failure history with special emphasis to critical repair areas and the effectiveness of permanent repairs and modifications.

5.5 Experience of U.S. Coast Guard Inspectors

As stated in NVIC 15-91, [15], Critical Area Inspection Plans are intended to help inspectors to gain familiarity with a vessel, the past failure history and critical areas.

Discussions with U.S. Coast Guard Traveling Inspectors have been held to obtain their impression about the effectiveness of the CAIP requirement and to define an improved CAIP report format.

Overall, the implementation of the CAIP requirement has led to a reduction in fractures. Owner participation has improved and more detailed analyses are performed to determine causes for fractures.

In general, the CAIP reports are perceived as being informative and helpful to learn about a particular vessel. However, some reports contain *too much* information that *makes you not want to read the report.* In particular, the inclusion of complete survey reports is seen as detrimental to the purpose of the CAIP requirement.

According to U.S. Coast Guard Traveling Inspectors, present CAIP reports could be improved by including the following information:

- Overview drawings of the tank structure indicating the critical inspection areas
- Representative sketches of fractures in critical inspection areas

As an example of the effectiveness of the CAIP requirement, the Atigun Pass class is mentioned. In previous inspections, hundreds of fractures were found in one inspection period, mainly fractures of the sideshell longitudinal to webframe connection. During the last inspection of the Exxon Benicia, **no** sideshell longitudinal fractures were observed.

5.6 SCAQMD Emission of Volatile Organic Compounds Reporting Requirement

As one example of reporting requirement for component failures, the reporting requirement for Rule 1173 violations established by the South Coast Air Quality Management District (SCAQMD) is described. Although not closely related to structural failures of tanker details, the reporting requirements nevertheless identify the stringent definition requirements for electronic transmission of data.

5.6.1 Overview

The South Coast Air Quality Management District has developed the nation's most advanced air pollution program to reduce air pollution in Los Angeles, Orange,Riverside and the non-desert portion of San Bernardino Counties. The District regulations are aimed at reducing Volatile Organic Compounds (VOC) and other emissions which contribute to air pollution.

In [10] the District Rule 1173 about **Fugitive Emissions of Volatile Organic Compounds** is documented and described. Rule 1173 is aimed at reducing VOC emissions by requiring the timely repair of leaking components. In order to achieve compliance with rule 1173, the SCAQMD has outlined a four part process:

- Identification - All components in VOC service have to be identified. A differentiation is made between major and minor components.
- Inspection - Rule 1173 requires that VOC components are inspected quarterly or annually depending on the accessability of the component and the overall history of leaks at the facility.
- Repairs - A timetable is provided in Rule 1173 which indicates the amount of time is alloted to operators to repair a particular type of leak. Components which are repaired five times in one twelve-month period must be replaced with Best Available Control Technology (BACT) or Best Available Retrofit Technology (BART).
- Reports and Recordkeeping - Records of leaks detected during quarterly inspections, and subsequent repairs and reinspections are to be submitted to the SCAQMD in a quarterly report following the leak, repair or reinspection. Reports can be submitted on a floppy disk.

5.6.2 Reporting Format

With the adoption of Rule 1173, the District has initiated a computer reporting procedure. Information submitted to the District on a floppy disk can be downloaded to the SCAQMD computer system.

Each company has to prepare a component summary sheet listing the component type, inspection period and no. of components identified. The component summary sheet has to be kept on site and has to be made available to the SCAQMD upon request.

For each component type a component identification plan has to be prepared that lists for each component the service type, the location and the accessability. The component idenfication plan has to be kept on site and has to be made available to the SCAQMD upon request.

The statistics summary sheet is a quarterly report that lists for each component type the total number of components inspected, the total number of liquid leaks, the total number of gas leaks in three severity categories, the number of replaced or retrofitted components and the number of inaccessible components. The statistics summary sheet can be submitted electronically. The data file contains one header line and six (6) data lines, one line for each component type (VALVES, FITTINGS, PUMPS, COMRESSORS, PRDS, OTHERS). Each data file will be submitted as an industry standard ASCII comma and quote delimited file on a standard 720 Kb MS-DOS or PC-DOS formatted disk. The file format is defined as follows:

Column Name	Type	Length	Expression
AEISID	Integer	8	SCAQMD identification number
QTR	Integer	1	Reporting quarter
YR	Integer	4	Reporting year
COMPNAME	Text	40	Name of reporting company
ADDRESS	Text	40	Address of facility
CONTACT	Text	40	Name of contact person
PHONE	Text	12	Phone number of contact
TYPE	Text	10	Type of Component
TOTAL	Integer	8	Total inspected for component type
TOTLL	Integer	8	Total number of components with liquid leaks
LEAK210K	Integer	8	Comp. with leak rate > 1,000ppm
LEAK250K	Integer	8	Comp. with leak rate > 10,000ppm
LEAKGT50	Integer	8	Comp. with leak rate > 50,000ppm
REPAIR	Integer	8	Replaced components (BACT/BART)
ANNUAL	Integer	8	inaccessible comp.

The quarterly/annual component leak report documents the individual leak incidents for each component type. The header line is followed by one data line for each leaking component. The leaking components will be grouped and listed by component type, i.e. Valves, Fittings, Others, Pumps, Compressors, and PRDs. Each data file will be submitted as an industry standard ASCII comma and quote delimited file on a standard 720 Kb MS-DOS or PC-DOS formatted disk. The file format is defined as follows:

Column Name	Type	Length	Expression
AEISID	Integer	8	SCAQMD identification number
QTR	Integer	1	Reporting quarter
YR	Integer	4	Reporting year
COMPNAME	Text	40	Name of reporting company
ADDRESS	Text	40	Address of facility
CONTACT	Text	40	Name of contact person
PHONE	Text	12	Phone number of contact
TYPE	Text	10	Type of Component
COMPTID	Text	10	Unique ID number
SERVICE	Text	4	Type of service (liquid, gas, both)
LOCATION	Text	10	Physical location of component
INSPDATE	Date	8	Date inspection was conducted
LEAKRATE	Integer	8	Leak rate measurement in ppm
LIQUID	Text	1	Was this a liquid leak ?
REPTYPE	Text	25	Type of repair
REPDATE	Date	8	Date of repair (mm/dd/yy)
POSTRATE	Integer	8	Post repair leak rate measurement in ppm

5.6.3 Summary

The documentation of component leaks that cause fugitive emissions of volatile organic compounds (VOC) is defined in [10]. A fixed format is provided to summarize and identify all components and to document all leaks detected during inspections. The documentation of components leaks can be submitted electronically following a clearly defined database format. It is the benefit of this procedure that all leaks can be readily entered into the SCAQMD database.

5.7 Improved CAIP Format Recommendation

Based on the evaluation of existing CAIP reports, a recommendation for an improved format is made. This format will follow the list of performance elements outlined in enclosure 2 of the Navigation and Vessel Inspection Circular 15-91 (NVIC 15-91), [15].

This list contains all the information elements that are important to ensure the efficiency of a CAIP report. In the following, the recommended information contents for each of the CAIP report elements is listed.

5.7.1 Executive Summary

The executive summary is intended to provide general information and summarize the vessel status. The following information has to be provided:

- Vessel name, construction type, date built, shipyard, original and subsequent owners, main trade route
- contents of CAIP report
- list of designated critical inspection areas

5.7.2 Vessel Particulars

The summary of vessel particulars is intended to provide a concise summary of the main vessel characteristics. This information has to give the surveyor or inspector sufficient information about the vessel and the tank locations. The following information has to be provided:

- Name, Official Number, design class, builder, delivery date, cargo type, classification
- LOA, LPP, breadth molded, depth molded, draft, SDWT, LTWT
- general arrangement plan indicating the tank locations
- list of tanks including name, tank type, capacity

5.7.3 Historical Information

Information with regard to structural failures and vessel structural modifications has to be provided. This information is intended to identify failures that have been successfully repaired with no recurrence. It is important to provide this information in a structured form that identifies the type of failure using illustrations wherever possible, the failure location and the repair method. The following information has to be provided to document structural failures:

- Total number of failures per failure class
- Longitudinal distribution of failures
- Transverse distribution of failures
- Information about main failures (ordered by number of occurrences)
  - description
  - location
  - illustration
  - cause (if known)
  - repair
  - effectiveness of repair

Structural modifications have to be documented identifying major modifications and detail modifications

- list of major structural modifications
  - location
  - description
  - illustration
  - cause
- detail modifications
  - location
  - description
  - illustration
  - cause

5.7.4 Active Repair Areas

The documentation of structural failures in active repair areas has to be more detailed than for other areas of the vessel. The following information has to be provided for each critical repair area:

- Information about specific failures (ordered by number of occurrences)
  - description
  - location
  - illustration
  - cause (if known)
  - repair
  - effectiveness of repair
- vessel structural modifications
  - major structural modifications
  - detail modifications
- structural analyses
  - reason for analysis
  - result summary
  - reference
- trends
  - description
  - graphical representation
  - causes

5.7.5 Structural Inspections

The documentation of the structural inspections is intended to provide a record of the vessel's inspection history. The following information can be presented in a concise, tabular form:

- Critical Area Inspection Intervals
- Internal inspections
  - tank
  - date
  - method
  - inspected by
  - inspector(s)
  - problems noted
- External surveys
  - date
  - inspection method
  - inspected by
  - problems noted

5.7.6 Tank Coating Systems

The section describing the vessel's tank coating system has to provide sufficient information about the original coating system, coating failures, coating repairs, planned renewals and the present coating condition. This information can be listed for each tank in a tabular form stating:

- original coating system
- coating renewal (date, type, cause)
- planned renewal
- present condition

5.7.7 CAIP Update

The final section of the Critical Area Inspection Plan indicates the plans for the CAIP update, including the frequency of the internal company reviews.

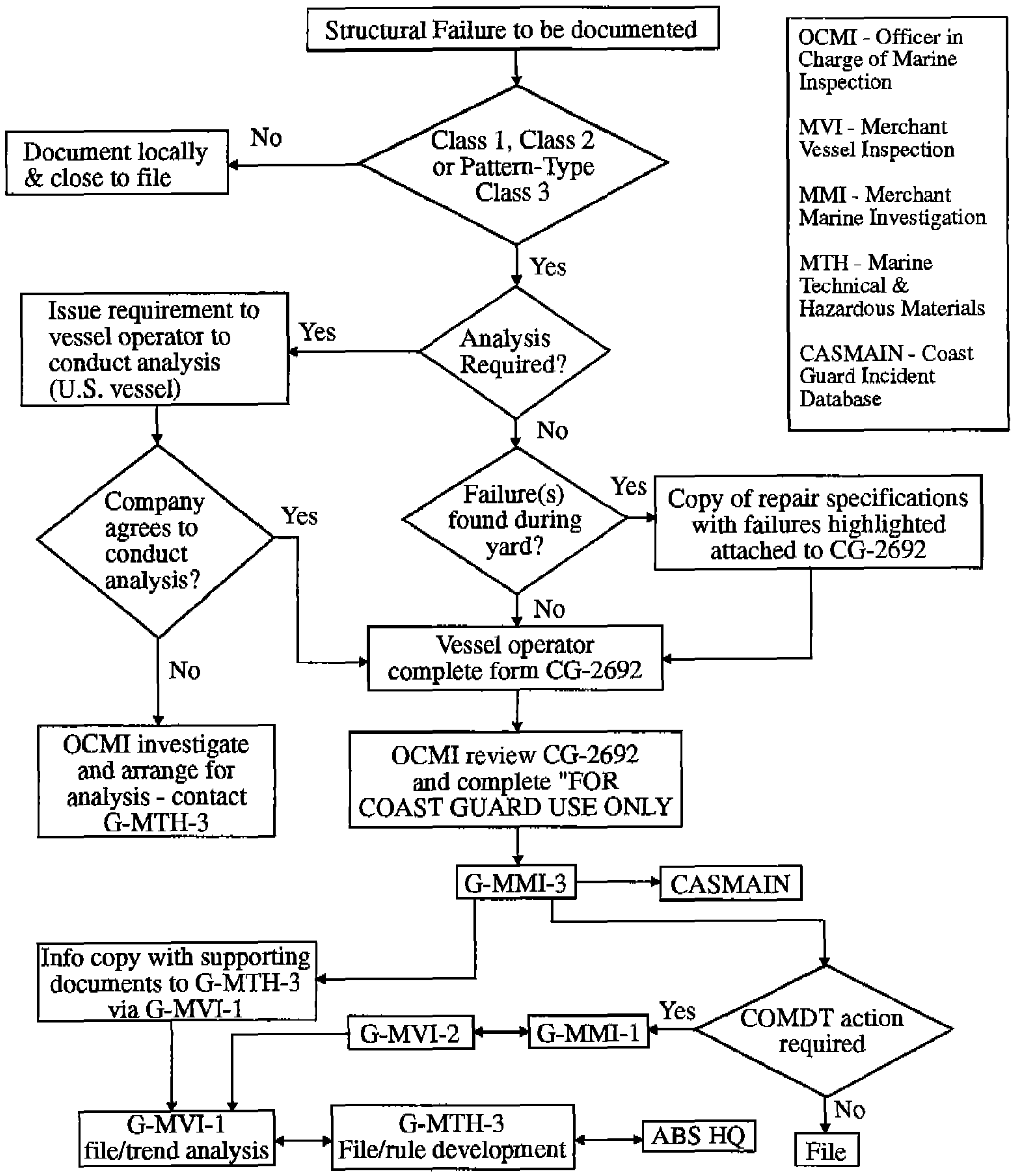


Figure 5.1: Documentation of Structural Failures

Chapter 6

Database Structure for SSIIS

6.1 Introduction

In chapter 2 the need for a general vessel information system has been documented. The large amounts of information that have to be stored and processed as the result of vessel operations make the need for a vessel database even more pronounced.

Several database systems have been developed to address some of the data management needs. These systems have been described and analysed in chapter 3 in order to determine important features and operational experiences.

In order to determine the information contents of an integrated vessel database system, several analysis software applications have been studied. The information need of each system has been summarized in chapter 4.

One of the requirements for the SSIIS database system is the ability to produce Critical Area Inspection Plan (CAIP) reports as required by the U.S. Coast Guard. After analysing existing CAIP reports and comparing them to the U.S. Coast Guard requirements as stated in [15], an improved CAIP reporting format has been developed that will be used to define the CAIP report format used by the SSIIS database system. This development is documented in chapter 5.

In the following chapter, the development of an integrated database structure for the Ship Structural Integrity Information System (SSIIS) is documented. In this development, the evaluation of existing database system in conjunction with the recognized information needs of the major analysis applications is used to define the overall, modular structure of the database system.

For each identified module, the general purpose and the anticipated information content is summarized. In order to create a prototype application that can be used to produce CAIP reports, a more detailed data structure is developed for the modules that contain information necessary for the development of CAIP reports. This includes the **Design**, the **Construction**, the **Inspection** and the **Repair** modules.

Within these modules, the data structure for the components relevant for the generation of CAIP reports is modelled with sufficient detail to be used for the development and implementation of the SSIIS prototype application. This prototype development is documented in chapter 7

6.2 General Structure

The evaluation of existing database systems has shown that, in order to create a versatile application, it is necessary to clearly separate the database structure from the database management system. The SSIIS project has to main objectives with regard to the development of a general database system:

- Overall datastructure for vessel database

- Database management prototype with CAIP reporting capabilities

A database system that is to be used by vessel operators, classification societies, regulatory agencies and engineering consultants, has to be clearly structured to allow for a modular structure of different database uses.

Fig. (6.1) shows the overall structure of the SSIIS database system. The core of the system is the **Vessel Database** which contains eight different information modules. The different modules can be grouped into the three areas of *vessel configuration*, *vessel maintenance* and *vessel operations*.

In order to manipulate the information contained in the **Vessel Database**, a **Database Management System, (DBMS)** is needed. This system has the three main purposes *Administration*, *Data Manipulation*, and *Data Analysis*.

This dual structure makes it possible to develop a modular database structure that is intended to contain all vessel relevant data, while the database management system can be custom tailored to suit specific needs of operators or regulatory agencies. The following sections document the development of both, the **Vessel Database** and the **Database Management** system.

6.3 Vessel Database Structure for SSIIS

6.3.1 Module Summary

The core of the database development for the Ship Structural Integrity Information System (SSIIS) consists of the design of the overall database structure. The data has to be organized into modules in order to permit a step-by-step development and implementation.

The modular concept makes it also easier to comprehend the large amount of information that has to be included in the SSIIS database structure. Eight different modules are used to contain the various vessel related information. Fig. (6.2) shows the different modules. The following eight modules are included in the SSIIS database structure:

- **Design**: This module contains all general vessel information grouped in vessel classes. For each class the hull form and the tank layout is included.
- **Construction**: Structural drawings for each vessel class are included in this module. In addition, frame locations are listed and a non-graphical definition of detail geometries is included.
- **Modifications**: Structural modifications, such as hull extensions, changes in the tank arrangement and general design changes in structural details are documented.
- **Inspection**: The type of inspection, the inspection company and the inspection date are listed. Inspection results of both structural inspections and corrosion surveys are included.
- **Maintenance**: Coating renewals, anode replacements and general engine maintenance are listed.
- **Repair**: Documentation of crack repairs and steel renewals is documented in this module.
- **Operations**: All operations related information is included in this module. This includes detailed cargo data for all tanks, route information, weather data, crew list, engine log and noon positions.
- **Monitoring**: Vessel response data obtained through on-board measurements is stored in this module

In the following sections, the information contents for the different modules is documented. For the modules, that are necessary for the development of the prototype applications, the data structure is defined in more detail. However, the datastructure for the prototype application is documented in chapter 7.

Relations that are simply linked to another relation represent *one-to-many* relationships. If two relations are linked through a third relation, where the name of the third relation consists of the names of the two other connections, this connection represents a *many-to-many* relationship.

Relations that are printed in grey are relations that are contained in a different module. These relations therefore document the connections between the different modules.

For each module, the general purpose of the module is described. Each relation within the module is listed stating the purpose and the main data contents in the module.

6.3.2 Design Module

6.3.2.1 Purpose

The **Design** module contains all the general vessel information. It is intended to be complete for all the information that is not operations dependent and that represents the initial, as-built state of each vessel. Fig. (6.3) shows the data structure of the **Design** module.

The information is subdivided into `Ship` and `Class` related information. This closely resembles the real-life configuration, where ships of the same class are of identical design and construction. It also minimizes repetitive data input.

Data that can vary for each voyage is contained in the **Voyage** module. Changes in the original vessel configuration ared documented in the **Modifications** module.

6.3.2.2 `Class` Relation

The `Class` relation contains all information with respect to a class of vessels. This includes the class name, the vessel particulars for all vessels of a particular class. Construction related information is contained in the **Construction** module. Information with regard to the hull form is contained in the `Hull Form` relation. General tank arrangement, tank geometry and corrosion protection (coating, anodes) are contained in the `Tanks`, `Coating`, `Anodes` and `Tank Form` relations.

The use of a `Class` relation makes it very easy to add sister ships to the database, since all class related information does not have to be re-entered.

Vessel modifications, global hull changes (elongations), changes in tank geometry or usage and changes to structural details are contained in the **Modifications** module.

6.3.2.3 `Hull Form` Relation

The `Hull Form` relation is linked to the `Class` relation. It is intended to contain the hull description for each class of vessels. It will in general involve the offsets for a set of design frames and the longitudinal offsets of the design frames.

In addition, any appended volumes have to be fully described. The format and contents of the different data files used by the HECSALV program, described in section 4.1, shows the information contents necessary for a complete description of the hull form.

Information in the `Hull Form` relation can mainly be used as input information for analysis software, but will also be used in conjunction with the information contained in the `Tanks` relation to create vessel illustrations within the database management system (i.e. General Arrangement drawings).

In order to fully develop the data structure and information contents of the `Hull Form` relation, additional research is needed. This has to include the evaluation of existing hull form representation formats, the development of efficient data structures and a classification system for the representation of appendages.

6.3.2.4 `Tanks` Relation

The `Tanks` relation contains the overall information with regard to the tank configuration for a class of vessels. This includes the general tank arrangement, the tank names, the tank types, the presence of heating coils, etc..

The **Tanks** relation is very important for the complete representation of the vessel configuration. Tanks are a primary definition of the location within a vessel. The different tank usages are important information for the correct determination of corrosion rates and the reasons for fatigue failure. In addition, the location of the different tanks has to be known to develop general arrangement plans based purely on database information.

The tank usage information simply distinguishes between ballast only, cargo / dirty ballast, and cargo tanks. A more complete description of the cargo composition is contained in the **Operations** module.

Information regarding the coating system used in each tank is contained in the `Coating` relation. The number and type of anodes used in ballast tanks is summarized in the **Anodes** relation. Most important, the tank form description for each tank is contained in the **Tank Form** relation. The subdivision of the tank information into several relations simplifies the data input and clarified the overall data structure.

6.3.2.5 Coating Relation

The `Coating` relation contains information with regard to the coating of specific tanks, in general only cargo tanks. This includes the coating material, the manufacturer, the humidity and temperature at the time the coating was applied and the coating thickness.

For a thorough database design, the material and manufacturer information should be included in an additional relation. This reduces input errors and ensures a uniform naming convention for coating products.

Including the humidity and temperature makes it possible to determine reasons for coating breakdowns. Since the exposition to direct sunlight on the hull will increase the temperature, it might be desirable to include information about possible heating effects due to sunlight in the relation.

6.3.2.6 Anodes Relation

The **Anodes** relation contains all the information with regard to the cathodic protection used in different tanks. This includes the type and number of anodes, the manufacturer and the type of attachment.

For a thorough database design, the material and manufacturer information should be included in an additional relation. This reduces input errors and ensures a uniform naming convention for anodes material and manufacturers.

6.3.2.7 Tank Form Relation

The **Tank Form** relation is linked to the **Tanks** relation. It is intended to contain the tank description for each tank of a particular vessel class. It will in general involve the offsets at both ends of a tank and the longitudinal position of the tank boundaries. In the case that the tank shape changes in longitudinal direction, the offsets and longitudinal position for this change in shape have also to be included.

The format and contents of the different data files used by the HECSALV program, described in section 4.1, shows the information contents necessary for a complete description of the tank forms.

Information in the **Tank Form** relation can mainly be used as input information for analysis software, but will also be used in conjunction with the information contained in the **Hull** relation to create vessel illustrations within the database management system (i.e. General Arrangement drawings).

In order to fully develop the data structure and information contents of the **Tank Form** relation, additional research is needed. This has to include the evaluation of existing tank form representation formats, the development of efficient data structures and an effective representation of tanks with changing cross-sectional areas.

6.3.2.8 Ship Relation

The **Ship** relation contains the data for individual vessels. All general vessel data, such as hull shape, tank information and construction is included in the **Class** relation and the **Construction** module.

The ship information consists largely of information about the builder, the owner, the operator, the classification society and the type of engine. All this information is contained in additional relations. In addition, the hull number, the U.S. Coast Guard identification number and a possible identification number issued by the classification society are included in the **Ship** relation.

Depending on owner/operator experience, it might be necessary to add additional information to the **Ship** relation.

6.3.2.9 Builder Relation

The **Builder** relation contains the necessary information with regard to the shipyard, where a particular vessel was build. This relation is linked to the **Ship** relation, which assumes that vessels of the same class can be built by different shipyards. If this assumption is unnessary, it is possible to link the **Builder** relation directly to the **Class** relation.

The **Builder** relation contains the name, address and point of contact for each shipyard. The use of a separate relation for the builder information reduces data entry errors and allows it to include expanded information about a shipyard with a minimal amount of additional data entry.

6.3.2.10 Owner Relation

The **Owner** relation contains the name, address and point of contact for each vessel owner. In addition, the date, when the vessel was bought, is included.If it is desired to preserve the history of the different vessel owners in the lifetime of a vessel, it is necessary to modify the datastructure and introduce an additional relation that links the different owners to a particular vessel including the date of the sale of the vessel.

6.3.2.11 Operator Relation

The **Operator** relation contains the name, address and point of contact for each vessel operator. In addition, the date, when the company started operating the vessel, is included. If it is desired to preserve the history of the different vessel operators in the lifetime of a vessel, it is necessary to modify the datastructure and introduce an additional relation that links the different operators to a particular vessel including the date of a change in opertors.

The use of both, the **Owner** and the **Operator** relation makes it possible to identify the cases, where the vessel owner and the vessel operator are not identical.

6.3.2.12 Classification Relation

The **Classification** relation contains the name, address and point of contact for the classification society of each vessel. In addition, the type of classification is also included.

The use of a dedicated relation to contain the classfication society avoids possible misspellings and makes it possible to include additional information (address, phone numbers) with a minimal additional data input.

6.3.2.13 Engine Relation

The `Engine` relation contains all the relevant engine related information. This includes the engine manufacturer, engine type, number of cylinders, the normal RPM, the number of screws, the number of blades per screw.

Based on the experience of vessel operators additional engine information can be included in this relation. Additional information can be relevant in relation to the daily engine log, that is included in the **Operations** module.

The engine manufacturer information can also be included in a separate relation similar to the `Builder` and `Classification` relations. This would make it possible to include more detailed information (address, etc.) into the database. The same argument can be used for the engine type.

6.3.3 Construction Module

6.3.3.1 Purpose

The **Construction** module contains all the information with regard to the structural confiuration of a vessel class. The module is directly linked to the `Class` relation.

In this module, all information with regard to the general vessel construction is entered. This can include the complete set of structural drawings in a computerized form such as AutoCad^{TM} drawings.

In addition, the vessel type has to be specified. The data format has to be flexible enough to incorporate new design types, e.g. mid-deck tankers. This requirement is realized through the use of a *many-to-many* relationship that will be explained in more detail in the following sections.

Additional research will be necessary to determine methods that make it possible to positively identify each structural component without the use of structural drawings. This will make it possible to combine defect data (cracks, etc.) with the actual structural configuration.

If a clearly structured representation of structural details can be developed that includes the geometric dimensions for all detail components, it might be possible to develop applications that can automatically generate finite element models for a structural detail at a particular location in the vessel.

Fig. (6.4) shows the data structure of the **Construction** module. In addition to the vessel type and the structural drawings, a table of frame locations and a table of Sideshell longitudinal locations is included.

These two tables can not be considered to be a final solution, since they depend on (or imply) a particular construction method. Additional research is needed to develop improved definitions for the location of structural details in a vessel.

6.3.3.2 `Vessel Type` Relation

The `Vessel Type` relation identifies the particular construction type of a vessel. It contains the name and the description of each vessel construction method. In order to have a flexible data structure that can be adapted easily to new construction methods, the relation is built based on the concept that a particular construction can consist of different components (single/ double bottom , single/double sides or mid-deck). The different components are contained in the `Component` relation.

The link between the `Vessel Type` and the `Component` relation is provided with the `Type - Component` relation. This particular design thus realizes a *many-to-many* relationship.

6.3.3.3 `Type - Component` Relation

The `Type - Component` relation contains the different components that comprise a particular vessel type. The relation consists only of the primary key of the `Vessel Type` relation and the primary key of the `Component` relation. This makes it possible to specify any number of different components for one vessel type and also to use one component in more than one vessel type.

6.3.3.4 `Component` Relation

The `Component` relation contains a list of possible structural components that form the different construction types. This makes it possible to include new construction styles whenever necessary, without modifying the data structure.

6.3.3.5 `Drawings` Relation

The `Drawings` relation contains the structural drawings for a particular vessel class. It is anticipated that the drawings are stored in the AutoCad^{TM} drawing format.

Structural drawings have the great advantage that it is possible to identify problem areas and to determine detail locations in a vessel. However, the costs for the generation of a full set of structural drawings for a vessel class is very high. In addition, a large amount of storage space is necessary to store the structural drawings.

A second problem with the structural drawings is related to the possible corruption of the location data. In existing applications, CATSIR and FracTrac, a crack is entered in the structural drawing and is associated with a record in the database. This record contains location related information. It is, however, not possible to guarantee that the location in the AutoCad^{TM} drawing matches the location in the crack database.

This ambiguity has to be removed before a full integration of structural drawings in the vessel database can be achieved. Detail classes have to be defined that can accurately represent the structural configuration.

For a given structural detail, specific configuration in conjunction with the geometric dimensions and the location within the vessel have to be specified. A given detail can then be associated with a structural drawing.

In order to identify the exact defect location in a particular detail, the structural drawing and the database information have to be linked to an even greater extent. Within the AutoCad^{TM} drawing, each individual construction part has to be coded in accordance with the specifications given in the database.

The above outlined requirements for a non-ambiguous connection between the vessel database and the AutoCad^{TM} drawings, clearly shows the difficulties in the development of this interface. These difficulties, together with the other disadvantages (cost and storage requirement), might outweigh the advantages of a graphical representation of the ship structure.

The inclusion of structural drawings in the SSIIS database structure will be a political decision based on the potential usage of the database. Additional research is necessary to provide sufficient information about the actual benefits and disadvantages of the inclusion of structural drawings in the database.

6.3.3.6 `Frame Loc` Relation

The `Frame Loc` relation contains a table of the frame locations for a given class of vessels. Since most of the longitudinal location information is based on the frame numbers, this list makes it possible to determine the exact longitudinal distribution of defects. This capability is important for the preparation of Critical Area Inspection Plan (CAIP) reports and other failure data analyses.

However, the use of an explicit table for the frame locations implies that transverse frames are used to construct the vessel. Although this is the pre-dominant form of construction, other construction types may be introduced that make the use of frame locations obsolete. Additional research is needed to evaluate the benefits of the frame location table against its possible limitations.

6.3.3.7 `S-Long Loc` Relation

The `S-Long Loc` relation contains the transverse and vertical positions of the sideshell longitudinals for a given class of vessels. The use of this location information allows it to show the vertical distribution of defects in sideshell details. This is helpful for the preparation of CAIP reports and other damage statistics.

As in the `Frame Loc` relation, the use of an explicit table for the sideshell longitudinal locations implies that sideshell longitudinals are used to construct the vessel. Although this is the predominant form of construction, other construction types may be introduced that make the use of sideshell longitudinal locations obsolete. Additional research is needed to evaluate the benefits of the sideshell longitudinal location table against its possible limitations.

6.3.4 Modifications Module

6.3.4.1 Purpose

The **Modifications** module is intended to contain information with regard to structural modifications to a particular vessel. By using this separate module, it is possible to conserve the history of the structural modifications, which is important for the generation of CAIP reports and for the general documentation of the vessel history.

Modifications can include the general hull form (elongations, etc.), which will also affect the longitudinal position of the frame locations. In addition, modifications can be made to the tank arrangement including changes in the tank geometry, usage, cathodic protection or coating.

General modifications of structural details are not included in the **Modifications** module to avoid conflicts with the **Repair** module.

In general, the information in the **Modifications** module has to include date information to allow it to reconstruct the order of structural modifications and to determine the present configuration. Additional research is needed to determine the most effective design and implementation to represent structural modifications.

The data structure of the **Modifications** module is shown in Fig. (6.5.

6.3.4.2 `Hull Form` Relation

The `Hull Form` relation contains the information pertaining the changes to the hull form made during the life time of a vessel. In general, these changes will consist of hull elongations, or shortening. The format of the `Hull Form` relation in the **Modifications** module has to be identical to the hull form description used in the **Design** module with the exception of an added modification date.

6.3.4.3 `Frame Loc` Relation

The `Frame Loc` relation contains the modified frame locations and the date of the modifications. In general, this information is related to changes in the `Hull Form` relation.

An effective method has to be developed to account for additional frames, which can change the established numbering sequence. It will probably be necessary to modify all frame location in front of a possible hull elongation point to account for the change in the longitudinal position.

The database management design has to provide an easy procedure to change the offsets of a set of frames by a specified amount in order to reduce data entry efforts.

6.3.4.4 `Tanks` Relation

The `Tanks` relation in the **Modifications** module contains the information with regard to modified tank geometry, changed tank usage, changes in the cathodic protection system or changes and replacements in the coating system. Changes are documented using the tank identifications that are introduced in the **Design** module. In addition, the date of the changes is included, which makes it possible to establish the order of the changes and to identify the present configuration.

Documenting the modifications to the tank arrangements, cathodic protection and coating system makes it possible to develop the tank and coating history documentation that is required as part of the Critical Area Inspection Plan reports.

Changes regarding the coating system used in each tank are contained in the `Coating` relation. The modifications in the number and type of anodes used in ballast tanks are summarized in the `Anodes` relation. Most important, changes to the tank geometry description is contained in the `Tank Geometry` relation. The subdivision of the tank modification information into several relations simplifies the data input and clarifies the overall data structure.

6.3.4.5 `Coating` Relation

The `Coating` relation contains information with regard to the changes in the coating of specific tanks, in general only cargo tanks. This includes the coating material, the manufacturer, the humidity and temperature at the time the coating was applied and the coating thickness.

For a thorough database design, the material and manufacturer information should be included in an additional relation. This reduces input errors and ensures a uniform naming convention for coating products. Only one relation to contain this information is needed, which can be addressed both from the **Design** and from the Modifications module.

Including the humidity and temperature makes it possible to determine reasons for coating breakdowns. Since the exposition to direct sunlight on the hull will increase the temperature, it might be desirable to include information about possible heating effects due to sunlight in the relation.

6.3.4.6 `Anodes` Relation

The `Anodes` relation contains all the information with regard to the cathodic protection used in different tanks. This includes the type and number of anodes, the manufacturer and the type of attachment.

For a thorough database design, the material and manufacturer information should be included in an additional relation. This reduces input errors and ensures a uniform naming convention for anodes material and manufacturers. Only one relation to contain this information is needed, which can be addressed both from the **Design** and from the Modifications module.

6.3.4.7 `Tank Geometry` Relation

The `Tank Geometry` relation is linked to the `Tanks` relation in the **Modifications** module. It is intended to contain the tank description for each tank of a particular vessel that has been modified. It will in general involve the offsets at both ends of a tank and the longitudinal position of the tank boundaries. In the case that the tank shape changes in longitudinal direction, the offsets and longitudinal position for this change in shape have also to be included.

The data structure and information contents of the `Tank Geometry` relation has to be identical to the `Tank Form` relation in the **Design** module with the addition of the date, when the modifications where made.

The database management system has to be designed to facilitate a simple copy procedure of the tank geometry information that permits it to enter only the changes in the configuration.

6.3.5 Inspection Module

6.3.5.1 Purpose

The **Inspection** module contains two sets of information. It summarizes all information related to individual inspection events including the inspection company, the location, the inspection date and the individual inspectors. In addition, the complete inspection results of both corrosion surveys (plate gaugings) and of structural surveys (defects and cracks) are listed for each inspection of a particular vessel.

The **Inspection** module is linked to the `Ship`, `Class` and `Tank` relations of the **Design** module. Inspection results are referenced by the ship, the vessel class and the particular tank. This makes it possible to include the only partial inspection of a vessel.

The definition of the detail configuration for both corrosion and crack results is based on the same detail definition procedure. This procedure is contained in the **Detail** sub-module, which is summarized in section 6.3.6.

For the representation of the crack information, which is most important for the preparation of Critical Area Inspection Plan reports, information with regard to the crack cause, the crack repair and the crack class (as defined by the U.S. Coast Guard) is included. In addition, information about the steel type is included, which makes it possible to investigate the effect of the use of High-Tensile-Steel (HTS) on the development of fatigue cracks.

In addition to the detail configuration, the `Corrosion` relation also contains information about the corrosion type in order to allow the distinction between general, pitting and grooving corrosion.

The data structure of the **Inspection** module is shown in Fig. (6.6.

6.3.5.2 `Inspection` Relation

The `Inspection` relation contains the logistic information about all inspections that have been performed. The information is linked to the `Ship` and `Class` relation. It contains the start and end dates of the inspection, the inspection company, the inspection location and the inspection technicians (inspectors).

Most of this information is provided through the use of additional relations, which reduces the amount of data input information and avoids input errors. Since it is possible that several inspectors perform one inspection and each inspector will be part of several inspections, a *many-to-many* relationship is needed to provide this information. This is achieved through the use of the `Inspection - Inspector` and the `Inspector` relations.

For a more complete database system for the use by operators, it might be possible or desirable to include information about the inspection costs. This information can be important for accounting purposes. The duration of the inspection can be obtained from the information contained in the **Operations** module.

6.3.5.3 `Location` Relation

The `Location` relation provides the information regarding the location, where a particular inspection is performed. This can be a port or during the voyage of a vessel.

The `Location` relation can contain the name of the port, possible points of contact, etc.. This information contents has to be derived from operator experience and preference.

6.3.5.4 `Company` Relation

The `Company` relation contains the information about the company that has performed the inspection. This information can include the name of the company, the address, phone number, point of contact and any additional information that can be helpful for the documentation of the inspection process.

6.3.5.5 `Inspection - Inspector` Relation

The `Inspection - Inspector` relation provides the link between the `Inspection` and the `Inspector` relation, thus forming a *many-to-many* relationship. It only contains the primary keys of the two relations. This makes it possible that more than one inspector can perform one inspection and one inspector can perform several inspections.

6.3.5.6 `Inspector` Relation

The `Inspector` relation contains the information with regard to the different inspectors. This can include the complete name, a contact address and phone number and any additional information that can be of use for the documentation of the inspection process.

In the present database structure, no information about the employer (Inspection company) is provided since this could lead to data corruption, if the employer that is specified does not match the company specified in the `Company` relation. If the employer information is considered to be important, a more complex structure has to be devised that takes into account the possibility that an inspector can switch the inspection company.

6.3.5.7 `Corrosion` Relation

The `Corrosion` relation contains the results of corrosion surveys. The relation is linked to both the `Inspection` and the `Tank` relation. This makes it possible to identify the corrosion survey results for individual tanks.

The corrosion type is specified using an additional relation, the `Corr_Type` relation. The `Corrosion` relation contains the plate gauging results that have been measured during the survey.

The detail configuration is identified with the help of the **Detail** sub-module, described in section 6.3.6. This sub-module is also used in the `Cracks` relation.

The information about the tank contents, chemical composition of the cargo, tank temperature, etc., can be found in the **Operations** module, since this information can change for each voyage. The database analysis procedures that have to be devised and implemented in the database management system have to account for these different cargo and ballast conditions.

In order to use a direct link between the gauging device and the database, a system has to be developed that makes it possible to define the gauging location with sufficient accuracy without the use of structural drawings. This can make it possible to store the gauging results electronically during the gauging process and simpy transfer them to the database at a later time.

6.3.5.8 `Corr_Type`

The `Corr_Type` relation contains the different possible corrosion types. This can include general corrosion, pitting corrosion and grooving corrosion. This relation can also include detailed descriptions of the different corrosion phenomena and graphics or pictures that show examples of the different corrosion types.

The `Corr_Type` relation is linked to the `Corrosion` relation and minimizes the amount of data input and reduces the possibilities for input errors.

6.3.5.9 `Cracks` Relation

The `Cracks` relation contains all the information from the structural survey of a vessel (all tanks or selected tanks only). The information is provided for each individual crack. For each crack the crack causes can be specified using a *many-to-many* relationship to account for the possibility of several causes contributing to a crack.

For each crack the crack class, as defined by the U.S. Coast Guard, is entered. The crack classes are defined in an additional relation. Along with the crack class, the actual crack length is entered.

The steel type that is used at the particular crack location is also specified in the `Cracks` relation. The steel type specifications are contained in an additional relation to minimize data input and to reduce input errors.

For each crack, repair information is specified. This can range from simply re-welding the crack to a complete re-design. The repair information is linked to the **Repair** module.

Very important for the analysis of fatigue crack problems, the origin of a crack is documented in the `Cracks` relation. The possible origins are contained in the `Origin` relation in order to minimize data input and to reduce input errors.

The definition of the detail configuration for a particular crack incident is included in the `Cracks` relation. The exact format for the detail representation is summarized in the section about the **Detail** sub-module, 6.3.6.

6.3.5.10 `Crack - Cause` Relation

The `Crack - Cause` relation provides the link between the `Cracks` and the `Cause` relation, thus forming a *many-to-many* relationship. It only contains the primary keys of the two relations. This makes it possible that more than one crack can have several causes and one cause can contribute to many cracks.

6.3.5.11 `Cause` Relation

The `Cause` relation lists the different contributing factors that can cause defects. This can include corrosion, fatigue, design, manufacturing, etc.. The relation can include explanatory notes and graphics to document the cause information. This information can be used to design an online help system that can facilitate the data input.

6.3.5.12 `Crack_Class` Relation

The `Crack_Class` relation contains the U.S. Coast Guard definitions for the different crack classes. This can include the class name, the literal definition, a possible reference document and a sketch that describes the crack class definition.

One problem with the crack class definition lies in the fact, that a crack classification depends both on the crack length and on the crack location. The use of the `Crack_Class` relation for the input of the crack class does not prohibit that a class might be classified in the wrong class.

An improved design has to ensure that the crack classification is performed based on the class definition so that no wrong classifications can occur. Alternatively, the classification can occur in the analysis stage based on the class definitions provided in the `Crack_Class` relation.

6.3.5.13 `Steel` Relation

The `Steel` relation contains the list of possible steel types that can be used in the construction of a detail. This minimizes data input and reduces possible input errors.

In the case that the complete detail definition and location procedure has been developed and included in the **Construction** module, which also contains the steel type, the use of the `Steel` relation in the **Inspection** module becomes unnecessary.

6.3.5.14 `Origin` Relation

The `Origin` relation contains the possible crack origin. In general, this will either be the weld between two components or a plate edge. The use of the `Origin` relation helps to identify the crack origin and can thus be used to develop improved fatigue analysis procedures.

The `Origin` relation can also contain graphical representations of the different possible crack origins, which can be used in the design and implementation of the database management system.

6.3.5.15 `Repair` Relation

The `Repair` relation is used to define the repair that is performed for a cracked structural detail. This relation is part of the **Repair** module and is described in section 6.3.8.

6.3.6 Detail Sub-Module

6.3.6.1 Purpose

The **Detail** sub-module is intended to define the construction and components of different structural details in the vessel. This information is used to identify the structural detail that has experienced a defect without the help of a structural drawing.

The **Detail** sub-module consists of a series of *many-to-many* relationships. Main structural configurations are made up of one (or several) built configurations. Each built configuration is made of one (or several) components. Each component can have one (or several) defect sites.

The use of this non-graphical description of a structural detail configuration greatly facilitates the data analysis of failure data, since the task can be completely automated.

In a future development, it has to be investigated, whether it is possible to combine this structural detail definition with geometric dimensions and the location information within the vessel to completely describe the vessels main structural configuration and critical structural details without the use of structural drawings. This would make it possible to develop procedures to automatically create finite element models for a specific structural detail at a given location.

The finite element model generation could be based on the procedure developed as part of the Structural Maintenance Project (SMP). See [40] and [31] for a description of the mesh generation software developed as part of the SMP project.

6.3.6.2 `Main` Relation

The `Main` relation contains a list of the different main structural configurations in a vessel. By linking it to the `Built` relation through a *many-to-many* relationship, it is possible that each main structural configuration can be composed of several built details.

In addition to the several built components, the `Main` relation can contain a graphical representation of the main structural configuration. This graphical representation can be used in the database management system to facilitate data input procedures and to developed a customized help system that is based partly on database information and is thus very flexible.

6.3.6.3 `Main - Built` Relation

The `Main - Built` relation provides the link between the `Main` and the `Built` relation, thus forming a *many-to-many* relationship. It only contains the primary keys of the two relations. This makes it possible that more than one Built structure can be used for one main structural configuration and each built component can be part of several main structural configurations.

6.3.6.4 `Built` Relation

The `Built` relation contains the different smaller structural details that are built from one or many different components. The `Built` relation is linked to the `Component` relation in a many-to-many relationship, thus permitting one built structure to contain several individual components and each component to be part of several built structures.

In addition to the name of the built component it is possible to include a graphical representation of the built structural detail and a verbal description. This, again, makes it possible to develop data input screens within the database management system that can use graphical information to facilitate data input.

6.3.6.5 `Built - Comp` Relation

The `Built - Comp` relation provides the link between the `Built` and the `Comp` relation, thus forming a *many-to-many* relationship. It only contains the primary keys of the two relations. This makes it possible that more than one component can be used for one built structure and each component can be part of several built structures.

6.3.6.6 `Component` Relation

The **`Component`** Relation contains the individual components that are used to describe the *Built* structural details. This can include the flange and the web of a built longitudinal or the cutout of a webframe.

Each component can have one or more defect sites. These sites identify the possible areas in a component, where a defect can be located. This information can be used to clearly determine the defect location. A *many-to-many* relationship is used to identify these defect sites, since it is possible that one component has more than one defect site and each defect site can be used in many components.

In addition to the name of the component it is possible to include a graphical representation of the component and a verbal description. This, again, makes it possible to develop data input screens within the database management system that can use graphical information to facilitate data input.

6.3.6.7 `Comp - Site` Relation

The **`Comp - Site`** relation provides the link between the **`Comp`** and the **`Site`** relation, thus forming a *many-to-many* relationship. It only contains the primary keys of the two relations. This makes it possible that more than one defect site can be used for one component and each defect site can be used in many components.

6.3.6.8 `Defect_Site` Relation

The **`Defect_Site`** relation contains the information about the possible defect sites. This includes the name of the defect sites, a description and possibly a graphical representation.

The defect site information is used to identify the main location of a defect. In addition, the `Origin` relation in the **Cracks** module identifies the exact origin of a crack. Although these two locations can coincide, the use of the additional defect site information can account for the fact that the crack originates at one location (the origin), but has propagated in a different location (the defect site).

6.3.7 Maintenance Module

6.3.7.1 Purpose

The **Maintenance** module contains the information about vessel maintenance. This includes engine, coating and anodes maintenance. It is different from the information contained in the **Modifications** module, since only actual maintenance is included, such as the replacement of anodes, the renewal of coating and standard engine maintenance.

All information is linked to the `Ship` and the `Class` relation. In addition, for the anodes and coating maintenance, a link to the `Tanks` relation is also established. For each tank in a vessel, it is therefore possible to determine the maintenance history. This is particularly important for the generation of Critical Area Inspection Plan reports.

Additional research and input from potential database users is needed to further develop the data formats and information contents of this module.

6.3.7.2 `Engine` Relation

The `Engine` relation contains all necessary information about the routine engine maintenance. This can include a list of replaced parts, lubrication procedures, retrofitted components, etc..

The engine maintenance information depends strongly on operator and engine manufacturer requirements. Additional research is needed to clearly determine the scope and information content of the `Engine` relation

6.3.7.3 Coating Relation

The Coating relation contains the information about the regular coating maintenance. This includes complete re-coating of tanks or the fix-up of small areas of coating breakdown.

In the case that a different coating procedure is used, this information has to be entered in the **Modifications** module, since it constitutes a change of the vessel configuration. Nevertheless, material information is entered in order to provide complete maintenance information.

A separate relation is used to provide the material information. This relation can also be used for the coating information in the **Design** and the **Modifications** modules. This ensures data integrity and prohibits data input errors.

6.3.7.4 Material Relation

The Material relation contains the information about the different coating materials. This can include the name, the manufacturer, the chemical composition, and other technical information.

In addition, usage requirements, such as maximum humidity or minimum temperatures can be entered here. This makes this information readily accessible and can be used for data analysis and reporting purposes.

6.3.7.5 Anodes Relation

The Anodes relation contains all information about the replacement of anodes. Information about the anode type is obtained from the Type relation. The Anodes relation does not contain information about the new installation of anodes in tank that were originally without cathodic protection. This type of information is included in the **Modifications** module.

6.3.7.6 Type Relation

The Type relation contains the information about the different anode types. This can include the name, the manufacturer, the chemical composition, the anode dimensions and other technical information.

In addition, usage requirements, such as maximum humidity or minimum temperatures can be entered here. This makes this information readily accessible and can be used for data analysis and reporting purposes.

6.3.8 Repair Module

6.3.8.1 Purpose

The purpose of the **Repair** module is to document structural repairs in tankers. It is linked to the **Inspection** module. This makes it possible to clearly document the repairs to a particular failure including detailed drawings.

The module includes crack repairs and steel renewal information. The steel renewal information is important to assess the structural integrity of a vessel and to assure that the vessel is in accordance with classification requirements.

Additional research is needed to clearly define the functionality and the interfacing between the **Repairs** and the **Inspection** module. Especially important is the issue of repairs of previously repaired details. In order to asses the quality and efficiency of a repair, it is necessary to identify successful and unsuccessful repairs.

A second important area for further development is the documentation of repair times and itemized repair costs. This information can help to determine the most appropriate repair based on economic considerations.

6.3.8.2 Repair Relation

The Repair relation contains information about crack repairs and steel renewals. It is linked to the Cracks relation in the **Inspection** module. For crack repairs, the detail has to be identified, particularly in cases, where the repair consists of a detail re-design. In addition, the repair type has to be specified and a structural drawing can be used to document the repair.

Steel renewal information is also included in the Repair relation. For steel renewal, only structural drawings are used to document the repair. Additional development is needed to link the steel renewal information to the Corrosion relation in the **Inspection** module and to provide sufficient detail about the location and the type of steel renewal.

6.3.8.3 Crack_Repair Relation

The Crack_Repair relation provides detailed information about the repair of a particular crack that has been included in the Cracks relation of the **Inspection** module. The type of structural detail is documented including possible changes in the original design. The crack location is already included in the Cracks relation and does not have to be repeated. Based on information stored in the Repair_Type relation, the method that has been used to repair the crack, is documented. A structural drawing can be included that identifies the repair.

Additional development is needed to determine a possible format that can provide information with regard to the cost and duration of a particular repair. This information can be used to determine the optimum repair solution based on economic considerations using a probabilistic analysis procedure.

The detailed format that can be used to document repairs to cracked details depends strongly on the detail representation that is used in the **Detail** sub-module. The development of these two formats is therefore strongly connected.

6.3.8.4 Repair_Type Relation

The Repair_Type relation consists of a standardized documentation of the different possible repair solutions. This has to include a repair name, a repair definition, a description of the purpose and advantages of the repair and a graphical representation of the repair method.

The development of the Repair relation can form the basis for a future knowledge based system that can assist users in the selection of the most appropriate repair. In conjunction with this knowledge based system, the importance of obtaining information with regard to repair costs and repair durations has to be stressed again.

6.3.8.5 Drawing Relation

The Drawing relation contains the graphical representation of the actual repair including detail dimensions. The link of this information to the Crack relation makes it possible to draw conclusions with regard to the repair effectiveness and to document particular crack repairs, as is required for severe cracks in Critical Inspection Areas.

The drawing format has to follow the same standards as the general structural drawings in the Construction module. This assures a smooth interface between the different database modules, which is particularly important for the reporting and query features of the database management system.

6.3.8.6 Steel_Renewal Relation

The Steel_Renewal relation is intended to contain information relating to the replacement of corroded plating. This has to include the plating location, the dimensions and the weight of the replaced plating.

In addition, the cost of the steel replacement and the required time has to be recorded. This information can help for the future planning of repair and maintenance operations and can help to determine the optimum maintenance strategy.

6.3.9 Operations Module

6.3.9.1 Purpose

The **Operations** module has the purpose to provide information about all relevant aspects of tanker operations. This information is intended for a wide variety of users and contains therefore very diverse information.

The data is organized based on individual voyages. Each voyage consists of several legs. For each leg the departure and destination port is identified. Cargo information can be entered individually for each leg.

The information about the crew for each leg can be of interest for accouting and general bookkeeping purposes. The information contents with regard to the crew has to be defined based on the need and general practice of tanker operators.

In general, the **Operations** module has to be refined and expanded in order to make it a useful tool for day-today operations and extended analysis of operating procedures. Significant input from tanker operators is needed to complete this task.

The accurate and complete collection and storage of operations related information and its subsequent use for planning and management purposes can provide sufficient incentives for tanker operators to use a general vessel information system. The development of the **Operations** module is therefore of the greatest importance in order achieve a wide acceptance of the SSIIS database system.

6.3.9.2 `Voyage` Relation

The `Voyage` relation constitutes the core of the **Operations** module. All operations related information is organized based on individual voyages. Each voyage is comprised of several `Voyage_legs`, which makes it possible to identify all ports and destinations and to determine the cargo type and loading conditions for the individual legs.

For each day of a voyage, a daily report is stored that summarizes the weather conditions, the engine particulars and the noon position of the vessel. This information can be very helpful to determine long-term loadings, evaluate engine performance and determine average speeds.

The `voyage` relation is linked to the `Ship` and the `Class` relation. Voyages are therefore stored for each vessel of each class. The use of voyages as the main definition of the travel service pattern makes it possible to determine a vessel's primary trade route, but is also flexible enough to recognize changes in this trade route.

6.3.9.3 `Noon_Reports` Relation

The `Noon_Reports` relation contains daily reports about weather, engine and vessel position. This information is contained in three additional relations. The `Noon_Reports` relation electronically stores information that is presently gathered and stored onboard of the vessel and is then transferred to the operator headquarters.

Presently, some operators are implementing electronic database system for the storage of this operations related information, see section 4.4 for the description of the Vessel Management system (VMS) that is currently being developed by Chevron.

The noon reports are organized by vessel and vessel class and the date, since only one report can exist for one vessel of a particular class for any given date.

6.3.9.4 `Weather` Relation

The `Weather` relation contains a summary of the weather condition for each day. This can include the average temperature, the wind speed and direction and barometric pressure. The purpose of this relation is to provide sufficient information to allow a correlation between the weather and the ship monitoring information contained in the **Monitoring** module.

In addition to the general weather information, it is important to include data about the sea state. This should include the average wave height and wave direction. It has to be investigated, whether this type of information is currently gathered by the vessel crew and what information can be obtained with minimal effort.

Appendix D contains the information that is included in the noon position reports that are part of the VMS database system. This information can be used as guidelines for the development of the `Weather` relation.

Additional research is needed to define the most appropriate format for the `Weather` relation. This research has to determine the data needs of vessel operators and engineers and to evaluate the data needs against the economic factors.

6.3.9.5 `Engine` Relation

The `Engine` relation contains all relevant information about the general engine performance for each day of a voyage. This information can be used to evaluate engine performance and to accurately document the use of the engine.

The information has to include the average RPM, the fuel consumption, the use of lubrication oil and any other relevant engine related information. Based on the information contained in the `Engine` relation, it is possible to determine the total engine usage and thus effectively schedule maintenance intervals.

Appendix D contains the information that is included in the noon position reports that are part of the VMS database system. This information can be used as guidelines for the development of the `Engine` relation.

6.3.9.6 `Position` Relation

The `Position` relation contains the exact noon position of the vessel. Additional information as the daily miles and the course can be included. The noon position can be used to accurately determine the vessels average course and average speed. It can also be used to determine the general ocean areas through which the vessel has travelled. This information is needed in order to determine the long-term load distribution based on generalized wave scatter diagrams.

6.3.9.7 `Leg` Relation

The `Leg` relation contains all information that is specific for one leg of a voyage. The relation is linked to the `Voyage` and the `Ship` and `Class` relations. This assures that the different voyage legs of a particular vessel can be accurately re-constructed.

In addition to the ship and the class information, the departure date and arrival date is included. The departure date is used as the primary key in conjunction with the ship and the class information. The database management system has to ensure data integrity by requiring that the departure date for a new *leg* of a vessel is later than the latest arrival date for that vessel.

6.3.9.8 `Ports` Relation

The `Ports` relation contains a list of ports and terminals that are used by the different vessels. This includes the exact location, information about draft limitations and the type of discharge facilities.

The `Ports` relation has to be developed further based on input from tanker operators. It could include a list of the available moorings and docks in each port, which could be used to correlate discharge and general harbor time with the type of mooring facility.

6.3.9.9 `Cargo` Relation

The `Cargo` relation contains the information about the exact cargo for one leg. This information includes the water and sulphur contents of the cargo, and the cargo temperature.

In order to obtain more detailed information, the `Cargo` relation can be linked to the `Tanks` relation and the cargo information can then be provided for each individual tank.

Cargo information can also include economic data used for general decision making. Cooperation with tanker operators is necessary to define the full information contents of the `Cargo` relation.

6.3.9.10 `Loading` Relation

The `Loading` relation contains the loading status for each tank. The includes the filling level, the amount of cargo or ballast in the tank and any additional information that is related to the tank loading.

In general, this information can be obtained from the output of different loading software, e.g. CARGOMAX. Evaluating the information contents of CARGOMAX and through discussions with tanker operators, a more complete information contents for the `Loading` relation can be developed.

6.3.9.11 `Leg - Crew` Relation

The `Leg - Crew` relation relation provides the link between the `Leg` and the `Crew` relation, thus forming a *many-to-many* relationship. It only contains the primary keys of the two relations. This makes it possible that many crew members can be on a vessel during one leg and each crew member can be on different legs.

6.3.9.12 `Crew` Relation

The `Crew` relation contains information about the vessel crew. This information is intended both for the vessel operation and for accounting and personnel purposes. It has to include the name and address of the crew member, his expertise and position onboard of a vessel and general accounting information.

Cooperation with the accounting departments of tanker operators is necessary to develop a functional `Crew` relation that contains sufficient and useful information about crew members.

6.3.10 Monitoring Module

6.3.10.1 Purpose

The purpose of the **Monitoring** module is to contain the results from vessel monitoring programs. These programs measure different vessel response characteristics at constant, short time intervals during each voyage. Vessel monitoring devices are currently being installed on many different tankers. Monitoring can help to reduce damage to a vessel by providing information about high loads on a vessel due to a storm, thus allowing the vessel crew to react by reducing speed and / or changing course.

In addition to the short term benefits of vessel monitoring to detect and avoid critical peak loads, it can also be used to document and re-create the long-term loading history of a vessel. This is of utmost importance for the estimation of fatigue damage on a vessel.

Additional research is necessary to determine the most appropriate format to store the response information. This format will be a trade-off between information accuracy and storage requirements. The maximum time interval between individual response measurements has to be determined. Due to the large amount of data that can be gathered, a method has to be developed to calculate and summarize the data and then to store only the summaries. This can maybe be done by estimating the response spectra for subsequent 2-3 hour periods and to store only the spectrum parameters.

However, it is believed that the use of monitoring data can lead to improved loading estimates for vessels and a more accurate representation of the loading over the lifetime of a vessel.

6.3.10.2 `Response` Relation

The `Response` relation contains all the response information for a given vessel, vessel class and voyage. It is therefore linked to the `Ship`, `Class` and `Voyage` relations. It has to contain sufficient information to allow the calculation of the long-term vessel loading history.

In addition, it has to be possible to trace the monitoring methods that are used, including equipment, sampling periods, company, etc.This will make it possible to backtrack and evaluate different procedures and to determine the effectiveness of monitoring equipment.

Additional research is needed to fully develop the contents of the `Response` relation. This will involve additional literature studies, discussions with operators and monitoring companies and the development of suitable performance standards.

6.3.10.3 `Location` Relation

The `Location` relation contains a list of the different locations that are used for the response measurements. This information is necessary to accurately identify the different response characteristics and to calculate the long-term loading for a vessel.

The `Location` relation can be expanded to use some of the more advanced location descriptors used to identify defect locations. This can help to unify the location descriptions and to cross-reference defect and loading locations.

6.3.10.4 `Acceleration` Relation

The `Acceleration` relation contains the accelerations for a given vessel of a class for a specific voyage. The accelerations are listed for specific locations that are identified in the `Locations` relation.

The exact format of the `Accelerations` relation has to be developed in more detail. This development has to address the current ship monitoring practice and define ways to compress the monitoring results to conserve storage space.

6.3.10.5 `Pressure` Relation

The `Pressure` relation contains the pressures for a given vessel for a specific voyage. Similar to the `Acceleration` relation, the format for the `Pressure` relation has to be defined in more detail.

The exact procedure to determine pressures on specific locations on the ship hull has to be investigated. The results of this investigation will determine the most suitable format and the data contents for the `Pressure` relation.

6.3.10.6 `Stress` Relation

The `Stress` relation contains the stresses that have been measured using strain gauges at specific locations on structural details on the ship. These strain measurements serve two purposes, they are used to alert the vessel crew of possible extreme conditions, where the material yield is exceeded and they are used to determine the transfer functions between the environmental loading and the stress response.

Additional research is needed to determine the exact format and information contents for the `Stress` relation. This has to include the definition of the exact location of the strain gauges, which exceeds the information in the `Location` relation.

6.4 Database Management System for SSIIS

6.4.1 Overview

The developed database structure that contains all necessary information with regard to tanker survey results is intended to replace the present form of storage for survey results and ship information, which implies that the database structure will be used in day-to-day operations by owner/operators. This requires the development of a database management system (**DBMS**) that facilitates these operations. This DBMS has to meet the following requirements:

- The system has to have a graphical user interface that makes all database operations easy to use.
- Input screens for all data structures that are ship or survey related have to be available to perform input of new data.
- The system has to have editing capabilities that allow the modification of existing data.
- The data input procedures have to permit only valid data. This requires that drop-down lists are available that only allow the choice among available information, e.g. corrosion information can only be entered for a ship that is included in the database, i.e. the `Vessel_ID` has to be chosen among the available `Vessel_ID`.
- Analysis and query capabilities have to be included in the system. The system has to allow the generation of customized queries in order to provide a flexible tool that can be adapted to changing evaluation needs.
- The system has to provide standardized reports that can be generated with a minimum of user input in order to guarantee a consistent report format that meets given standards and recommendations. For the SSIIS project, the most important report format requirement is the Critical Area Inspection Plan report format that has been outlined in chapter 5.

The prototype development, documented in chapter 7 contains a basic DBMS, which is intended to provide an example for the general design and implementation of a database management system.

As shown in Fig. (6.1) the `DBMS` and the `Vessel Database` form the overall SSIIS system. The developed database structure is documented in section 6.3. The `DBMS` uses the vessel database and performs all the necessary database manipulations, and all data input and output functions.

The purpose of the `DBMS` can be subdivided into three main modules:

- **Administration**
- **Data Input**, **Data Edit**
- **Queries**, **Reports**

Fig. (6.12) shows a more detailed summary of the database management system. For each of the three categories, the necessary components are defined. In the following sections, the different components for each of the three main module are summarized and described.

6.4.2 Administration

6.4.2.1 Purpose

The **Administration** module of the DBMS has to ensure the database integrity, provide system security, and allow a customized setup of the database. Additional features that are of importance for the overall functionality of the database will be included in this module in the course of the development.

A sophisticated database administration can prevent data losses due to corrupted input data and can provide the password protection of sensitive parts of the database. This is particularly important for a general database system such as the SSIIS database. It has to be assured that data can be accessed by authorized users only. The database administration has to be able to allow access to selected areas only.

6.4.2.2 User Privileges

The SSIIS database system consists of a large amount of data that is used for a wide variety of purposes. It has to be assured that each user has only access to a defined part of the database. The database administrtation has to provide access to any part of the database for individual users. The user privileges and password protection have to be able to be changed or revoked at any time.

A list function that identifies all authorized users and their individual privileges has to be available to the database administrator. This makes it possible to get an overview about all database users and to identify the different privilege levels.

The implementation of the user privileges strongly depends on the general SSIIS structure, the hardware and operating system and the database software used to create SSIIS. In addition, other existing large database systems (i.e. FAA database) have to be studied to determine the most efficient implementation.

6.4.2.3 Database Integrity

Through extensive use and data input and data deletion, it is possible that a database becomes corrupted. Data indexes are not coherent any longer and previously used storage space does not get reallocated. This status can be detrimental to the database performance and can possibly lead to data corruption.

It is therefore necessary for the database administrator to perform database maintenance operations that involve data backup and a complete reallocation of storage capacities.

The database maintenance functions have to be password protected to assure that only authorized users, in general the database administrator, is able to perform the operations.

6.4.2.4 Database Setup

The database setup functions include the possibility to customize input screens and include customized `Help` information. In addition, any company specific additions to the general database setup have to be included here.

6.4.3 Data Input / Edit

6.4.3.1 Purpose

The **Data Input** and **Data Edit** capabilities form the core of the DBMS. One of the main functions of any database system is the storage of data. The input and manipulation of data is therefore one of the main functions that a DBMS has to provide.

6.4.3.2 Data Import

In many cases, data is gathered and stored on a different database system. In order to avoid unnecessary, repetitive input, the DBMS has to provide `data import` facilities that make it possible to translate data from different database system to the SSIIS format. In many cases, these translation routines have to be customized for specific problems. The DBMS has to provide the general functionality that makes it possible to implement these customized translation procedures.

6.4.3.3 System Data

The SSIIS database structure contains many relations for information that has to be entered only at the initialization of the database and will rarely need to be revised or modified. However, input procedures and input screens have to be available to enter this system data.

The input procedures for the system data can be grouped together. This makes it possible to assign user privileges for this data entry routines in an easy manner, since this data should only be entered or modified by especially authorized users.

6.4.3.4 Vessel Data

The vessel data has to be entered for each new vessel that is entered in the system. For vessels that have sister ships that are already in the database, the data input is minimal. For a new class of vessels, the complete hull, tank, and structural information has to be entered.

The data input screens and procedures have to be designed in a form that makes it fast and efficient to enter a new vessel class into the database. The use of graphical tablets to enter the hull form has to be investigated. Clear guidelines for the preparation and use of structural drawings have to be developed in order to limit the necessity to generate specialized structural drawings only for the vessel database.

6.4.3.5 Operational Data

The input of operational data forms the core of the day-to-day data entry needs. This includes the data generated during voyages and the information from vessel surveys. Automated procedures have to be developed that limit the amount of data input.

The use of plate thickness gauging devices, that electronically store both the gauging location and the measured plate thickness, can greatly reduce the amount of data input for corrosion surveys. However, research is needed to derive a location definition that makes it possible to clearly (and with sufficient accuracy) identify the gauging locations.

6.4.4 Queries, Reports

6.4.4.1 Purpose

Although data storage is the primary function of a database, only the subsequent analysis and presentation of this data makes it necessary to store data in an electronic form. A database management system has to provide convenient and accurate reporting functions that are custom tailored to the specific needs of the database users.

It has to be possible to define database queries that can evaluate any possible combination of different database relations. In addition, standardized queries have to be provided that summarize and evaluate the most common information. These queries can then form the basis for various standard reports that are based on the database analysis. The most prominent report resulting from the SSIIS database will be the CAIP report for a vessel. A dedicated function has to be provided by the database management system, that automatically creates the core of a CAIP report, which only needs a few individual comments and summaries.

6.4.4.2 Customized Queries

The SSIIS database system contains a large amount of information about all aspects of tanker configurations and operations. Although standardized queries can be prepared for most of the basic information, the need to evaluate different contributing factors and to study the influence of all possible parameters makes it necessary to provide the possibility to create customized queries for all of the information contained in the database.

These customized queries have to be linked to a graphical output routine that makes it possible to quickly generate comprehensive charts of the query results.

6.4.4.3 CAIP Reports

The U.S. Coast Guard has implemented the requirement the preparation of Critical Area Inspection Plan (CAIP) reports for specific vessel classes. These reports are based on the results of structural surveys and are intended to summarize the structural status and failure history of a vessel.

One of the main objectives of the SSIIS project is the definition of a comprehensive CAIP report format based on the evaluation of existing reports. The documentation of this process and of the resulting CAIP report format is included in chapter 5.

The database management system of the SSIIS database has to provide a procedure that facilitates the generation of a CAIP report for a specified vessel and assures the uniformity of the different CAIP reports.

6.4.4.4 Vessel Reports

The SSIIS database is intended to contain all relevant information that results from the design, construction and operation of a vessel. Standardized reports that summarize the vessel configuration, the vessel construction, the survey and maintenance history and the service history have to be included in the DBMS. The exact extent of the standardized reports has to be determined based on the input from operators, classification societies and other potential database users.

6.4.4.5 Data Analysis

Although customized queries and the graphical representation of the query results are important tools for the documentation of the database contents and can help to determine trends, statistical data analysis is another important aspect of the DBMS.

Using the results from customized queries, statistical analyses have to be performed to determine average values, standard deviations or simply additional data properties that are based on a combination of other available data.

6.4.4.6 Inspection Summaries

For each inspection that is performed, the inspection results are included in the SSIIS database. In order to get an overview about the inspection results, it is necessary to prepare inspection summaries that list the most important inspection findings. Most of this summary can be generated automatically. The exact format of the inspection summaries has to be determined based on operator experience and on the possible use of the summaries for the generation of the CAIP reports.

6.5 Conclusions

In this chapter, the general format of the SSIIS database system has been outlined. The system consists of the actual database structure and a database management system (DBMS) that performs the administrative, data entry and reporting functions using the database structure.

The main components of the database structure have been clearly defined. For each module the necessary data relations are summarized and listed in an itemized form. Necessary additional research is clearly defined.

The different components of the DBMS are outlined. The actual development of a functional DBMS depends strongly on the development software and the actual database system that will be used. A simplified version of the DBMS will be developed as part of the SSIIS prototype development, documented in chapter 7.

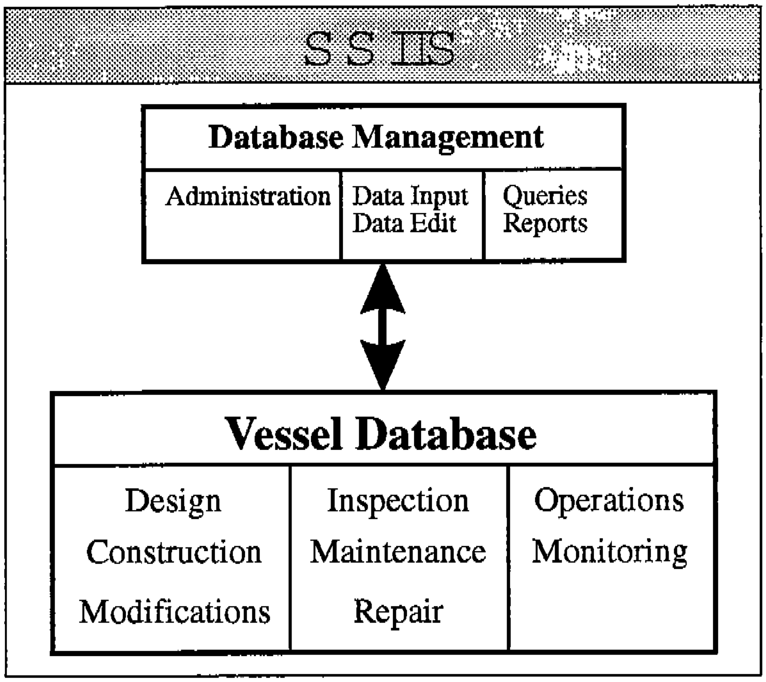


Figure 6.1: Database Overview

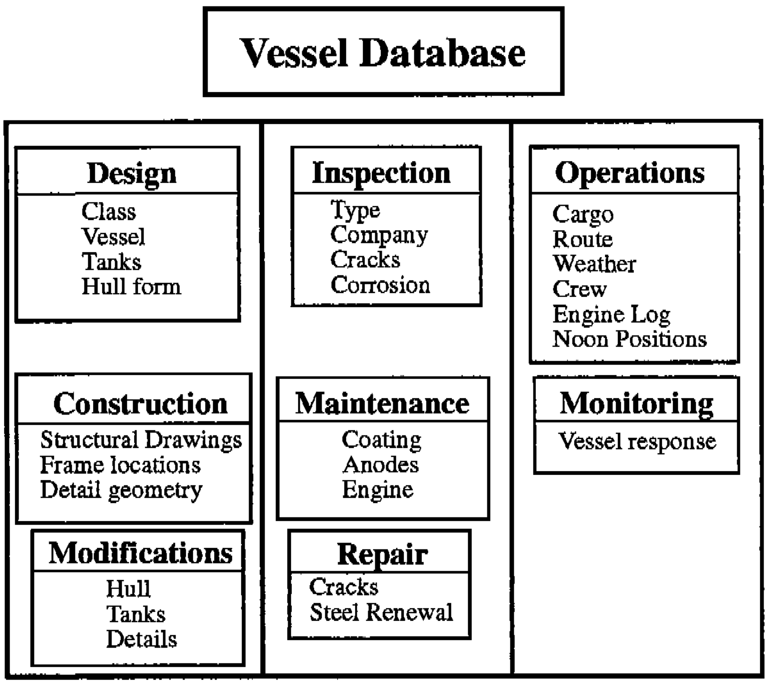


Figure 6.2: Vessel Database Structure

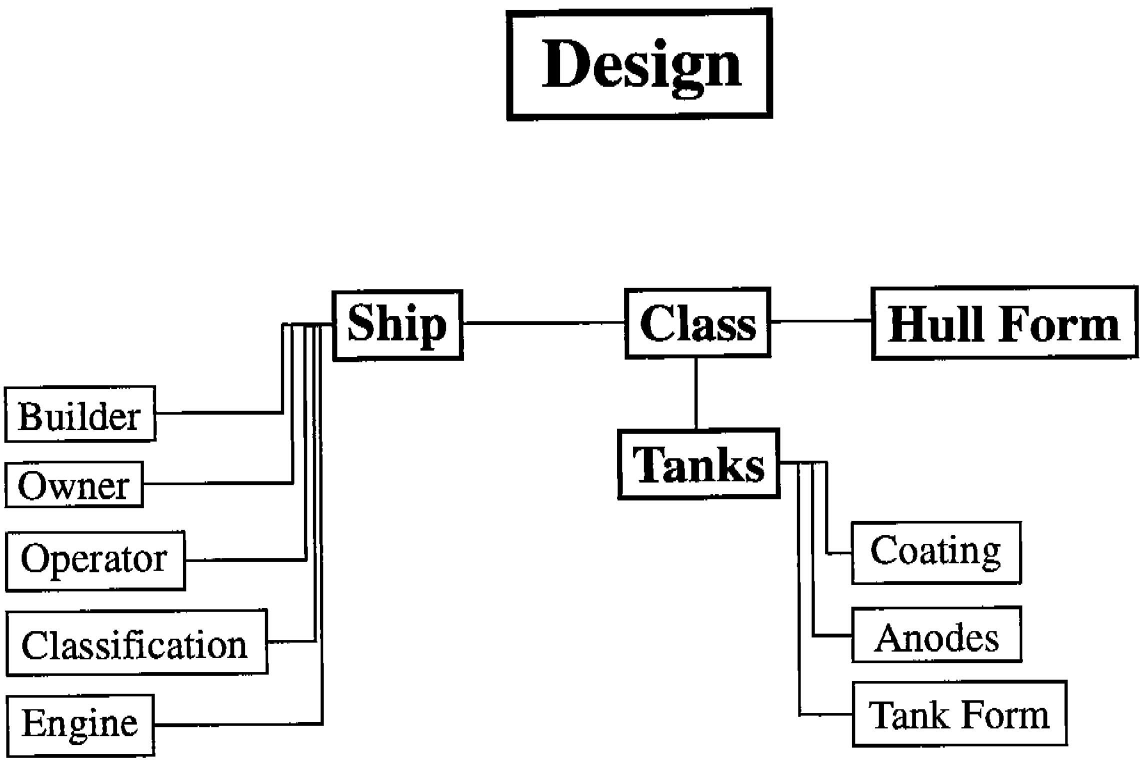


Figure 6.3: **Design** Module

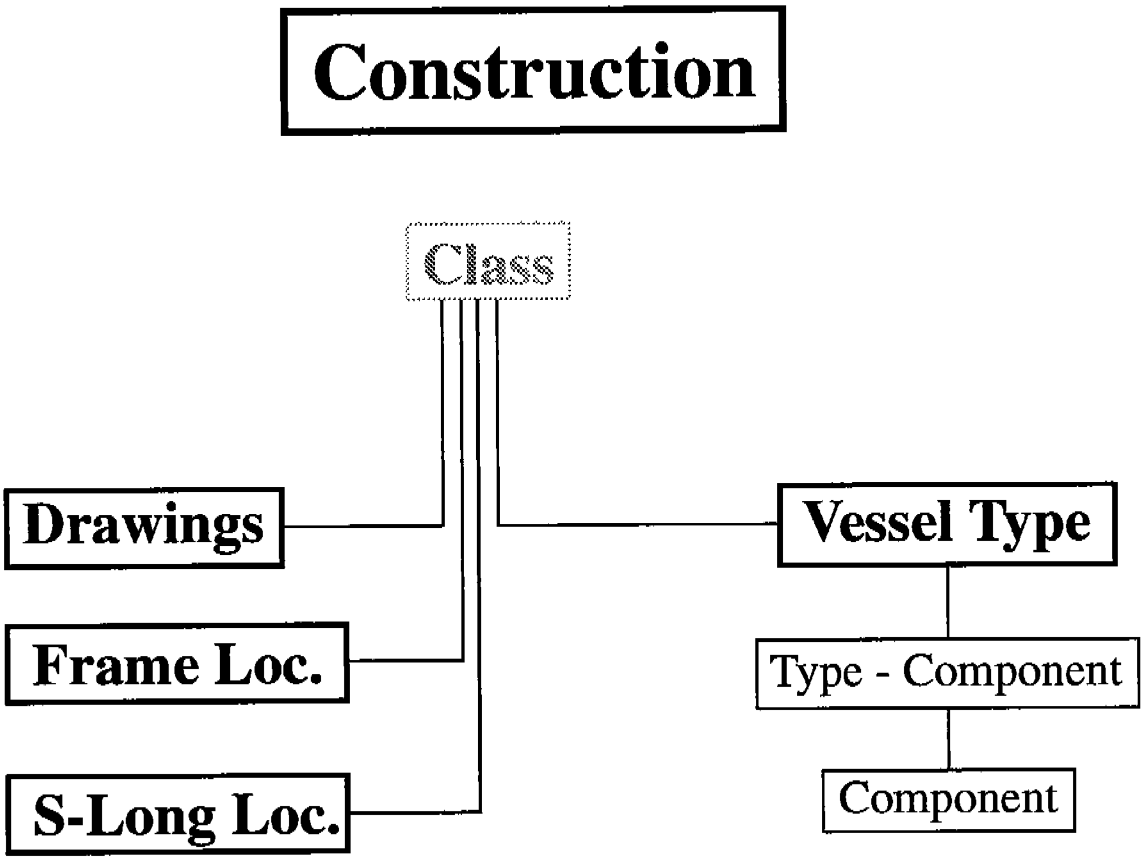


Figure 6.4: **Construction** Module

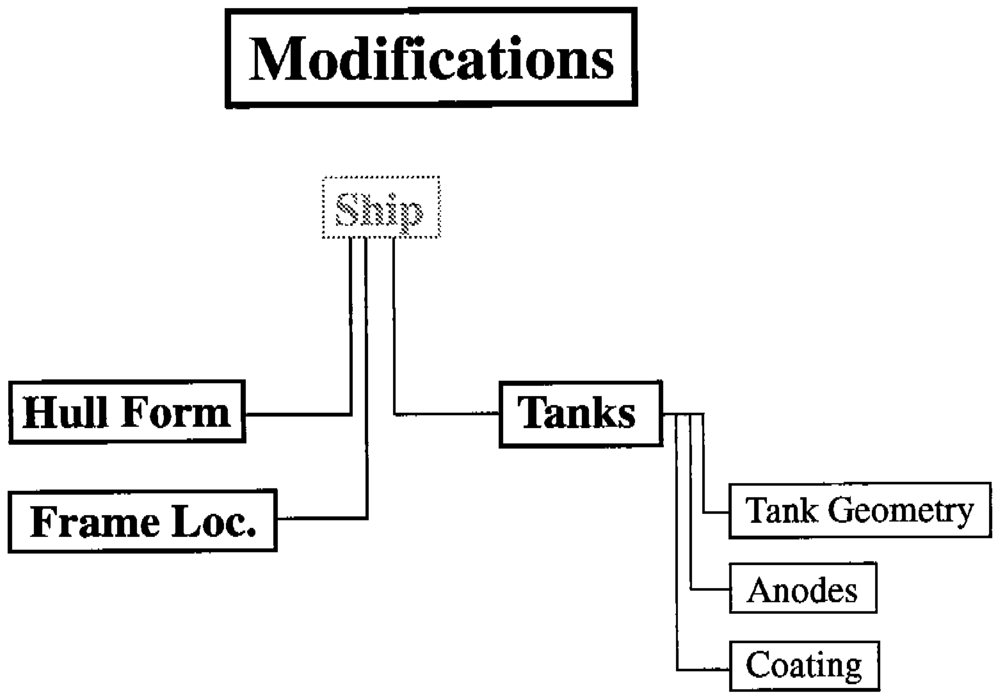


Figure 6.5: **Modification** Module

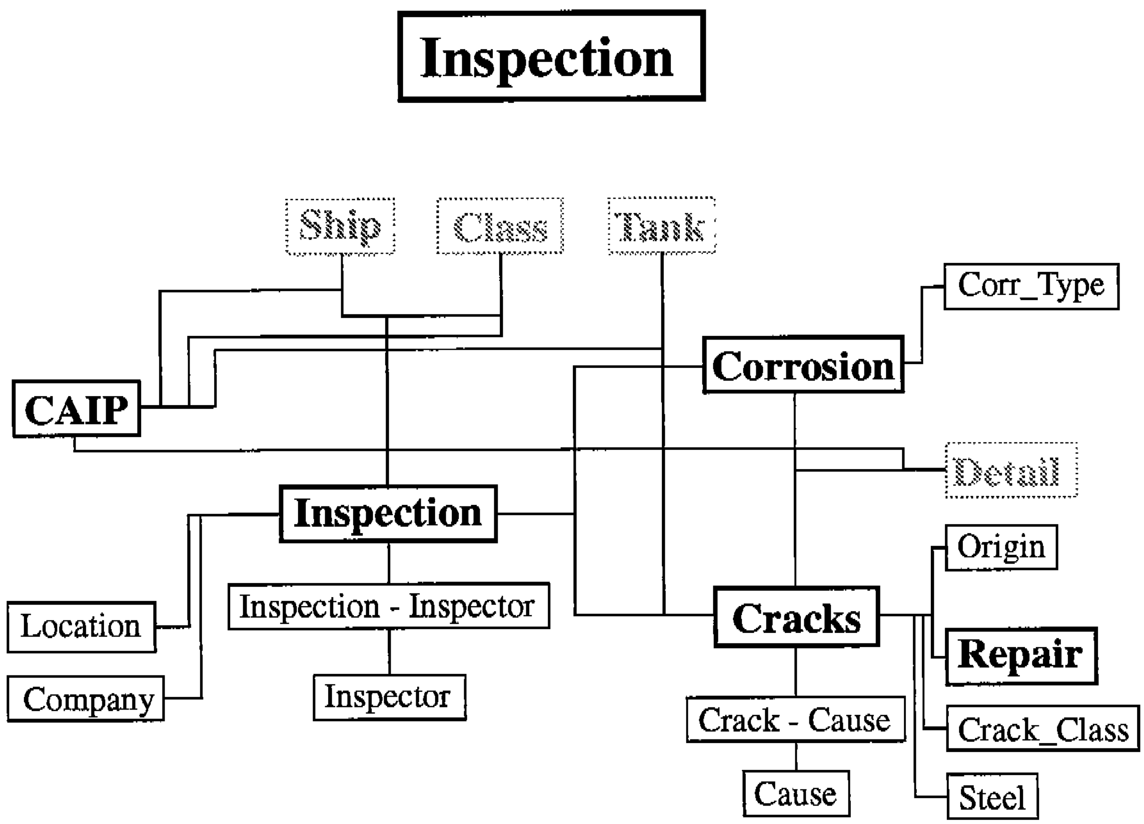


Figure 6.6: **Inspection** Module

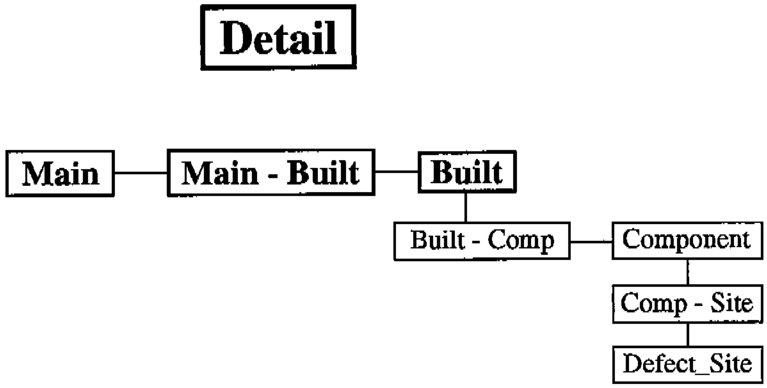


Figure 6.7: **Detail** Sub-Module

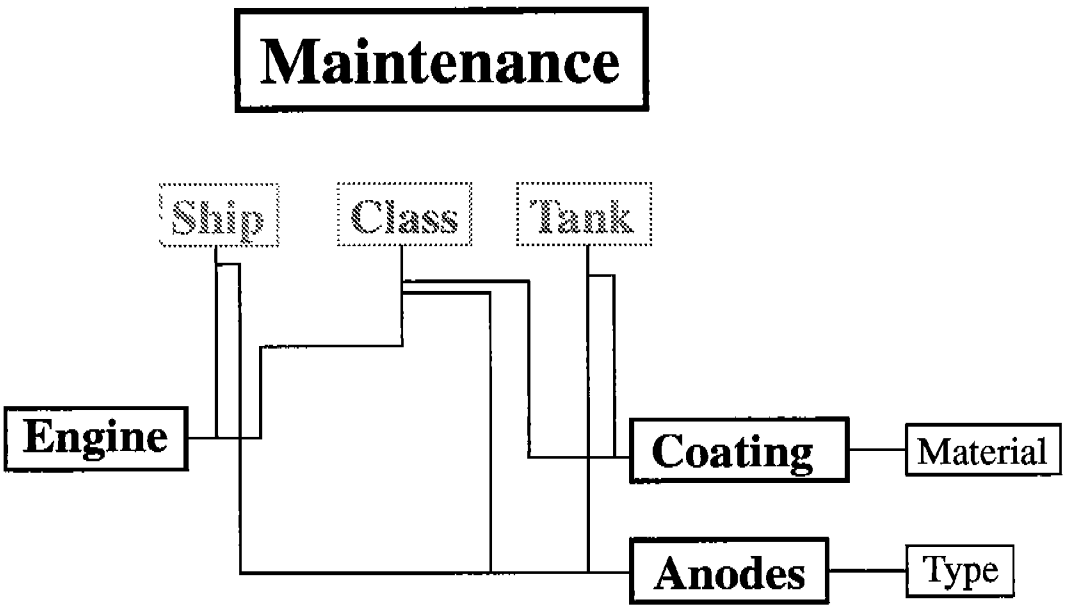


Figure 6.8: **Maintenance** Module

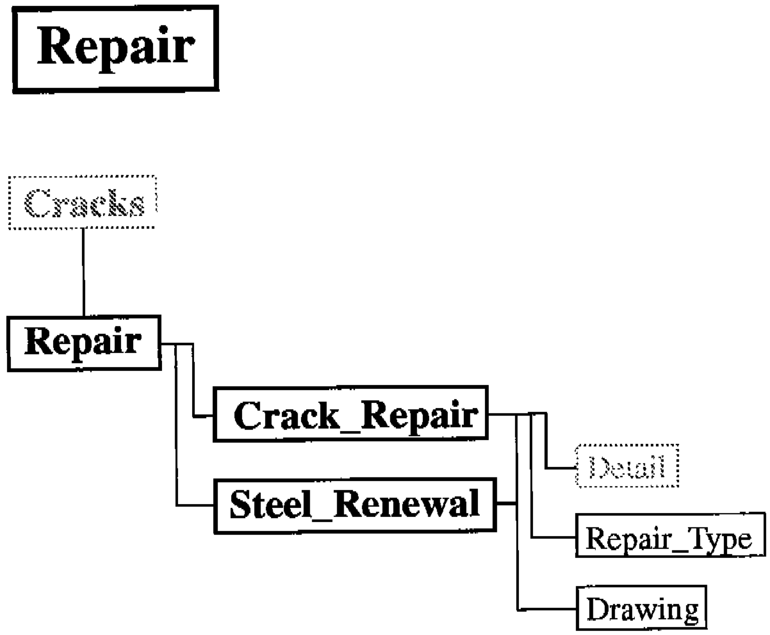


Figure 6.9: **Repair** Module

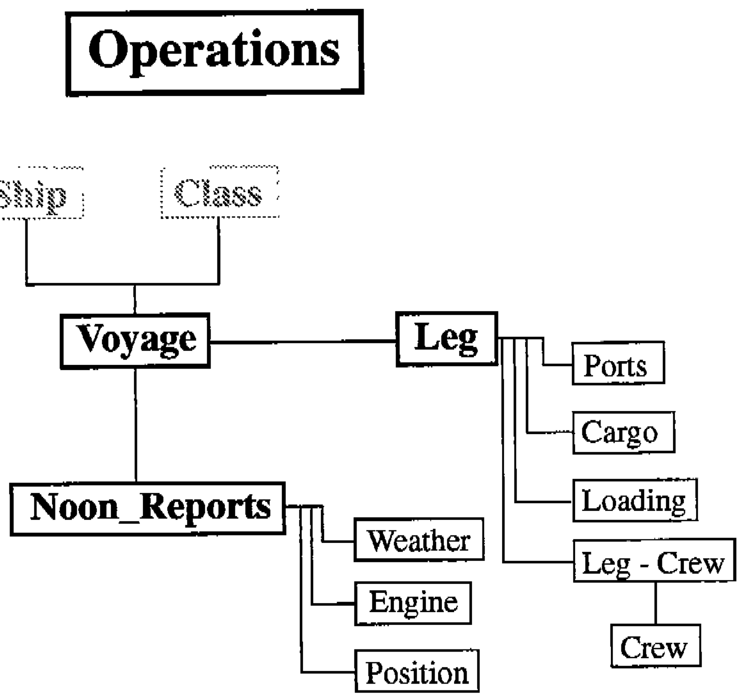


Figure 6.10: **Operations** Module

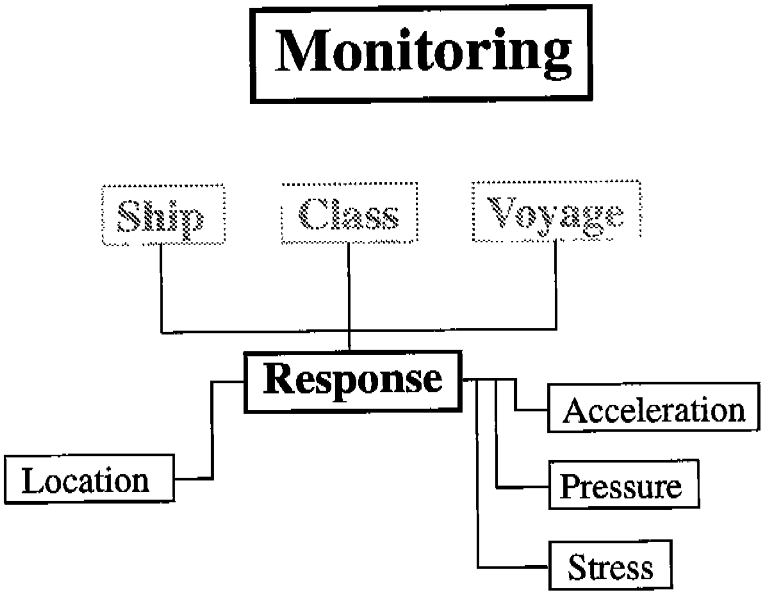


Figure 6.11: **Monitoring** Module

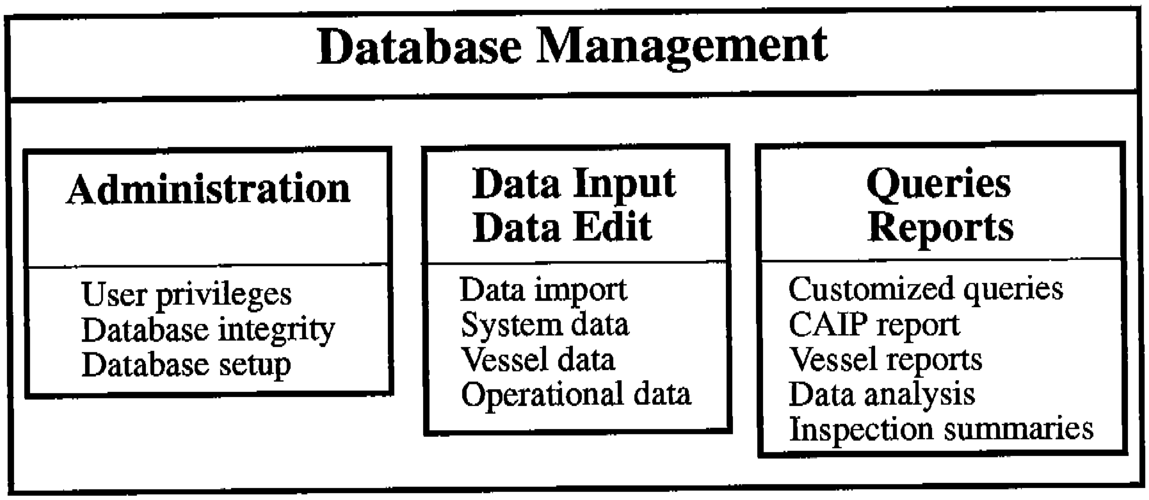


Figure 6.12: Database Management System

Chapter 7

Prototype Development

7.1 Introduction

The third main objective of the SSIIS project consists of the development of a prototype database system that demonstrates possible applications for the SSIIS database structure. This includes a functional user interface, a coherent data structure that shows the connectivity of the vessel and survey data and a reporting module that can generate standard reports and also allows it to create customized queries.

The main reason that has led to the development of the SSIIS database structure was the need for a unified methodology for the preparation of Critical Area Inspection Plan (CAIP) reports. The developed database system has to be able to produce CAIP reports based on the available vessel information and survey results. The application prototype is therefore largely focused on the CAIP report generating module.

Based on the data requirements for the CAIP reports and on the core data necessary for the general representation of the vessel structure, a reduced data structure is implemented using a relational database concept. Using this implemented data structure, a database management system is developed that documents all the main features of an effective DBMS for the SSIIS vessel database system. Included in the DBMS is a function for the generation of CAIP reports.

7.2 CAIP Reporting Requirements

Based on the CAIP report format developed in chapter 5 a CAIP report function is implemented in the prototype application. This function is intended to document the ability of the SSIIS database system to generate functional and effective CAIP reports with a minimum of user input.

Some of the desired functionality can not be implemented in the limited prototype application since no graphical representations of the structural geometry is provided.

The CAIP report is structured into the following sections:

- **Executive Summary**: The executive summary uses some information from the database in combination with user input to provide a concise and up-to-date summary.
- **Vessel Summary**: The vessel summary is completely based on database information. The general arrangement plan is supplied as a drawing instead of being based on tank and hull information directly.
- **Failure History**: The failure history is based entirely on the database information. It includes failure distributions over the shiplength and additional summaries. No graphical representations of failures are included.

- **Critical Inspection Area Summary**: The critical inspection area summary is limited due to the missing graphical failure information. The different areas are summarized and the available failure information is listed.
- **Coating History**: Since the modifications module is not implemented, the coating history is only provided as an example and is not based on database information.
- **CAIP Update**: The CAIP update information is based on company planning and is not available in the SSIIS database at the present time. Editing capabilities are therefore provided to enter the planned CAIP updating information

7.3 Prototype Data Structure

The database structure has been developed to include all ship specific information and the corrosion and crack related survey results. The format has been developed based on the database structure shown in Fig. (6.2) and on the CAIP reporting requirements outlined in section 7.2.

The database structure consists of several *relations*. The theory of relational databases requires that each *record* in a *relation* is uniquely defined by a *key*. This *key* can consist of a combination of data items, e.g. the *key* of the **Tank** relation is defined by the `Class_ID`, the `Tank_#` and the `Tank_Loc`.

In the following sections each relation is described in detail including the *key*, the data items in the body of the relation and the links to other relations. The sections are named according to the relation name. Each data item that has a # in the first column is linked to an other relation.

7.3.1 Relation: VESSEL

The relation **VESSEL** contains the ship specific information for the ships entered in the database. This includes only information that is only relevant for one ship. All information that is identical for a class of ships is contained in the **CLASS** relation.

VESSEL			
	Vessel_ID	Num	4.0
	Class_ID	Num	4.0
	Name	Char	30
#	Owner	Char	20
#	Operator	Char	20
#	Classification	Char	4
	Delivery	Date	8
#	Shipyard	Char	20
	Hull_No	Num	5.0

Key: The key of this relation is the `Vessel_ID`. This is simply a four digit number. Each entry in the **VESSEL** relation has to have a unique number.

Links: Four data items are linked to an other relation:

Data Item		Linked Relation
Class_ID	———	**CLASS**
Classification	———	**CLASSIF**
Shipyard	———	**YARD**
Owner	———	**COMPANY**
Operator	———	**COMPANY**

7.3.2 Relation: CLASSIF

The relation **CLASSIF** contains the information regarding the classification society that has classified the ship. Using this relation instead of entering the name of the classification society directly, reduces the amount of input and also avoids the possibility of an input error by misspelling the name. This relation contains of a character code word, the name of the classification society and the country.

CLASSIF			
	Classif_ID	Char	4
	Name	Char	20
	Country	Char	20

Key: The key of this relation is the `Classif_ID`. This key is a four character code word. This has been chosen since most classification societies are known under an abbreviated form of their name.

Links: None of the data items is linked to another relation.

7.3.3 Relation: COMPANY

The relation **COMPANY** contains the information regarding the company that owns and/or operates a vessel. Using this relation instead of entering the name of the owner/operator directly, reduces the amount of input and also avoids the possibility of an input error by misspelling the name. This relation contains of a character code word, the name of the company and the address.

CLASSIF			
	Company_ID	Num	4
	Name	Char	20
	Address	Char	40

Key: The key of this relation is the `Company_ID`. This is a integer value that has to be unique for each company.

Links: None of the data items is linked to another relation.

7.3.4 Relation: YARD

The relation **YARD** contains the information regarding the shipyard that built a vessel. Using this relation instead of entering the name of the shipyard directly, reduces the amount of input and also avoids the possibility of an input error by misspelling the name. This relation contains of a character code word, the name of the shipyard and the address.

YARD			
	Yard_ID	Num	4
	Name	Char	20
	Address	Char	40

Key: The key of this relation is the `Yard_ID`. This is a integer value that has to be unique for each shipyard.

Links: None of the data items is linked to another relation.

7.3.5 Relation: CLASS

The relation **CLASS** contains the information that is specific for a class of vessels. This includes the main dimensions, the construction type and the propulsion system.

CLASS		
Class_ID	Num	4.0
Class_Name	Num	4.0
LOA	Num	4.3
LBP	Num	4.3
Depth	Num	3.3
Beam	Num	3.3
Draft	Num	3.3
Summer_DWT	Num	7.0
Double_Bot	Log	1
Double_Side	Log	1
LBhd_Pos	Num	2.3
Turbines	Log	1
Cylinders	Num	2.0
No_Blades	Num	2.0
Screw_Rpm	Num	3.0
Speed_Load	Num	2.2
Speed_Ball	Num	2.2
Thrusters	Log	1
Bilge_K	Log	1

Key: The key of this relation is the `Class_ID`. This is a integer value that has to be unique for each class.

Links: None of the data items is linked to another relation.

7.3.6 Relation: TANK

The relation **TANK** contains information for each tank for each ship. This information includes size, location, contents and tank washing. This information is very detailed, in order to be able to include all relevant information for a vessel.

The tank information is class specific. Tanks for one class of ships are usually identified by a number and the location with respect to the width of the ship (Port, Center and Starboard). Therefore the *key* for the **TANK** relation consists of three items, *Class_ID, Tank_#* and *Width_Loc*.

TANK			
	Class_ID	Num	4.0
	Tank_#	Num	2.0
	Width_Loc	Char	1
	Length	Num	4.3
	Beam	Num	3.3
	Depth	Num	3.3
	Capacity	Num	6.1
#	Frame_aft	Num	3.0
#	Frame_for	Num	3.0
	Type_ID	Char	1
#	Corr_Protect	Char	2
	Cargo_Heated	Char	1
	IGS_Sulphur	Num	2.1
	Tank_Washing	Char	1
	Wash_Medium	Char	1
	Wash_Freq	Num	2.0

Key: This key of this relation consists of three data items, the `Class_ID`, `Tank_#` and `Width_Loc`. The combination of these three items has to be unique for each record.

Links: Four data items are linked to an other relation:

Data Item		Linked Relation
Frame_Aft	————————	**LENGTH**
Frame_For	————————	**LENGTH**
Type_ID	————————	**TANKTYPE**
Corr_Protect	————————	**CORR_PRO**

7.3.7 Relation: TANKTYPE

The relation **TANKTTYPE** contains the information regarding the type of tank. This relation allows it to use a code word for the type of tank and link it to a description. It also ensure that no invalid tank type can be entered.

TANKTYPE			
	Type_ID	Char	1
	Description	Char	20

Key: The key of this relation is the `Type_ID`. This key is a one character code word.

Links: None of the data items is linked to another relation.

7.3.8 Relation: CORR_PRO

The relation **CORR_PRO** contains the information regarding the corrosion protection system. The code word for the corrosion protection system can be linked to a description.

CORR_PRO		
Corr_Pro_ID	Char	1
Description	Char	20

Key: The key of this relation is the `Corr_Pro_ID`. This key is a one character code word.

Links: None of the data items is linked to another relation.

7.3.9 Relation: SIDE

The relation **SIDE** contains the information regarding the width location within the vessel. The code word of the `Width_Loc` is assumed to take five different values, which allows it to divide the width of the ship in five parts. These five divisions can be related to the tank location (port, center or starboard) and the ship side (port or starboard).

SIDE		
Width_Loc	Char	2
Tank_Loc	Char	1
Side	Char	1

Key: The key of this relation is the `Width_Loc`. This key is a two character code word.

Links: None of the data items is linked to another relation.

7.3.10 Relation: LENGTH

The relation **LENGTH** contains the information regarding the longitudinal positions for each class of ships. This relation links the frame numbers to the distance from the Aft perpendicular, which allows it enter information according to the frame number and still be able to obtain the distance from the aft perpendicular. This can be used to non-dimensionalize the longitudinal position.

This relation requires a key that consists of two data items, the `Class_ID` and the `Frame_#`.

LENGTH		
Class_ID	Num	4.0
Frame#	Num	3.0
Dist_AP	Char	4.3

Key: The key of this relation is the `Class_ID` and the `Frame#`. The combination of these two data items has to be unique for each record.

Links: None of the data items is linked to another relation.

7.3.11 Relation: INSPECTION

The relation **INSPECTION** contains the information regarding the inspection. Each entry specifies one inspection for a particular ship. Therefore two items form the key for this relation.

The **INSPECTION** relation contains for each inspection information about the date, location, company and technicians.

INSPECTION			
	Vessel_ID	Num	4.0
	Inspection_ID	Char	5
	Start_Date	Date	8
	End_Date	Date	8
#	Location	Char	20
#	Company	Char	20
	Ut_Tech1	Char	20
	Ut_Tech2	Char	20
	Ut_Equip	Char	20

Key: This key of this relation consists of two data items, the `Vessel_ID` and the `Inspection_ID`. This means that the combination of the Vessel_ID and the Inspection_ID has to be unique for each record.

Links: Two data items are linked to an other relation:

Data Item	Linked Relation
Location	**PORT**
Company	**INSP_COMPANY**

7.3.12 Relation: INSP_COMPANY

The relation **INSP_COMPANY** contains the information regarding the company that performed the inspection. Using this relation instead of entering the name of the inspection company directly, reduces the amount of input and also avoids the possibility of an input error by misspelling the name. This relation contains of a character code word, the name of the company and the address.

CLASSIF			
	Company_ID	Num	4
	Name	Char	20
	Address	Char	40

Key: The key of this relation is the `Company_ID`. This is a integer value that has to be unique for each company.

Links: None of the data items is linked to another relation.

7.3.13 Relation: CRITICAL_AREA

The relation **CRITICAL_AREA** contains the information regarding the defined critical inspection areas for a vessel. The relation includes the vessel, class information and tank information for each critical inspection area.

	CRITAREA		
	CritArea	Num	10.0
#	Vessel_ID	Num	4.0
#	Class_ID	Num	4.0
#	Tank#	Num	2.0
#	Tank_Pos	Char	1
	Description	Char	60

Key: The key of this relation is the `CritArea`, `Vessel_ID`, `Class_ID`, `Tank#` and `Tank_Pos`.

Links: None of the data items is linked to another relation.

7.3.14 Relation: CORROSION

The relation **CORROSION** contains the information for all corrosion wastage incidents. This includes the detailed description of the location, the corrosion type and the plate thickness information.

As can be seen in the following table, a large portion of the data items in the **CORROSION** relation are linked to other relations. Only the more or less arbitrary information regarding the location and the plate thickness are input directly.

	CORROSION		
	Corr_Count	Num	10.0
#	Vessel_ID	Num	4.0
#	Tank#	Num	2.0
#	Tank_Pos	Char	1
#	Width_Loc	Char	2
#	Frame#	Num	3.0
	Height	Num	2.3
	Width	Num	2.3
#	Inspection_ID	Char	5
#	Corr_Type	Char	1
#	Corr_ID	Char	10
	Wastage	Num	2.1
	Thick_Orig	Num	2.1
	Thick_Rest	Num	2.1

Key: This key of this relation is the data item `Corr_Count`. This is an integer value that has to be unique for each record.

Links: Eight data items are linked to another relation:

Data Item		Linked Relation
Vessel_ID	————	**VESSEL**
Tank#	————	**TANK**
Tank_Pos	————	**TANK_POS**
Width_Loc	————	**SIDE**
Frame#	————	**LENGTH**
Inspection_ID	————	**INSPECTION**
Corr_Type	————	**CORRTYPE**
Corr_ID	————	**CORRID**

7.3.15 Relation: CORRID

The relation **CORRID** contains the information regarding the exact description of the corrosion incident. This includes the description of the structural detail, where the corrosion has been measured.

CORRID			
	Corr_ID	Char	5
#	Corr_1	Char	3
#	Corr_2	Char	3

Key: The key of this relation is the `Corr_ID`. This key is a ten character code word.

Links: Three data items are linked to an other relation:

Data Item		Linked Relation
Corr_1	————	**MEMBER1**
Corr_2	————	**MEMBER2**

7.3.16 Relation: CRACK

The relation **CRACK** contains the information necessary for the documentation of cracks. This includes the detailed description of the location, the crack type and some repair information.

As can be seen in the following table, a large portion of the data items in the **CRACK** relation are linked to other relations. Only the more or less arbitrary information regarding the location and the plate thickness are input directly.

	CRACK		
	Crack_Count	Num	6.0
#	Vessel_ID	Num	4.0
#	Tank#	Num	2.0
#	Width_Loc	Char	2
#	Frame#	Num	3.0
	Dist_Frame	Num	2.3
	Height	Num	2.3
	Width	Num	2.3
#	Inspection_ID	Char	5
#	Crack_ID	Char	15
	Length	Num	2.3
#	Class	Num	1.0
#	Steel	Char	3
	Rep_Date	Date	8
#	Rep_Type	Char	3
#	Cause_ID	Char	6
	Comment	Char	20

Key: This key of this relation is the data item `Crack_Count`. This is an integer value that has to be unique for each record.

Links: Eleven data items are linked to an other relation:

Data Item		Linked Relation
Vessel_ID	——————	**VESSEL**
Tank#	——————	**TANK**
Width_Loc	——————	**SIDE**
Frame#	——————	**LENGTH**
Inspection_ID	——————	**INSPECTION**
Crack_ID	——————	**CRACKTYPE**
Class	——————	**CLASS**
Steel	——————	**STEEL**
Rep_Type	——————	**REP_TYPE**
Cause_ID	——————	**CAUSE**

7.3.17 Relation: CRACKTYPE

The relation **CRACKTYPE** contains the information regarding the exact crack type. This includes primarily the description of the exact structural detail and the crack location on the detail.

	CRACKTYPE		
	Crack_ID	Char	16
#	Crack_1	Char	3
#	Crack_2	Char	3
#	At_1	Char	3
#	At_2	Char	3
#	Crack_Start	Char	3

Key: The key of this relation is the `Crack_ID`. This key is a six character code word.

Links: Six data items are linked to an other relation:

Data Item		Linked Relation
Crack_1	————————	**MEMBER1**
Crack_2	————————	**MEMBER2**
At_1	————————	**MEMBER1**
At_2	————————	**MEMBER2**
Crack_Start	————————	**START**

7.3.18 Relation: TANK_POS

The relation **TANK_POS** contains the information regarding the horizontal position in the tank. The corrosion database format divides each tank into three zones, forward , middle, aft. This relation contains the code word for the position and a description.

TANK_POS			
	Tank_Pos_ID	Char	1
	Description	Char	15

Key: The key of this relation is the `Tank_Pos_ID`. This key is a one character code word.

Links: None of the data items is linked to another relation.

7.3.19 Relation: CORRTYPE

The relation **CORRTYPE** contains the information regarding the type of corrosion. In the present state of the corrosion database format three types of corrosion are considered (general corrosion, pitting, grooving). This relation contains the code word for the corrosion type and a description.

CORRTYPE			
	CorrType_ID	Char	1
	Description	Char	15

Key: The key of this relation is the `CorrType_ID`. This key is a one character code word.

Links: None of the data items is linked to another relation.

7.3.20 Relation: DETAIL

The relation **DETAIL** contains the information regarding the structural configuration for a detail. In the simplified implementation of the prototype development this relation replaces the submodule **Detail** that has been defined in chapter 6. The detail is defined with a text based definition.

DETAIL			
	Detail_ID	Char	3
	Description	Char	600

Key: The key of this relation is the `Detail_ID`. This key is an integer value.

Links: None of the data items is linked to another relation.

7.3.21 Relation: START

The relation **START** contains the information regarding the location of the start of a crack. This information is necessary for a detailed analysis of failure probabilities and allows it to clearly distinguish cracks in the same type of detail, but starting at different points.

START			
	Start_ID	Char	3
	Description	Char	20

Key: The key of this relation is the `Start_ID`. This key is a three character code word.

Links: None of the data items is linked to another relation.

7.3.22 Relation: CRACK_CL

The relation **CRACK_CL** contains the information regarding the class of a crack. The definition is based on the system of crack classes established by the U.S. Coast Guard.

CRACK_CL			
	Crack_Cl_ID	Num	1.0
	Description	Char	20

Key: The key of this relation is the `Crack_Cl_ID`. This key is a one digit integer.

Links: None of the data items is linked to another relation.

7.3.23 Relation: STEEL

The relation **STEEL** contains the information regarding the steel type of a detail. This definition is intended to allow the distinction between mild steel and high tensile steel (HTS).

STEEL			
	Steel_ID	Char	3
	Description	Char	20

Key: The key of this relation is the `Steel_ID`. This key is a three character code word.

Links: None of the data items is linked to another relation.

7.3.24 Relation: REPAIR

The relation **REPAIR** contains the information regarding the type of repair that has been used. This can include e.g. rewelding, redesign, etc. .

REPAIR			
	Rep_ID	Char	3
	Description	Char	20

Key: The key of this relation is the `Rep_ID`. This key is an integer value.

Links: None of the data items is linked to another relation.

7.3.25 Relation: CAUSE

The relation **CAUSE** contains the information regarding the cause for a crack. This cause can be a combination of up to three contributors.

CAUSE			
	Cause_ID	Char	6
#	Primary	Char	2
#	Secondary	Char	2
#	Tertiary	Char	2

Key: The key of this relation is the `Cause_ID`. This key is a three character code word.

Links: Three data items are linked to an other relation:

Data Item		Linked Relation
Primary	————	**CAUSE_DEF**
Secondary	————	**CAUSE_DEF**
Tertiary	————	**CAUSE_DEF**

7.3.26 Relation: CAUSE_DEF

The relation **CAUSE_DEF** contains the information regarding the possible contributors for the cause of a crack. This can include *fatigue, corrosion, damage, etc.* .

CAUSE_DEF			
	Cause_Key	Char	2
	Description	Char	20

Key: The key of this relation is the `Cause_Key`. This key is a two character code word.

Links: None of the data items is linked to another relation.

7.3.27 Relation: LEG

The relation **LEG** contains the information regarding to the individual legs on a voyage for a vessel. For each leg, the arrival and departure port, the cargo, the loading conditions and the crew are listed.

	VOYAGE		
	Leg_ID	Num	6.0
#	Vessel_ID	Num	4.0
#	Class_ID	Num	4.0
	Start_Date	Date	8
	End_Date	Date	8
#	Departure_Port	Num	3
#	Destination_Port	Num	3
#	Cargo_ID	Num	3
	Ballast_Type	Char	1
	Ballast_Cond	Char	1
	Ballast_Temp	Num	3.0
	Ballast_Humid	Num	2.1

Key: The key of this relation is the `Leg_ID`, the `Vessel_ID` and the `Class_ID`. The `Leg_ID` is an integer value.

Links: Three data items are linked to an other relation:

Data Item		Linked Relation
Departure_Port	———————	**PORTS**
Destination_Port	———————	**PORTS**
Cargo_ID	———————	**CARGO**

7.3.28 Relation: PORTS

The relation **PORTS** contains the information regarding the different ports on a vessel route. This relation is again particularly useful since only a very limited number of ports exist.

	PORTS		
	Ports_ID	Num	3
	Name	Char	20
	Country	Char	20
	Longitude	Char	20
	Latitude	Char	20
	Description	Char	15

Key: The key of this relation is the `Ports_ID`. This key is an integer value.

Links: None of the data items is linked to another relation.

7.3.29 Relation: CARGO

The relation **CARGO** contains the information regarding the type of cargo that is transported. This relation is again particularly useful since only a very limited number of distinct possibilities are available as cargo.

	CARGO		
	Cargo_ID	Char	1
	Description	Char	15
	Cargo_Sulphur	Num	2.1
	Cargo_Water	Num	2.1
	Cargo_Waxy	Char	1

Key: The key of this relation is the `Cargo_ID`. This key is a one character code word.

Links: None of the data items is linked to another relation.

7.4 Implementation

7.4.1 System Requirements

The SSIIS database has been implemented based on the data structure documented in section 7.3 using a commercially available database development software, `Microsoft Access 1.1` [1] . The software requires an IBM compatible PC with a minimum of 2MB of RAM (4MB recommended) running Microsoft Windows 3.1.

Usage information for `Microsoft Access 1.1` can be found in [26], [30]. A language reference is contained in [25]. Information about programming in `Microsoft Access Basic` is contained in [33].

7.4.2 General Design

The implementation of the working model is to a large extent based on the use of *Forms*, *Queries*, *Tables* and *Macros*. The datastructure has been implemented using the table definition procedures of `Access`. Data relations have been established between the tables that ensure referential integrity.

With the datastructure implemented, the database management has been developed based on the requirements outlined in section 6.4 This includes administration, data entry and reporting / query capabilities. The database management system uses a menu based structure to implement these capabilities.

Some advanced features are not completely implemented. The corresponding menu items are provided to document the general setup of the database management system. A massage is displayed that states that the function is not implemented.

The database is started by selecting the button on the Windows desktop. A main data screen is displayed that contains five different menu items. The main data screen is shown in Fig. (7.1). The following five menu items are available:

- **Administration**: This leads to a menu that contains all the administrative functions.
- **Data Entry**: All data entry functions are accessed from this menu item.

[1]Microsoft Access 1.1, Relational Database Management System for Windows, Microsoft Corporation, 1992

- **Report / Query**: All reporting and query functions are in the menu that is displayed if this item is selected.
- **Database Window**: This item allows it to use the advanced features of `Access`.
- **Exit**: The database session is terminated.

The software provides complete data entry capabilities. Data for all tables can be entered. In addition, general reporting capabilities are outlined including the ability to generate CAIP reports for individual vessels.

7.4.3 Administration

As outlined in section 6.4 the SSIIS database management system has to have administrative functions that allow it to change system settings, manage user privileges and maintain data integrity. These functions are grouped in a selection screen that is accessed by selecting the **`Administration`** button on the **Main** screen. The administration screen is shown in Fig. (7.2).

7.4.4 Data Entry

Data entry screens have been designed for all tables. The data entry is organized in a screen with 4 different menu items, which is accessed from the main menu by selecting (double-clicking) the `Enter Data` button. The data entry selection screen is shown in Fig. (7.3). It contains the following four menu items:

- **System Data**: This identifies data that is necessary background information that has to be available in the database to ensure data integrity. The selection screen for the entry of the system data is shown in Fig. (7.4). The individual data entry screens for the system data are described in appendix E.1.
- **Vessel**: All vessel related data is input in this menu. This includes the vessel, class, tank data. The selection screen for the entry of the vessel data is shown in Fig. (7.5). The individual data entry screens for the vessel data are described in appendix E.2.
- **Inspection**: All inspection data entry is accessed from this menu item. This includes the actual inspection location, date and company. In addition, crack and corrosion survey results entry screens can be accessed from this menu screen. The selection screen for the entry of the inspection data is shown in Fig. (7.6). The individual data entry screens for the inspection data are described in appendix E.3.
- **Operations**: The information regarding vessel operations can be entered based on this menu item. This includes the individual voyage legs, the monitoring information and the ports. The selection screen for the entry of the operations data is shown in Fig. (7.7). The individual data entry screens for the operations data are described in appendix E.4.

7.4.5 Reports / Queries

The third selection on the **Main** screen leads to the menu for the different reporting functions. This menu is shown in Fig. (7.8). It contains the following four menu items:

- **Vessel Summary**: Based on the selection of a vessel from the list of available vessels, a summary of this vessel is provided, including general arrangement, vessel particulars and a tank summary.
- **Fracture Summary**: For a selected vessel and inspection date, a summary of fractures is provided. This includes the distribution of fractures over the shiplength, a summary of the most frequent crack locations and a summary of the repair status.

- **Corrosion Summary**: The corrosion summary contains a three-dimensional view of the vessel with colour-coded gauging location identifying the relative wastage.
- **CAIP Report**: The CAIP report for a selected vessel follows the format outlined in chapter 5. It consists of an executive summary, a vessel summary, a fracture summary for critical inspection areas and a coating summary.

7.4.6 Summary

A prototype application of the SSIIS database system has been developed and implemented based on the data structure and database management requirements that are outlined in chapter 6.

The overall structure of the SSIIS database is clearly defined including all necessary database management components. Data entry screens and procedures are provided for all tables that are included in the database.

The administrative functions are indicated, but not effectively implemented since they are only necessary for a commercial, multi-user application. The selection screen for the administrative functions identifies the different functional requirements.

Four different reporting functions are indicated in the reporting selection screen. This includes vessel, crack, corrosion and CAIP reporting functions. These reporting functions are partially implemented to document the capabilities of the SSIIS database system with respect to the generation of CAIP reports.

The developed application prototype can be used as a starting point for a commercial development or a more thorough implementation as part of a follow-up university project. Most functions have to be improved in order to make them more robust and to prohibit data entry errors.

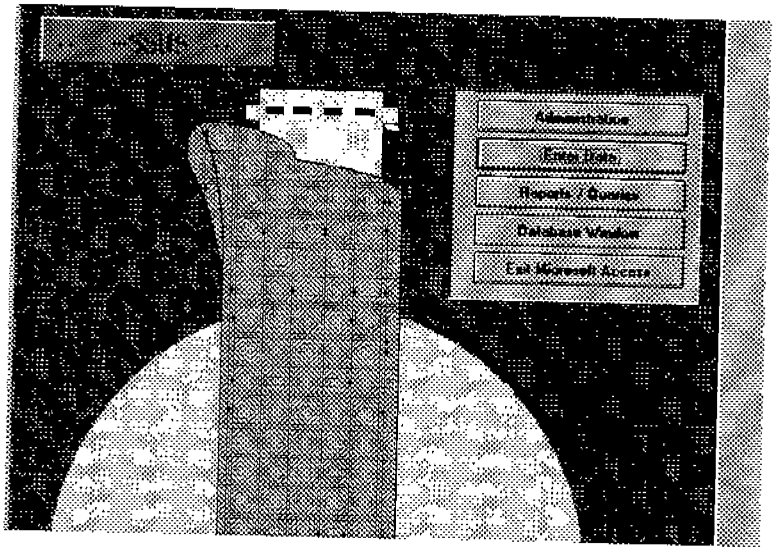


Figure 7.1: Main Database Screen

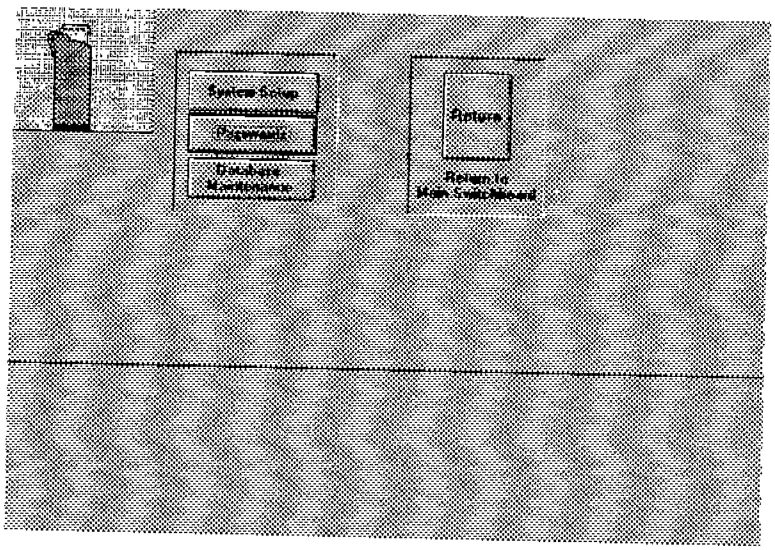


Figure 7.2: Administration Selection Screen

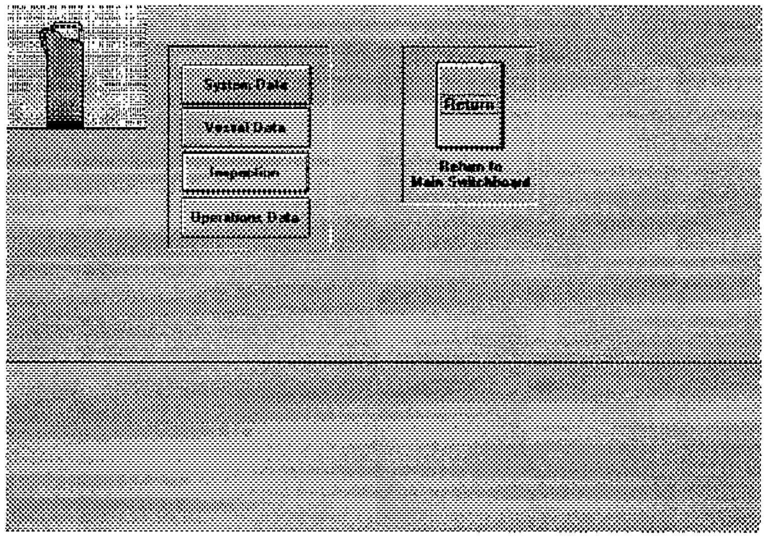


Figure 7.3: Data Entry Selection Screen

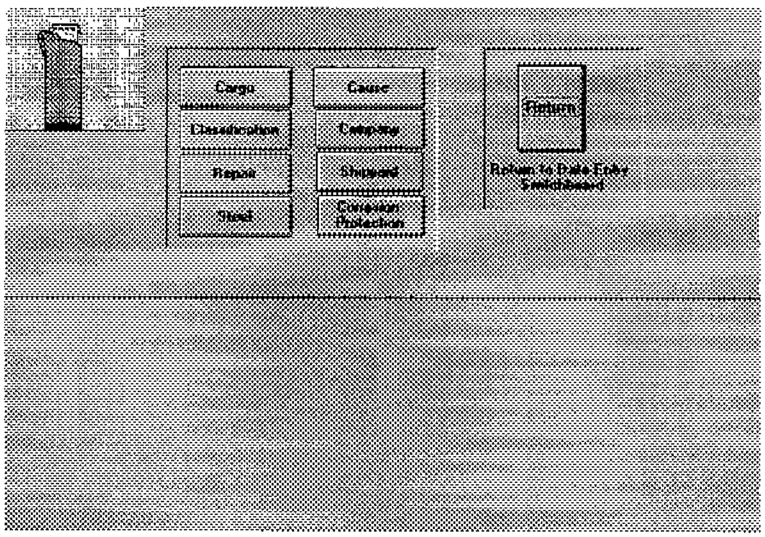


Figure 7.4: System Data Entry Screen

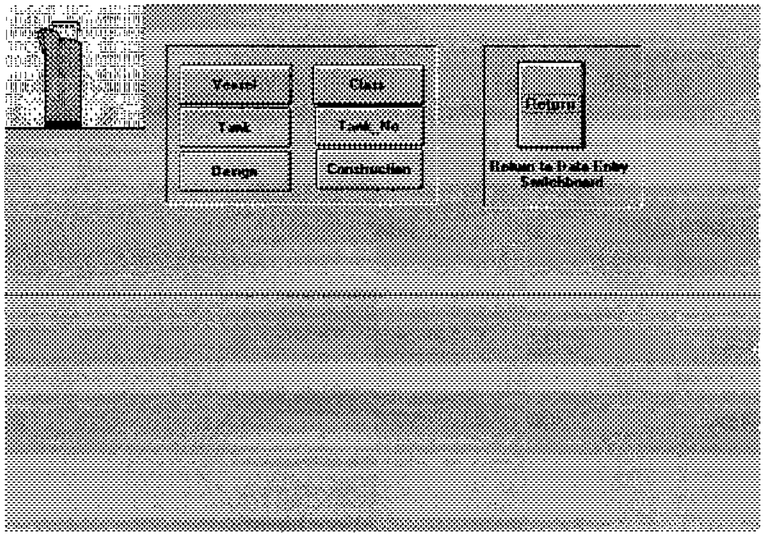


Figure 7.5: Vessel Data Entry Screen

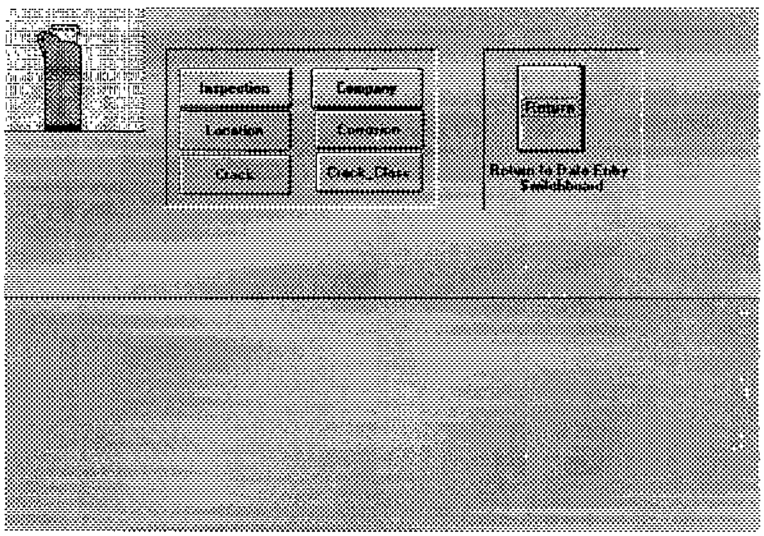


Figure 7.6: Inspection Data Entry Screen

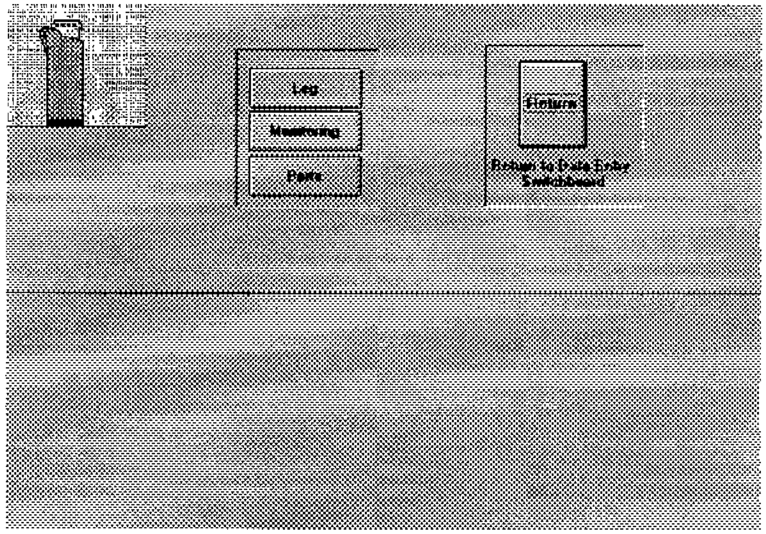


Figure 7.7: Operations Data Entry Screen

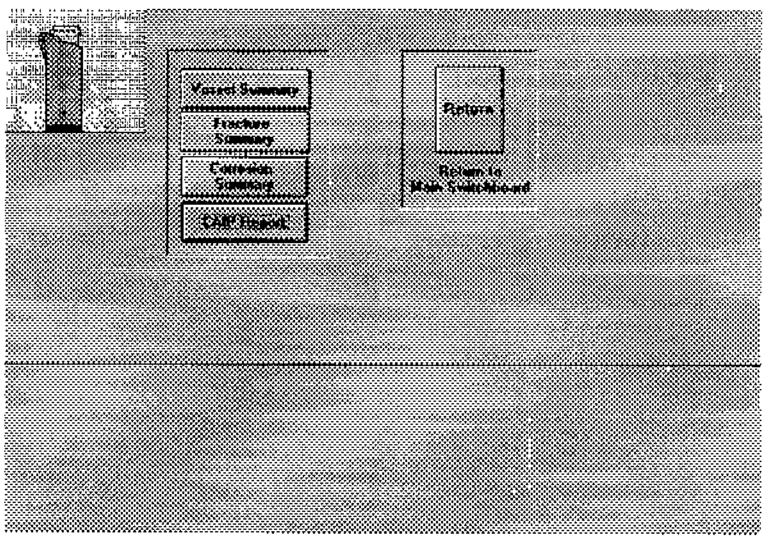


Figure 7.8: Reports Menu Screen

Chapter 8

Conclusion and Recommendations

8.1 Conclusions

Within the SSIIS project a general database system for oil tankers has been developed. The development was based on a detailed review of existing database systems, a definition of reporting requirements for Critical Area Inspection Plan (CAIP) reports and a survey of the data needs of existing vessel analysis software.

The analysis of existing database software includes the most important software applications that are currently used. Sufficient background information about the general design of a vessel database has been obtained from the analysis of the existing software systems. Several of the existing systems can be adapted to produce CAIP reports that meet the format requirements developed in chapter 5.

Existing CAIP reports have been reviewed with the intent to develop an improved report format that combines a high information contents with a simplified, graphical representation of failure trends. The review of the existing CAIP reports has shown several different report formats that varied widely in format and data contents. Based on this review, a new report format has been developed with the aim to unify the CAIP reports and make them more usable for vessel inspectors and operators.

The resulting format definition is used in the development of the application prototype and will result in a more concise CAIP report that can be used to quickly identify the vessel's structural configuration and the history of structural failures.

The general format for the SSIIS database has been defined. This format consists of the actual database structure and a database management system. All components of the datastructure have been defined, identifying the purpose and the data contents. For the components necessary for the generation of the CAIP reports, the data contents has been defined in more detail.

The database management system is outlined including the definition of all the functional requirements necessary for a general vessel database. These definitions can be used as a starting point for the development of a commercial application.

The developed application prototype is intended to show the general functionality of a vessel database system. The preliminary data structure has been defined with the main emphasis on the structural and inspection data that is necessary for the generation of CAIP reports. The database management system is implemented to show the general structure. Only the functions necessary for data input and the generation of CAIP reports are implemented.

8.2 Recommendation for Future Development

Additional research is needed to further determine the data needs of analysis software. This will require the survey of vessel analysis software, particularly operations and management related procedures. The resulting conclusions with regard to the data requirements of these software packages have to be included in the design of the SSIIS datastructure.

The advances in vessel response monitoring and the resulting data have to be studied further. Research is necessary to determine a storage format for monitoring data that does not require a large amount of disk storage space. Operator input is necessary to identify the amount of available and necessary operations data. This includes economic information (accounting and payroll), routing and harbour data (waypoint chains, harbour delays) and the desired amount of monitoring data.

In general, the structure and the data contents of all modules of the data structure have to be improved. Only the Vessel and Inspection module are to a large extent complete. A refined representation of design modifications and repairs has to be developed that makes it possible to identify the present condition of a vessel and to document the history of structural changes.

A detailed definition of the graphics format used for the representation of the structural configuration of a vessel has to be developed. This includes the level of detail and the organization of the structural drawings. It has to be guaranteed that the location of defects in a structural drawing matches the location description in the database.

The developed application prototype can be used as a starting point for a more sophisticated, or commercial application. The data entry procedures have to be re-evaluated to ensure data integrity. The representation of the structural geometry has to be improved to meet the requirements outlined in chapter 6. The reporting module has to be improved to provide the capability to generate fully automated CAIP reports.

In general, the present development represents the starting point for the development of a general Ship Structural Integrity Information System (SSIIS). All necessary components are defined. In a second year development, the different database modules have to be improved based on extensive input from vessel operators.

Appendix A

CATSIR Database Structure

A.1 Vessel Information Module

Vessel Information		
Vessel ID	Units	Name
Class Name	Owner	Society
Registry	Date	Builder
Shipyard	Hull No.	Official No.
USCG No.	Conversion	Date
LOA	LBP	Depth
Beam	DRaft	Summer DWT
Dbl. Bottom	Dbl. Side	
Product	Crude	SBT
IGS Fitted	IGS Gas Source	% Sulphur
COW	Heating Coils	
Engine	No. Cyl.	Screws No.
No. Blades	Normal RPM	Speed loaded
Speed Ballasted	Bow Thrust	Bilge Keel
Comments		

Vessel History		
Vessel ID	Vessel Owner	
From	To	

Tank Information		
Vessel ID	Tank ID	Description
Side	Service	Length
Beam	Depth	Capacity
Frame From	Frame To	Frame Spacing
Bottom Long Type	Bottom Long Spacing	
Side Long Type	Side Long Spacing	
Deck Long Type	Deck Long Spacing	
COW fitted	COW on Top	COW on Bottom
Coils	IGS	Comments

Drawing Log & AutoCad^{TM}		
Vessel ID	Tank ID	Drawing No.
Frame	As-Built	Description
Comments		

Survey (Inspection)		
Vessel ID	Event ID	Location
Company	Start Date	End Date
Equipment	Technicians	Type
Comment		

Survey (Inspection)		
Vessel ID	Tank ID	Drawing
Event	No. Anodes	Location
Attachment	Date	Manufacturer
Lot No.	Chemistry	Weight
Length	Width	Thickness
% Wastage	Condition	Comment

Coating Data		
Vessel ID	Tank ID	Drawing
Event	Manufacturer	Lot No.
Humidity	Temperature	Surf. Prep.
Prod. No.	Color	Breakdown
Primer Type	Primer Date	Primer Time
Primer DFT	Stripe	1st Coat. Date
1st Coat Time	1st Coat DFT	Total Area
2nd Coat. Date	2nd Coat. Time	2nd Coat. DFT
Coat. Type	Comment	

Crack Survey		
Vessel ID	Tank ID	Drawing
Event	Crack ID	Frame
Side	Zone	Member
Distance	Vt. Zone	Type
Length	Prim. Cause	Sec. Cause
Repair Type	Date	Cost
USCG Class	CS Class	Comment

Gauging - Wall Thickness		
Vessel ID	Tank ID	Drawing
Event	Location	Reading ID
Member	Steel Type	Original Thick.
Allow. Waste	Current Thick.	Actual Waste
Loss	Surface	Photo ID
Comment		

Photographic Log		
Vessel ID	Tank ID	Roll
Frame	Event	Caption

Pitting Survey		
Vessel ID	Tank ID	Drawing
Event	Rel. Loc.	Long. Stiff. 1
Long. Stiff. 2	Frame 1	Frame 2
Pits Range 1	Pits Range 2	Pits Range 3
Pits Range 4	Comments	

Renewal Records		
Vessel ID	Tank ID	Drawing
Event	Type	New/Renew
Dimensions	Flat Bar	Coverage
Weigth		

A.2 Tank Voyage Log Module

Tank Voyage Log		
Vessel ID	Tank ID	Route
Load Date	Discharge Date	
Load Port	Discharge Port	
Cargo Type	Cargo Level	
Heated	Temperature	Spot/Regular
Ballast Date	COW Date	Ballast Origin
COW Duration	Ballast Level	COW Temp
COW Pressure		
Wash Date	Wash Type	Wash Duration
Wash Temp	Wash Pressure	
Mucked Date	No. Buckets	Scale
Comment		

Appendix B

SID - Tree Structure for Detail Identification

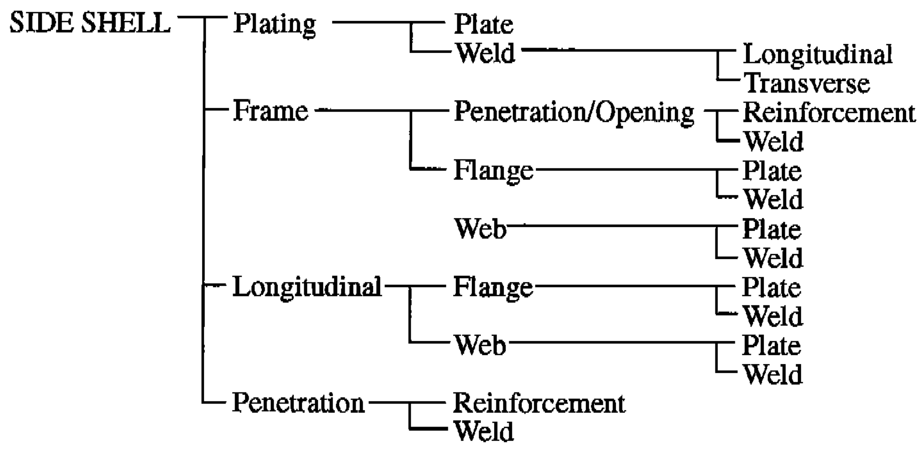


Figure B.1: SID - Sideshell Components

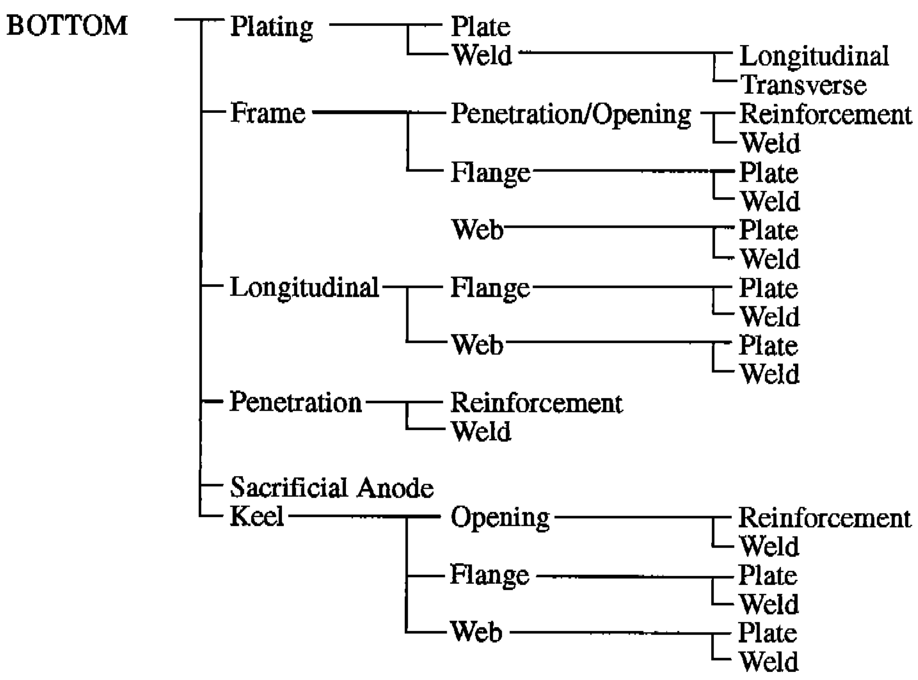


Figure B.2: SID - Bottom Components

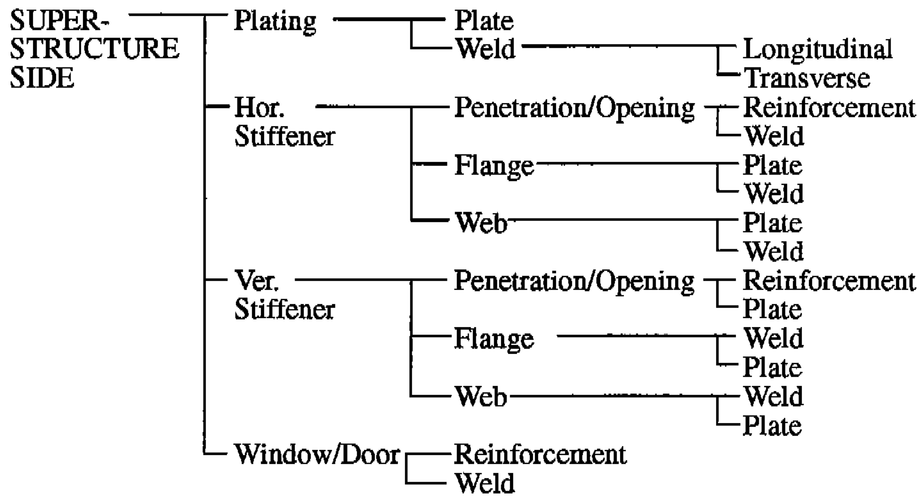


Figure B.3: SID - Super-Structure Side Components

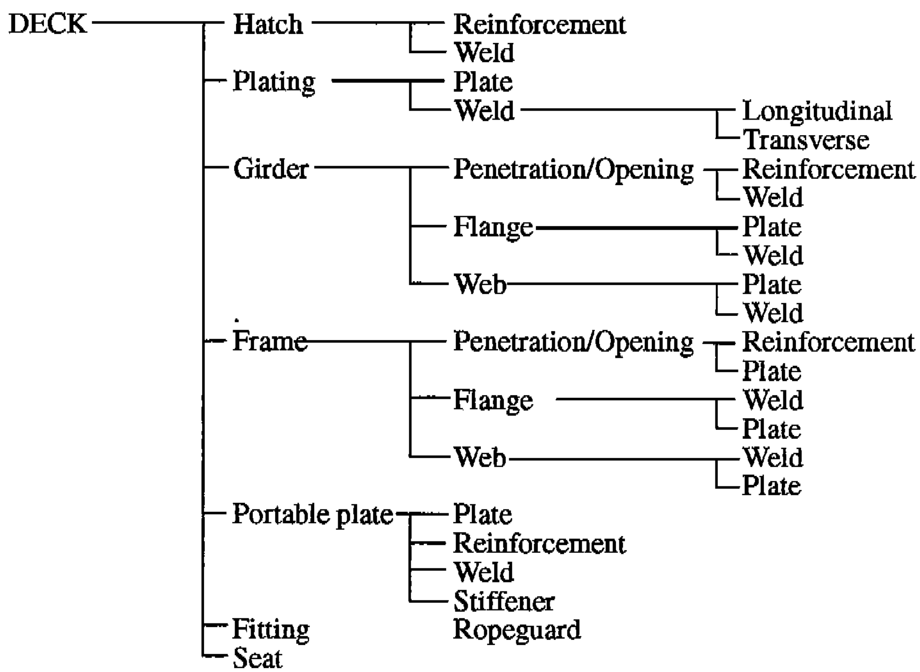


Figure B.4: SID - Deck Components

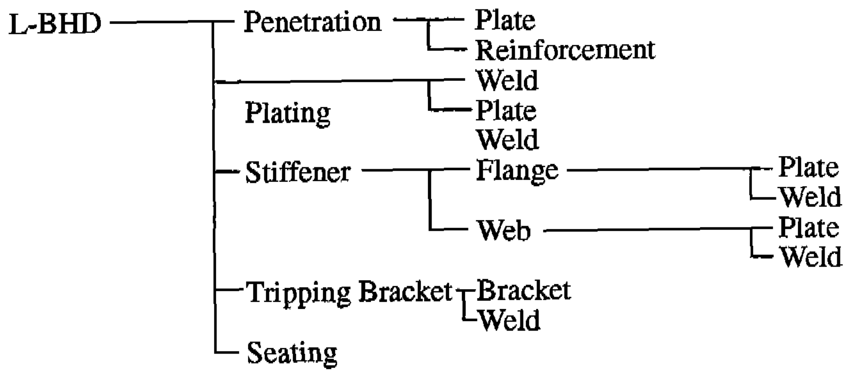


Figure B.5: SID - Longitudinal Bulkhead Components

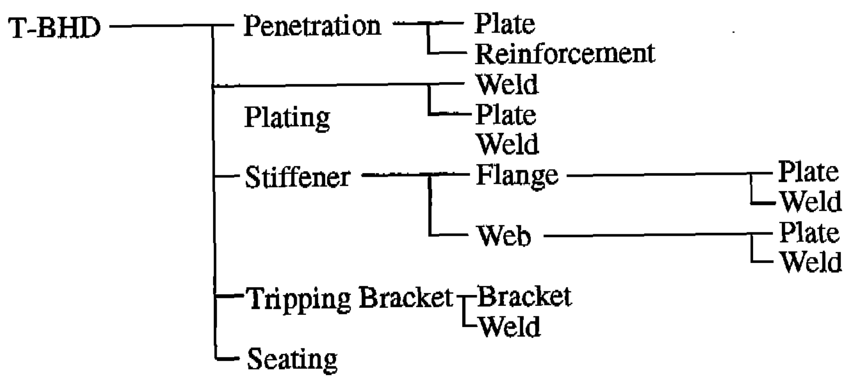


Figure B.6: SID - Transverse Bulkhead Components

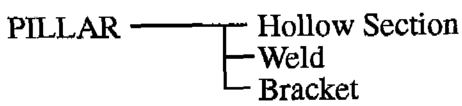


Figure B.7: SID - Pillar

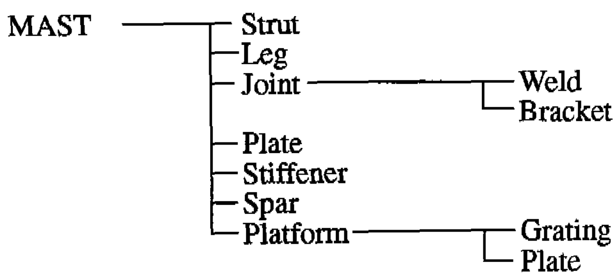


Figure B.8: SID - Mast Components

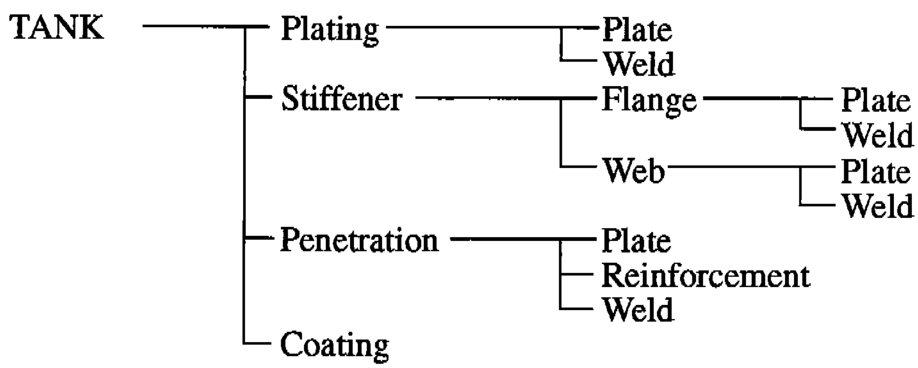


Figure B.9: SID - Tank Components

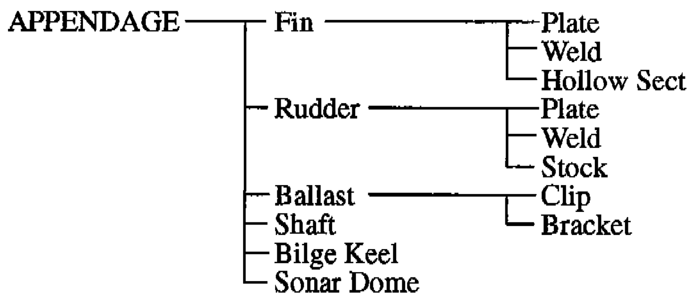


Figure B.10: SID - Appendage Components

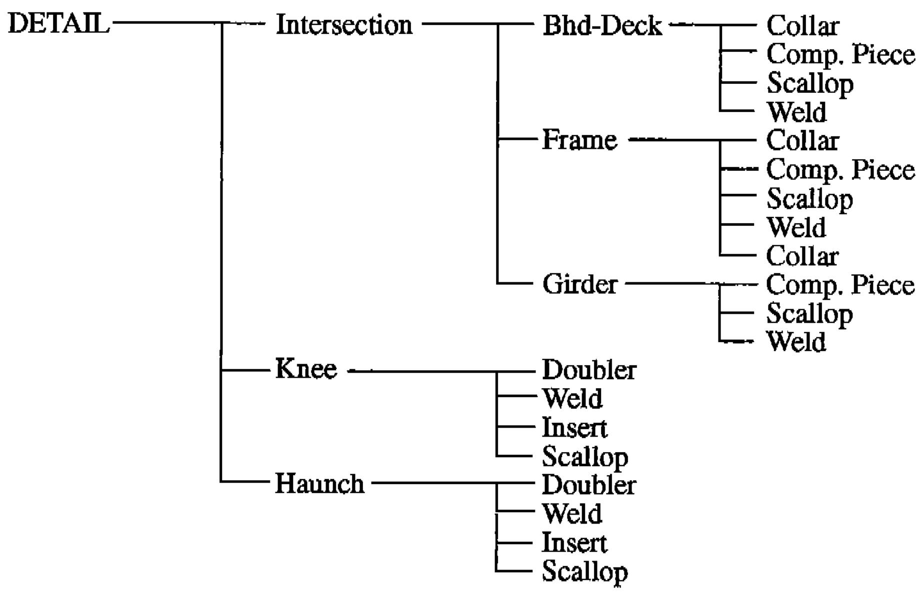


Figure B.11: SID - Detail Components

Appendix C

HECSALV - Data Files

C.1 Hull File (.HUL)

The (.HUL) file contains the hull offset data for the HECSALV software. All data is stored in metric units (M.Tons - meters). All longitudinal distances are referenced about amidships.

Ship	-	name of ship
Unit	-	unit flag 0=metric 1=British
LRF	-	longl reference flag 0=amidship 1=AP 2=FP
LBP	-	length between perpendiculars
Beam	-	molded beam
Depth	-	molded depth
Rule	-	integration rule 0=parabolic 1=trapezoidal
Keel	-	keel thickness
WPMargin	-	height margin for computing waterline breadth
NApp	-	no. of appended volumes
App	-	appendage allowance
Appt	-	average shell plating thickness
NAppHComp	-	no. of compartments appended to the hull
NSta	-	no. of stations on the hull
NC	-	no. of circular arcs used to define the hull
Sym	-	string indicating symmetric stations
NProfile	-	no. of points on the profile view
NPlan	-	no. of points on the plan view
NMarginLine	-	no. of points on the marginline
OffProfileXi	-	Longl (x) position of Profile point i
OffProfileYi	-	vertical (y) position of Profile point i
OffPlanXi	-	Longl (x) position of Plan point i
OffPlanYi	-	vertical (y) position of Plan point i
MarginLineXi	-	Longl (x) position of profile point i

MarginLineYi	-	vertical (y) position of profile point i
MarginLineZi	-	transverse (y) position of profile point i
Xoffi	-	Longl (x) position of point i
NPi	-	no. of points on station i
NCi	-	no. of circular arcs for station i
Yoffij	-	vertical (y) offset of point j at station i
Zoffij	-	transverse (z) offset of point j at station i
Circij	-	pointer to the arc or chine indicator for point j
CircRij	-	radius for arc j at station i
CircZ	-	transverse (Z) location of center of arc j
CircY	-	vertical (y) location of center of acr j
AppVolDi	-	description of appended volume i
AppVol	-	appended volume i (positive or negative)
AppVolY	-	vertical (Y) location of appended volume i
AppVolX	-	longl (X) location of appended volume i
AppVolZ	-	transverse (Z) location of appended volume i
AppVolV	-	vertical extent of appended volume i
AppHCompFNamei	-	file name for appended compartment i
AppHCompi	-	flag for appended compartment i
F.SavePlan	-	flag if plan and profile offsets are to be recomputed
User	-	user name or initials
Prj	-	project no.
Des	-	Description of project
Udate	-	date entered
Rev	-	revision no.
LPrec	-	length precision flag
WPrec	-	weight precision flag
LOrder	-	order of longl presentation
ShipClass	-	ship class

C.2 Compartment File (.CMP & .CMA)

The (`.CMP`) & (`.CMA`) files contains the compartment offset data for the HECSALV software. All data is stored in metric units (M.Tons - meters). All longitudinal distances are referenced about amidships.

A	-	compartment name
N1	-	location of 1st station within station no. array
N2	-	location of last station of compartment
N3	-	no. of stations used to describe the compartment
NC	-	no. of circular arcs used to describe cmpt

NP	-	no. of points used to define the compartment
NPlan	-	no. of points on plan view of compartment
NProfile	-	no. of points on profile view of compartment
NDFld	-	no. of downflooding points associated with compt
Rule	-	integration rule
CompPerm	-	permeability of compartment
CompPermVol	-	volume of compartment corrected for permeability
NAppCComp	-	no. of compartments appended to the compartment
CinpVol	-	molded volume of compartment
CinpVCG	-	VCG of total compartment
CinpLCG	-	LCG of total compartment
CinpTCG	-	TCG of total compartment
CinpMaxFS	-	slack free surface
CinpFS98	-	98% free surface
CinpAftBnd	-	aft-most boundary of compartment
CinpFwdBnd	-	fwd-most boundary of compartment
OffProfileXi	-	longl (X) location of profile point i
OffProfileYi	-	vertical (Y) location of profile point i
OffPlanXi	-	longl (X) location of plan point i
OffPlanZi	-	transverse (Z) location of plan point i
OffDFLDXi	-	longl (X) location of dfld point i
OffDFLDYi	-	vertical (Y) location of dfld point i
OffDFLDZi	-	transverse (Z) location of dfld point i
Xoffi	-	longl (X) location of station i
NPi	-	no. of points on station i
NCi	-	no. of circular arcs for station i
Yoffij	-	vertical (y) offset of point j at station i
Zoffij	-	transverse (z) offset of point j at station i
Circij	-	pointer to the arc or chine indicator for point j
CircRij	-	radius for arc j at station i
CircZ	-	transverse (Z) location of center of arc j
CircY	-	vertical (y) location of center of acr j
Sym	-	string indicating symmetric stations
Ship	-	name of ship
Class	-	ship class
LBP	-	length between perpendiculars
Beam	-	molded beam
Depth	-	molded depth
User	-	user name or initials

Prj	-	project no.
Des	-	Description of project
Udate	-	date entered
Rev	-	revision no.
Unit	-	unit flag 0=metric 1=British
LRF	-	longl reference flag 0=amidship 1=AP 2=FP
LPrec	-	length precision flag
WPrec	-	weight precision flag
LOrder	-	order of longl presentation
BhdXmin	-	longl location (X) of aft-most station compartment
BhdXmax	-	longl location (X) of fwd-most station compartment
BhdNSTA	-	no. of stations for compartment interpolation
CompXoffi	-	longl loc. of each comp station i
BhdZmin	-	location of bhd to port
BhdBoundType	-	flag for port bhd
BhdBoundSTR	-	name of port bhd file name
BhdZmax	-	location of bhd to stbd
BhdBoundType	-	flag for stbd bhd
BhdBoundSTR	-	name of stbd bhd file name
BhdYmin	-	location of lower deck
BhdBoundType	-	flag for lower deck
BhdBoundSTR	-	name of lower deck file name
BhdYmax	-	location of upper deck
BhdBoundType	-	flag for upper deck
BhdBoundSTR	-	name of upper deck file name
BhdGSpace	-	girth spacing between interpolation points
BhdTol	-	max. tolerance used to eliminating points
BhdInterpRule	-	interpolation rule
SphereNS	-	no. of stations for sphere
SphereRadius	-	radius of sphere
SphereXLoc	-	longl (X) location of center of sphere
SphereYLoc	-	vertical (Y) location of center of sphere
SphereZLoc	-	transverse (Z) location of center of sphere
SphereTopBot	-	flag (full / above plane / below plane)
SpherePlaneLoc	-	location of point on plane for location
SpherePlaneAngle	-	angle of plane about horizontal plane

C.3 Ship Data File (.SDA)

The (`.SDA`) file contains the ship data for the HECSALV software. All data is stored in metric units (M.Tons - meters). All longitudinal distances are referenced about amidships.

Class	-	ship class
Ship	-	name of ship
LBP	-	length between perpendiculars
Beam	-	molded beam
Depth	-	molded depth
SLL	-	summer loadline draft
LOA	-	length over all
Unit	-	unit flag 0=metric 1=British
LPrec	-	length precision flag
WPrec	-	weight precision flag
LRF	-	longl reference flag 0=amidship 1=AP 2=FP
LOrder	-	order of longl presentation
Yard	-	yard and hull no.
Heel	-	heel optional flag
NHydro	-	no. of drafts in hydrostatics table
ChgKM	-	no. of change with trim KM curves
NStaBJ	-	no. of stations in bonjean tables
NwlBJ	-	no. of waterlines in bonjean tables
NAng	-	no. of angles in GZ tables
NDisp	-	no. of displacements in GZ tables
NStr	-	no. of strength read-out points
SEA	-	flag for at sea and in harbor data
F.StrOpt	-	longl strength flag
PDia	-	propeller diameter
PCL	-	height of shaft centerline above baseline
MOLD	-	flag for molded vs keel drafts
NGrain	-	grain stability flag
NGrAllow	-	no. of grain stability allowable values
NGMRQdraft	-	no. of drafts for required GM data
F.PropImm	-	propeller immersion formula flag
NVarPts	-	no. of volumes for variable VCG/FS data
NGMRQ	-	no. of required GM curves
NLsDistr	-	no. of points of lightship weight distr. curve
NWtBlock	-	no. of blocks of weight for lightship weight distr
Ship1	-	lightship weight
Ship2	-	lightship vcg
Ship3	-	lightship lcg
Ship4	-	lightship tcg
Ship5	-	lightship not used
Ship6	-	lightship fixed constant weight
Ship7	-	lightship fixed constant vcg
Ship8	-	lightship fixed constant lcg
Ship9	-	lightship fixed constant tcg
Ship10	-	lightship fixed constant free surface moment
DMark1	-	longl location of aft marks

DMark2	-	height of aft marks at location DMark1
DMark3	-	longl location of midship marks
DMark4	-	height of midhsips marks at location DMark3
DMark5	-	longl location of fwd marks
DMark6	-	height of fwd marks at location DMark5
DMarkxy	-	longl and height locaiton for non-vertical marks
DragAtMarks	-	vertical offset of aft, midships, fwd marks
NGroup	-	max. no. of tank and cargo groups in SDA file
NCi	-	pointer to last tank in group i
Ni	-	name for group i
ContLen	-	string describing applicable container lengths
VisLocation11	-	longl location of helmsman
VisLocation12	-	vertical location of helmsman
VisLocation21	-	longl location of obstruction to sight
VisLocation22	-	vertical location of obstruction to sight
VisLocation31	-	longl location of bow at main deck
VisLocation32	-	vertical location of bow at main deck
VisLocation1	-	reqd visibility in distance fwd of FP
VisLocation2	-	reqd visibility in no. of ship lengthsn
VisLocation3	-	assumed length of ship for visibility check
Gi	-	density of fluid for group i
TkStr	-	tank name for tank i
TKShortStr	-	short tank name for tank i
Ci	-	default weight to be allocated to tank i
TKi1	-	volume of tank i
TKi2	-	vcg of tank i
TKi3	-	lcg of tank i
TKi4	-	tcg of tank i
TKi5	-	slack free surface inertia of tank i
TKi6	-	98%-5deg free surface inertia of tank i
TKi7	-	aft tank boundary of tank i
TKi8	-	fwd tank boundary of tank i
SGi	-	default density of fluid for tank i
FRi	-	descriptor for strength read-out point i
XFRi	-	longl location of strength read-out point i
SLSi	-	weight of lightship and fixed constant aft of XFRi
MLSi	-	moment of lightship and fixed constant aft of XFRi
Allow1i	-	at sea allowable shear force at read-out point i
Allow2i	-	at sea allowable hogging moment at read-out point i
Allow3i	-	at sea allowable sagging momentat read-out point i
Allow4i	-	in harbor allowable shear force at read-out point i
Allow5i	-	in harbor allowable hogging moment at read-out point i

Allow6i	-	in harbor allowable sagging moment at read-out point i
SMPropi1	-	hull girder inertia (horz. axis)
SMPropi2	-	section modulus to deck (horz. axis)
SMPropi3	-	section modulus to keel (horz. axis)
SMPropi4	-	shear area (horz. axis)
SMPropi1	-	hull girder inertia (vert. axis)
SMPropi2	-	section modulus to deck (vert. axis)
SMPropi3	-	section modulus to keel (vert. axis)
SMPropi4	-	shear area (vert. axis)
Hydroi1	-	lcf draft
Hydroi2	-	displacement
Hydroi3	-	KMt
Hydroi4	-	LCB (m-MS)
Hydroi5	-	LCF (m-MS)
Hydroi6	-	MT1m (m-MT)
ChgKMTrimi	-	trim for column i in chang in KMt with trim
ChgKMi	-	change in KMt for trim ChgKMTrimi and draft Hydroi1
XBJi	-	longl locationof station i in bonjean tables
DraftBJi	-	draft i in bonjean table
BJji	-	bonjean area at station j and draft i
Angi	-	angles indegrees for gz table
Dispi	-	displacements for gz tables
DFldi	-	downflooding angle corresponding to Dispi
GZij	-	MS value for Dispi and Angj
GMDescj	-	description of required gm curve j
GmRQij	-	required gm value for curve j and draft Hydroi1
GMRQdraft	-	drafts corrseponding to reqd gm values
NVari1	-	pointer to 1st variable vcg/fs data for tank i
NVari2	-	pointer to last variable vcg/fs data for tank i
PVolj	-	volumes in variable table
PVCGj	-	vcg's in variable table
PLCGj	-	lcg's in variable table
PTCGj	-	tcg's in variable table
PFSj	-	free surface inertias in variable table
F.Material	-	flag for type of steel, alum, etc
MatName	-	material name
Emodulus	-	modulus of elasticity
MaxStressT	-	yield stress (tensile flange)
MaxStressC	-	yield stress (compression flange)
U.Stress	-	stress unit flag

LsWti1	-	longl location of pt i of lightship wt distr curve
LsWti2	-	weight ordinate of pt i on lightship wt distr curve
WtBlocki1	-	weight in block i
WtBlocki2	-	lcg of weight block i
WtBlocki3	-	aft bound of weight block i
WtBlocki4	-	fwd bound of weight block i
User	-	user name or initials
Prj	-	project no.
Des	-	Description of project
Udate	-	date entered
Rev	-	revision no.

C.4 Compartment Access Offset Data File (.CML)

The (.CML) file contains the compartment access offset data for the HECSALV software. All data is stored in metric units (M.Tons - meters). All longitudinal distances are referenced about amidships.

TNoComp	-	total no. of compartments
TNProfile	-	no. of points on profile view for all cmpts
TNPlan	-	no. of points on plan view for all cmpts
TNDfld	-	no. of downflooding points for all compts
FListStri	-	file name for cmpt i
MIDi	-	name of cmpt i
TCPerm	-	compartment permeability for cmpt i
TCVol	-	100% volume for compartment i
NTProfi	-	no. of points on profile view of cmpt i
NTPlan	-	no. of points on plan view of cmpt i
NTDfldi	-	no. of downflooding points of cmpt i
TOffProfi1	-	longl (X) location of profile point i
TOffProfi2	-	transverse (Y) location of profile point i
TOffPlani1	-	longl (X) location of plan point i
TOffPlani2	-	transverse (Z) location of plan point i
TOffDfldi1	-	longl (X) location of dfld point i
TOffDfldi2	-	transverse (Y) location of dfld point i
TOffDfldi3	-	transverse (Z) location of dfld point i
Ship	-	name of ship
Class	-	ship class
LBP	-	length between perpendiculars
Beam	-	molded beam
Depth	-	molded depth
User	-	user name or initials
Prj	-	project no.

Des	-	Description of project
Udate	-	date entered
Rev	-	revision no.

Appendix D

VMS - Required Input Information

D.1 Vessel Table

The Vessel Table contains the following information:

Vessel Name	Long Name	LR#
UCA		
Summer DWT	Winter DWT	Tropic DWT
Light Ship	Crew Stores	LOA
Beam	Summer Draft	TPI
Cargo Capacity	Fuel Capacity	Panama Net. Ton.
Suez Net. Ton/		
Engine Type	RPM	RPM Multiplier
SHP	Power	Propeller
Power Constant		
Full Speed Loaded	Full Speed Ballast	Min. Speed Loaded
Min. Speed Ballast		
M.E. Fuel at Sea	Aux. Fuel at Sea	M.E. Fuel in Port
Aux. Fuel in Port	M.E. Lubes	Fuel to Discharge
Fuel to Heat	Fuel Loaded Factor	Fuel Ballast Factor
Yard	Year Built	

D.2 Fuel Cost Initialization

The Fuel Cost Initialization information has to be entered once only for each vessel on program installation:

Fuel Capacity	Fuel Cost
Diesel Capacity	Diesel Cost
Lube Capacity	Lube Cost

D.3 Vessel Daily Cost

The Vessel Daily Cost information has to be entered once per year for each vessel and is needed for yoyage economics calculations. All costs are daily costs.

Vessel	Year	
Crew Labor	Stores, Tools and Feeding	Miscellaneous
Incremental Overhead	Operating Insurance	Voyage Maintenance and Repair
Periodic Overhaul		

D.4 Voyage Itinerary

The Voyage Itinerary information lists the port of departure and point of arrival and all intermediate ports. For each port the terminal, the activity and the date and time are listed. Date and time information is used as an Estimated Time of Arrival for the `Noon Position Reports`.

Vessel	Voyage Number	
To/From Flag	Port	Terminal
Activity	Bunker	Date
Time		

D.5 Cargo Orders

The Cargo Orders uses information from the Voyage Itinerary table to determine the load and discharge ports. For the discharge ports cargo information is entered.

Vessel	Voyage Number	Activity
Load Port	Terminal	
Grade	Discharge Port	Terminal
Consignee	Basis	Quantity
Rate		

D.6 Bunker Orders

The Bunker Orders uses information from the Voyage Itinerary table to determine the bunker ports. For these ports bunker information is entered.

Vessel	Voyage Number	Activity
Port	Terminal	
Diesel Quantity	Diesel Rate	Diesel Cost
Fuel Quantity	Fuel Rate	Fuel Cost
Lube Quantity	Lube Rate	Lube Cost

D.7 Charter Party Information

The Charter Party table specifies information needed for laytime and demurrage calculations.

Vessel	Voyage Number	Charterer
Allowed Time	Durrage Daily Rate	Charter Party Form
Charter Party Date	Laydays Commence	Laydays Cancel

D.8 Port Costs and Canal Fees

Both port costs and canal fees are entered in this table.

Vessel	Voyage Number	
Port	OCode	Cost
Canal	OCode	Fee

D.9 Waypoint Chain

The Waypoint Chain lists for a specific route defined by departure and destination port the sequence of waypoints. Defined Waypint chains can be recalled for use in the Current Sea Leg table.

WP Chain ID	Description	
Seq #	Chart #	Latitude
Longitude	Track	Course
Distance		

D.10 Current Sea Leg

For a given voyage, the Current Sea Leg information is based on a defined waypoint chain.

Voyage	From	To
WP Chain	WP #	Chart #
Latitude	Longitude	Track
Course	Distance	

D.11 Noon Position Report

The Noon Position Report is completed daily and at stand-by arrival.

Vessel	From	To
Voyage Number	Date	Time
Zone	OP Code	Activity
Latitude	Longitude	Daily Miles
Deck Log	Elapsed Hours	Course
Detention Time	Detention Miles	Beaufort
Wind Direction	Wind Angle	Swell Height
Swell Direction	Draft	Displacement
Trim	Sea Temperature	
Daily Speed	Daily RPM	Daily Slip
Daily Eng/Mls	Total Dist.	Dist Trav.
Dist. to go	ETA	Total Eng. Miles
AVG RPM	AVG Slip	AVG Speed
Tot. Time	Tot. Det. Time	Tot. Det. Miles
REQ. Speed		
Cargo Heat	Steam on Deck	Cargo Pump
Daily M.E. HFO	Daily M.E. DO	Daily M.E. CO
Daily Aux HFO	Daily Aux DO	Daily Aux CO
Total M.E. HFO	Total M.E. DO	Total M.E. CO
Total Aux HFO	Total Aux DO	Total Aux CO
Remain. M.E. HFO	Remain. M.E. DO	Remain. M.E. CO
Remain. Aux HFO	Remain. Aux DO	Remain. Aux CO

D.12 Engine Log

This log is completed daily at noon.

Voyage Number	Activity	OP Code
Date	Time	Time Zone
ME FO Meter	BLR FO Meter	DG Meter
Cyl Oil Meter	ME Counter	HP
M.E. Daily Cons.	Boiler Daily Cons.	D.G. Daily Cons.
Cyl Oil Daily Cons.		
HFO Meter ROB	DO Meter ROB	CO Meter ROB
HFO CargoMax ROB	DO CargoMax ROB	CO CargoMax ROB
RPM	Elapsed Time	OBS Daily Miles
Engine Miles	Slip per day	ME SFC
CYl SFC	ME Meter Factor	BLR Meter Factor
DO Meter Factor	Cyl Meter Factor	

D.13 Maneuvering and Port Fuel Consumption

The Maneuvering and Port Fuel Consumption distinguishes between port and maneuvering fuel consumption. The consumption for different activities is listed.

Vessel	Voyage Number	Voyage Description
Man. OP Code	Man. Date	Man. Miles
Man. Elapsed Time	Man. HFO	Man. DO
Man. CO		
Port OP Code	Port Date	Port Elapsed Time
Port HFO	Port DO	Port CO

D.14 Port Activity

The Port Activity contains a detailed list of the individual activities while in port including the elapsed time and laytime calculations.

Vessel	Voyage Number	OP Code
Port	Terminal	Berth
Activity	Date	Time
Elapsed Time	Laytime Start	Laytime End
Ship Delays	Terminal Delays	

D.15 CargoMax to Cargo Upload

The cargo tables are updated using the CargoMax information.

Vessel	Voyage Number	Port
Old Fuel GSV	Old Fuel TOV	Old Fuel FW
New Fuel GSV	New Fuel TOV	New Feul FW
Old Diesel GSV	Old Diesel TOV	Old Diesel FW
New Diesel GSV	New Diesel TOV	New Diesel FW
Old Fresh GSV	Old Fresh TOV	Old Fresh FW

New Fresh GSV	New Fresh TOV	New Fresh FW
Old Balstp GSV	Old Balstp TOV	Old Balstp FW
New Balstp GSV	New Balstp TOV	New Balstp FW
Old Misc GSV	Old Misc TOV	Old Misc FW
New Misc GSV	New Misc TOV	New Misc FW

D.16 Shore / Bill of Loading Cargo Figures

The bill of loading figures are required for the deadfreight calculations.

Vessel	Voyage Number	OpCode
Lightering	Port	Terminal
Grade	Consignee	API
NSV 60deg F	S&W	GSV 60deg F
TCV 60deg F	Net Tons	

Appendix E

SSIIS Prototype - Documentation

As part of the SSIIS database system prototype, data input screens have been developed for all tables contained in the datastructure. These input screens are organized in four different submenus:

- System Data
- Vessel Data
- Inspection Data
- Operations Data

In the following sections the individual data screens are described including a graphical representation of each implemented data entry screen.

E.1 System Data Entry

The **System** data entry selection screen is shown in Fig. (7.4). It contains eight menu choices, which are described in the following sections.

E.1.1 Cargo

The **Cargo** data entry screen is shown in Fig. (E.1). Different Cargo types can be entered in this screen.

E.1.2 Cause

The **Cause** data entry screen is shown in Fig. (E.2). Different causes for failures can be entered in this screen including a long definition of the failure mechanisms.

E.1.3 Classification

The **Classification** data entry screen is shown in Fig. (E.3). Different classification societies are entered in this screen including the name, an abbreviation and the country.

E.1.4 Company

The **Company** data entry screen is shown in Fig. (E.4). Different owners and operators are entered in this screen including the name and the complete address. The information in this table is used to identify both owners and operators.

E.1.5 Repair

The **Repair** data entry screen is shown in Fig. (E.5). Different repair solutions are entered including a long description of the repair.

E.1.6 Shipyard

The **Shipyard** data entry screen is shown in Fig. (E.6). The complete name and address for different shipyards is entered in this data entry screen.

E.1.7 Steel

The **Steel** data entry screen is shown in Fig. (E.7) . Different steel types can be entered in this screen.

E.1.8 Corrosion Protection

The **Corrosion Protection** data entry screen is shown in Fig. (E.8). Different corrosion protection systems can be defined including a long description of the procedure.

E.2 Vessel Data Entry

The **Vessel** data entry selection screen is shown in Fig. (7.5). It contains four menu choices, which are described in the following sections.

E.2.1 Vessel

The **Vessel** data entry screen is shown in Fig. (E.9). Vessel information can be entered in this screen. The available vessel classes, owner/operators, classification societies and shipyards are listed. This ensures that only valid data can be entered.

E.2.2 Class

The **Class** data entry screen is shown in Fig. (E.10). The general structural configuration is entered in this screen including vessel particulars.

E.2.3 Tank

The **Tank** data entry screen is shown in Fig. (E.11). It contains the general tank dimensions for each tank of a specific vessel class that can be selected from a list of available classes. The information about available tank numbers is also provided using a list that is obtained from the Tank_No table.

E.2.4 Tank Number

The **Tank Number** data entry screen is shown in Fig. (E.12). It contains for each vessel class the possible tank numbers.

E.3 Inspection Data Entry

The **Inspection** data entry selection screen is shown in Fig. (7.6). It contains six menu choices, which are described in the following sections.

E.3.1 Inspection

The **Inspection** data entry screen is shown in Fig. (E.13). Inspection information is listed for each vessel of a specified class including the inspection location, the inspection company, the inspector and the date of the inspection. Location, company, vessel and class information is provided in a list format to allow only the choice of available data. This ensures data integrity.

E.3.2 Inspection Company

The **Inspection Company** data entry screen is shown in Fig. (E.14). It allows the entry of the name and address of different inspection companies.

E.3.3 Inspection Location

The **Inspection Location** data entry screen is shown in Fig. (E.15). It allows the entry of different inspection locations.

E.3.4 Corrosion

The **Corrosion** data entry screen is shown in Fig. (E.16). Corrosion data is entered for each inspection of an individual vessel of a specified class. With the exception of the actual corrosion data (thickness, location) all information is entered based on lists of available data to ensure data integrity.

E.3.5 Crack

The **Crack** data entry screen is shown in Fig. (E.17). Crack data is entered for each inspection of an individual vessel of a specified class. With the exception of the actual crack information (length, location) all information is entered based on lists of available data to ensure data integrity.

E.3.6 Crack Class

The **Crack Class** data entry screen is shown in Fig. (E.18). The definitions of different crack classes are entered in this screen.

E.4 Operations Data Entry

The **Operations** data entry selection screen is shown in Fig. (7.7). It contains three menu choices, which are described in the following sections.

E.4.1 Leg

The **Leg** data entry screen is shown in Fig. (E.19). For each voyage leg for a particular vessel the departure and destination ports and dates are entered. In addition, cargo and ballast conditions are included.

E.4.2 Monitoring

The **Monitoring** data entry screen has not been implemented. Additional research is needed to define the data structure for the monitoring module.

E.4.3 Ports

The **Ports** data entry screen is shown in Fig. (E.20). It allows the entry of the port name and the geographic location (longitude and latitude) and the country.

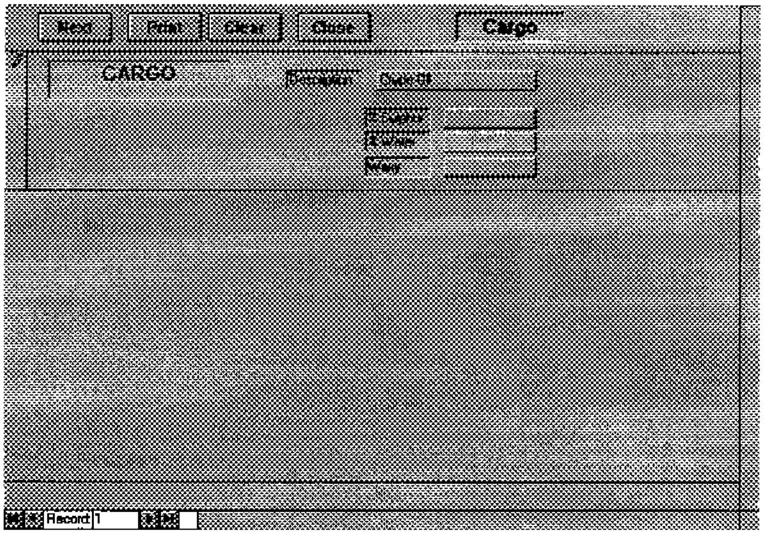


Figure E.1: Cargo Entry Screen

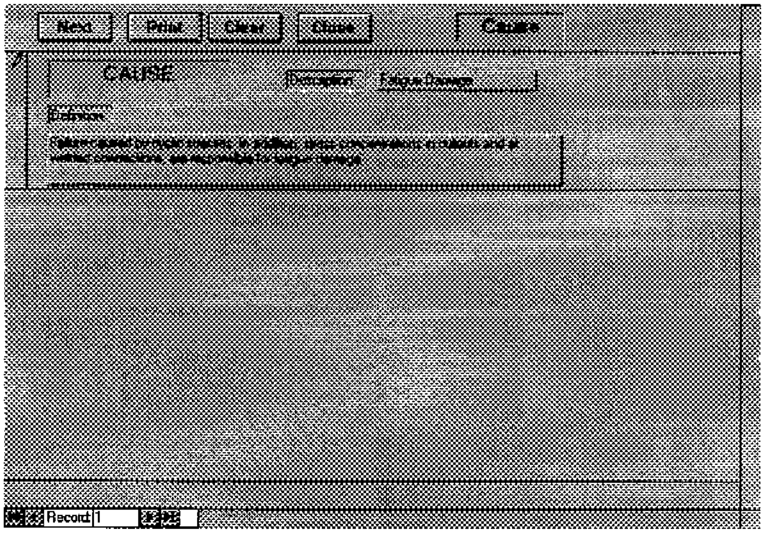


Figure E.2: Cause Entry Screen

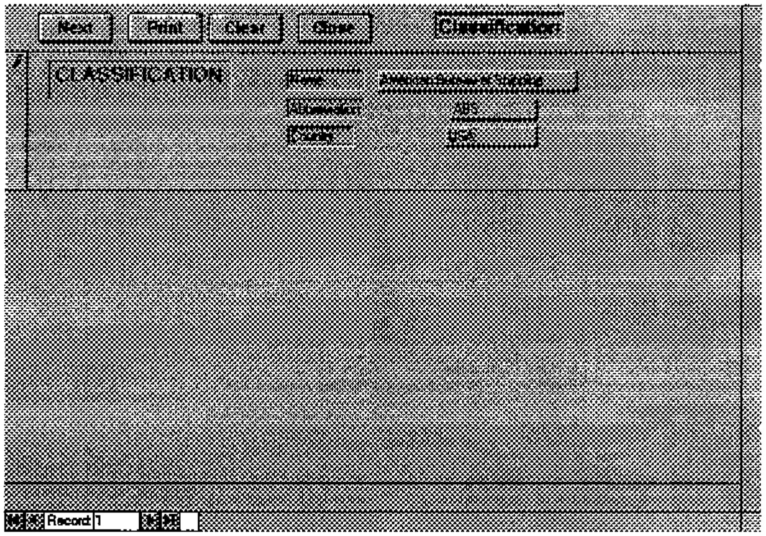


Figure E.3: Classification Entry Screen

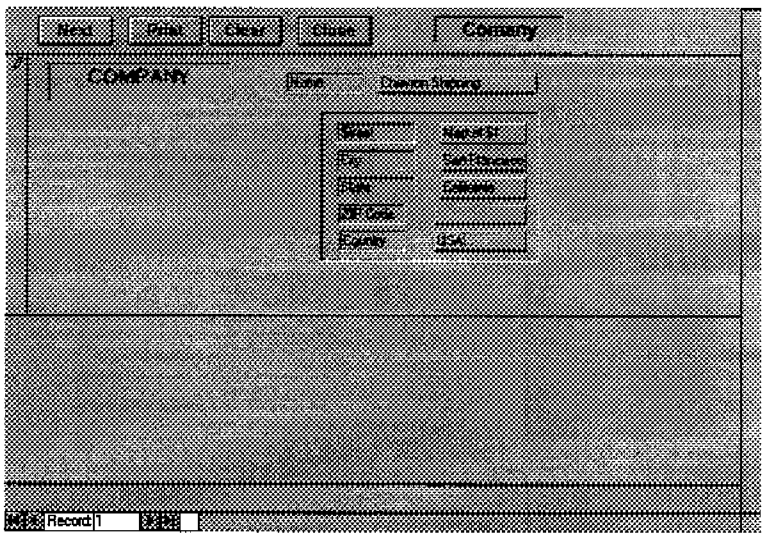


Figure E.4: Company Entry Screen

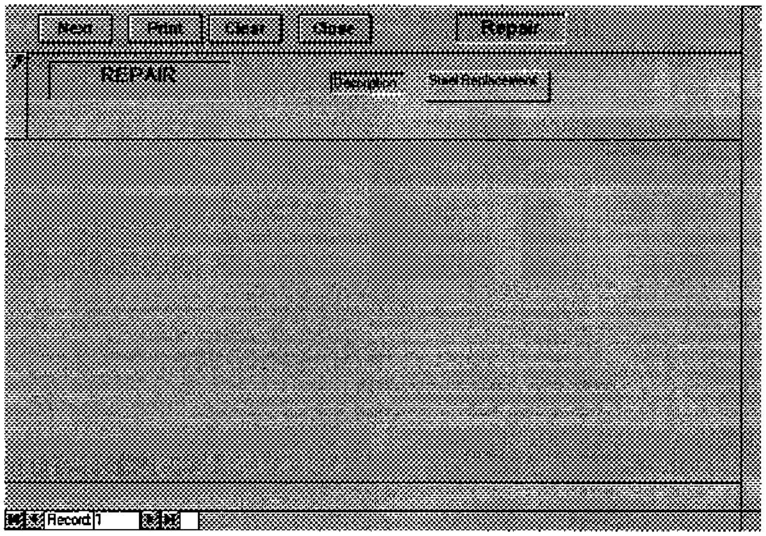


Figure E.5: Repair Entry Screen

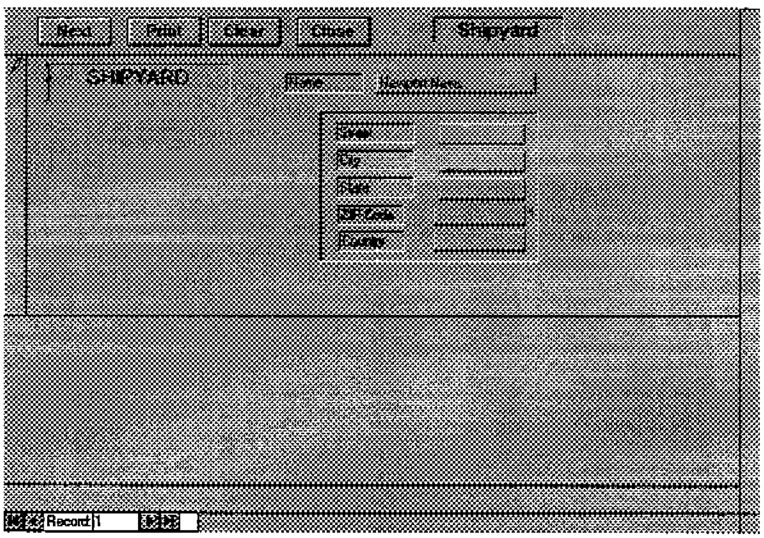


Figure E.6: Shipyard Entry Screen

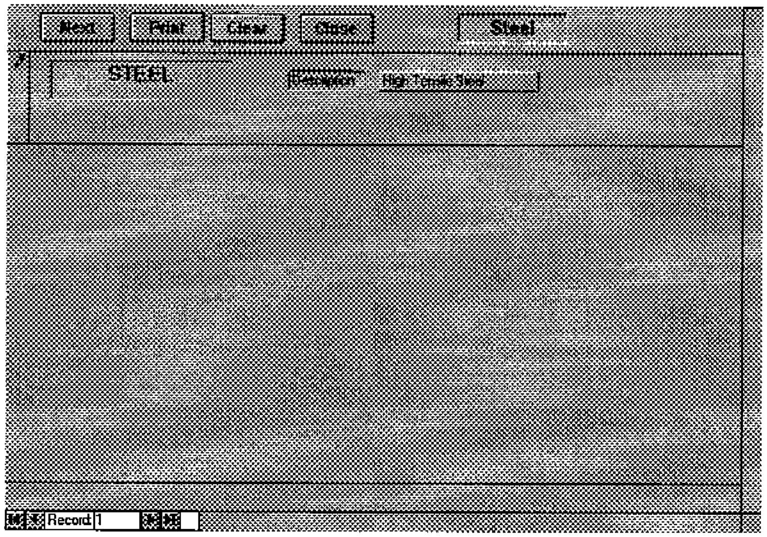


Figure E.7: Steel Entry Screen

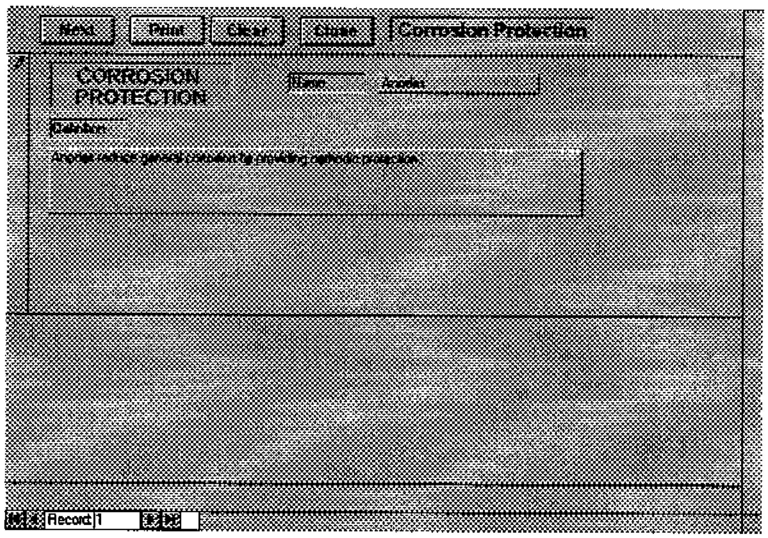


Figure E.8: Corrosion Protection Entry Screen

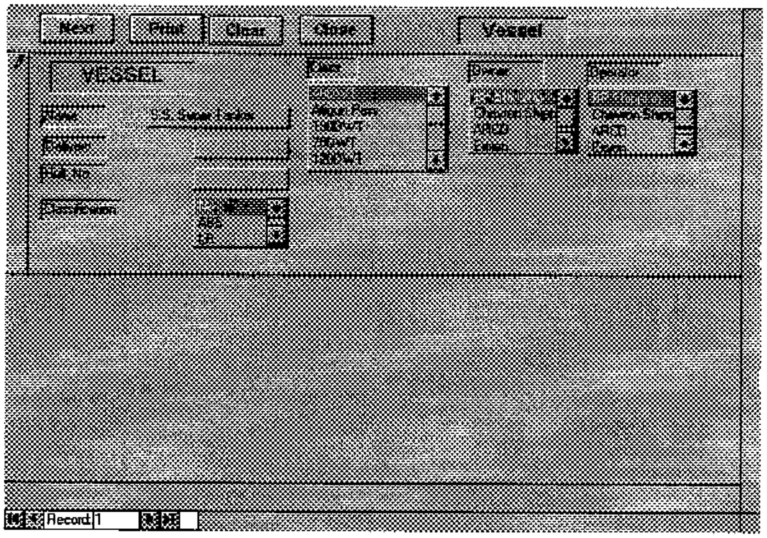


Figure E.9: Vessel Entry Screen

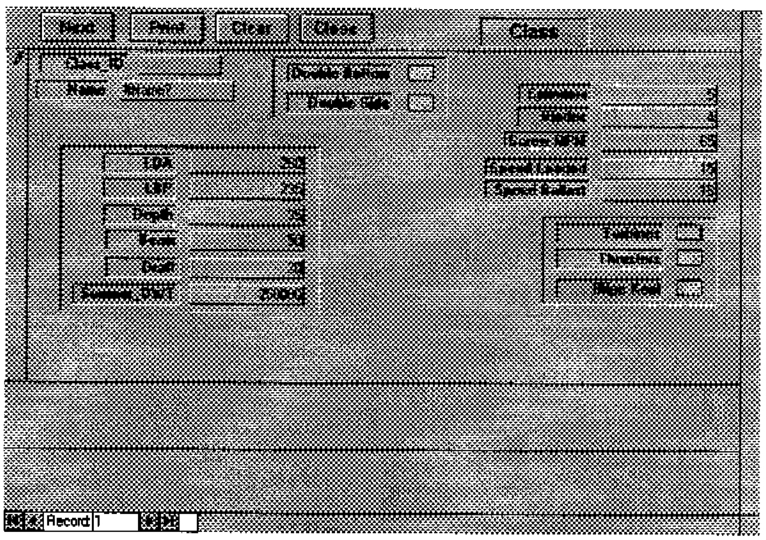


Figure E.10: Class Entry Screen

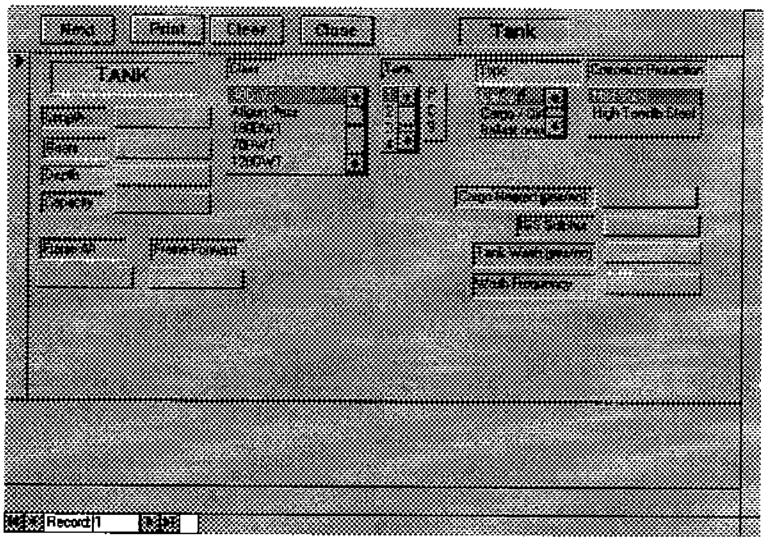


Figure E.11: Tank Entry Screen

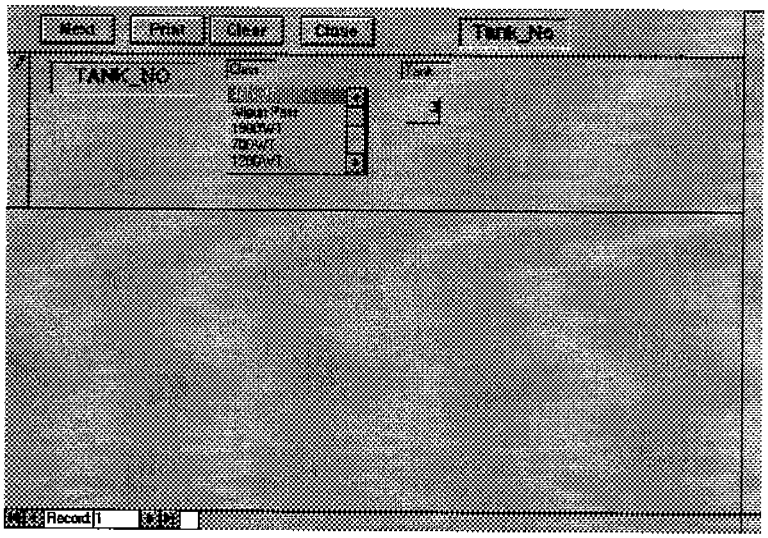


Figure E.12: Tank Number Entry Screen

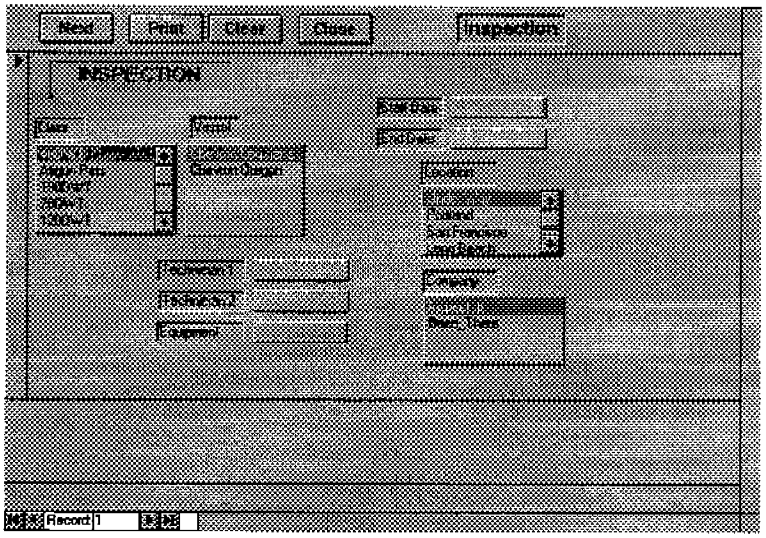


Figure E.13: Inspection Entry Screen

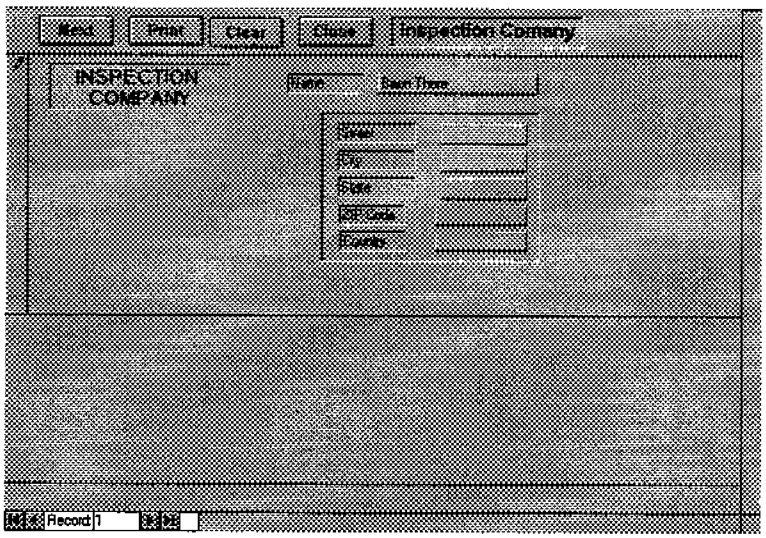


Figure E.14: Inspection Company Entry Screen

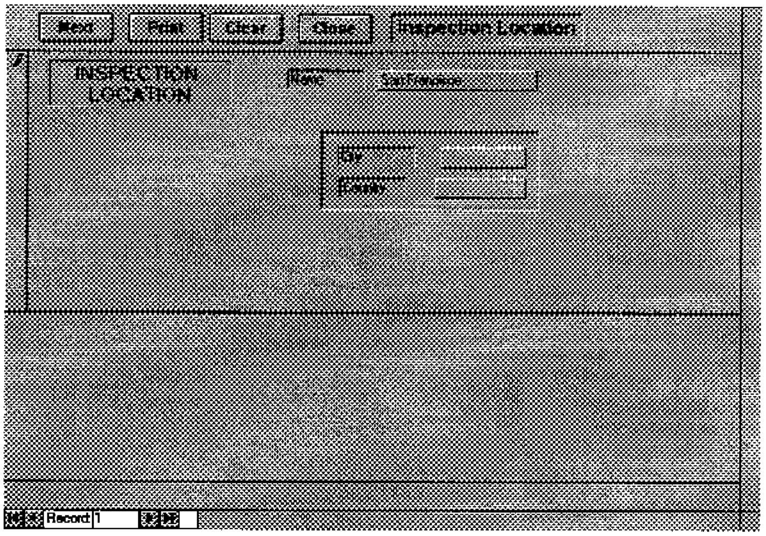


Figure E.15: Inspection Location Entry Screen

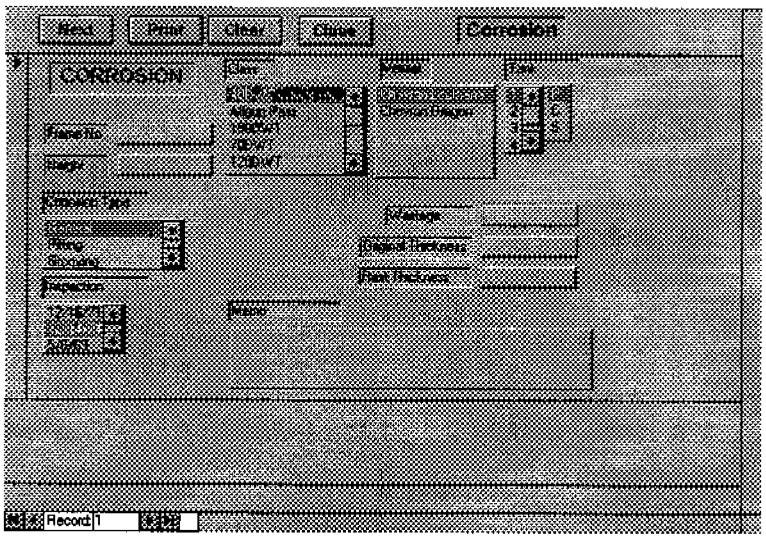


Figure E.16: Corrosion Entry Screen

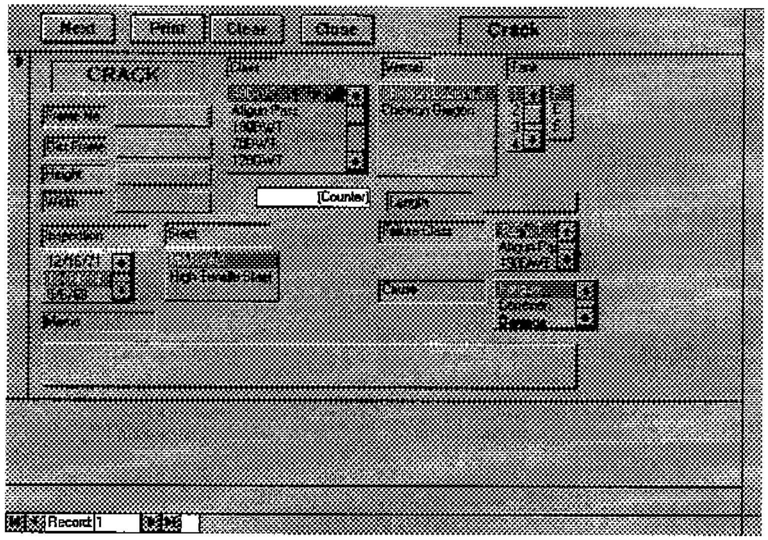


Figure E.17: Crack Entry Screen

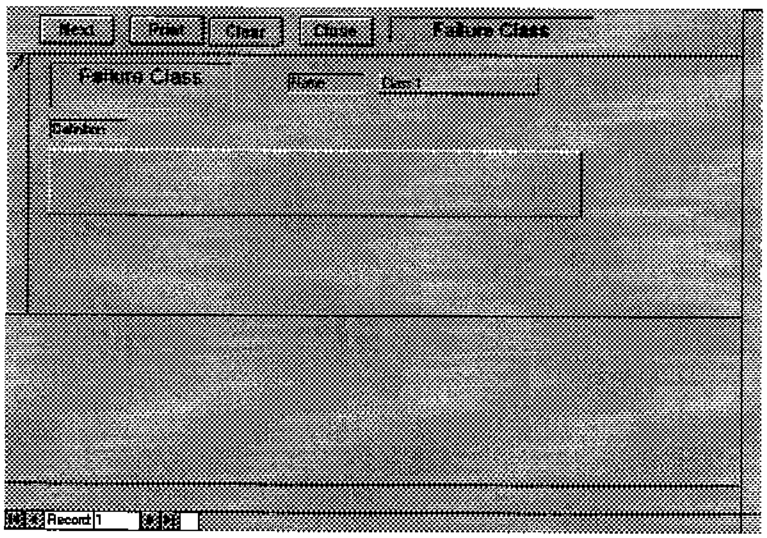


Figure E.18: Crack Class Entry Screen

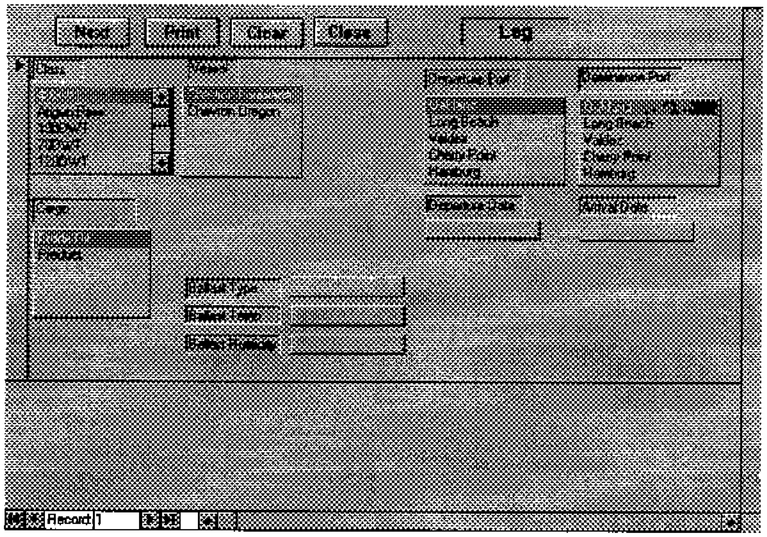


Figure E.19: Leg Entry Screen

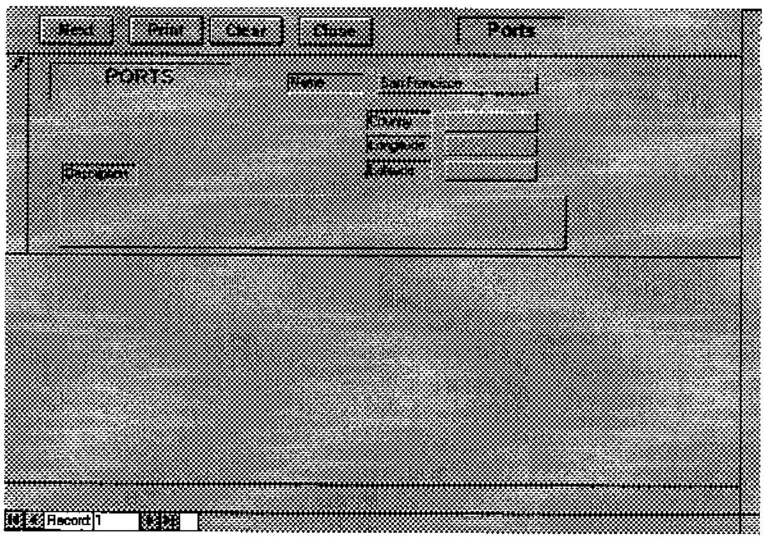


Figure E.20: Ports Entry Screen

Appendix F

Addresses of Software Developers

In the following, for each of the programs (database and applications) that have been documented in this report, a contact address is listed.

F.1 Databases

CATSIR	Chevron Shipping Company 555 Market Street San Francisco, CA 94105 (415) 894-7700
	OCEANEERING / SOLUS SCHALL 1441 Park Ten Boulevard Houston, TX 77218 (713) 579-0627
HFDB	ARCO Marine 300 Oceangate Long Beach, CA, 90902-4341 (310) 590-4527
FracTrac	MCA Engineers, Inc. 2960 Airway Avenue, #A-103 Costa Mesa, CA 92626 (714) 662–500
SID	MIL Systems Engineering Inc. 700-1600 Carling Avenue Ottawa, Ontario K1Z 8R7 CANADA (613) 722-2247
SIMS	University of California at Berkeley Department of Naval Architecture & Offshore Engineering 202 Naval Architecture Bldg. Berkeley, CA 94720 (510) 642-5464

F.2 Application Programs

HECSALV	Herbert Engineering Corp. 98 Battery Street, Suite 500 San Francisco, CA 94111 (415) 296-9700
CARGOMAX	Herbert Engineering Corp. 98 Battery Street, Suite 500 San Francisco, CA 94111 (415) 296-9700
TACTICS	American President Lines (APL) 1111 Broadway Oakland, CA 94607 (510) 272-8000
	Ship Research Incorporated 455 17th Street, Suite 301 Oakland, CA 94612
VMS	Chevron Shipping Company 555 Market Street San Francisco, CA 94105 (415) 894-7700

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[6] E.F. Codd. Relational completeness of data base sublanguages. In *Data Base Systems*, volume Vol. 6 of *Courant Computer Science Symposia Series*. Prentice-Hall, Englewood Cliffs, N.J., 1972.

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Project Technical Committee Members

The following persons were members of the committee that represented the Ship Structure Committee to the Contractor as resident subject matter experts. As such they performed technical review of the initial proposals to select the contractor, advised the contractor in cognizant matters pertaining to the contract of which the agencies were aware, and performed technical review of the work in progress and edited the final report.

Mr. Paul Cojeen	U.S. Coast Guard
LCDR Rob Holzman	U.S. Coast Guard
Mr. Yung–kuang Chen	American Bureau of Shipping
Mr. Kurt Hansen	U.S. Coast Guard
Mr. Fred Seibold	Maritime Administration
Dr. Robert Sielski	National Academy of Science, Marine Board Liaison
CDR Steve Sharpe	U.S. Coast Guard, Executive Director Ship Structure Committee