DIMENSIONS OF HUMAN RESOURCE MANAGEMENT
ON COMMERCIAL VESSELS

by

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ABSTRACT

The focus of this thesis is on the management of human resources on commercial ships. This report and other concerns studying human resources on ships result from the high percentage of marine casualties caused by human error. Shipboard work environments that cause stress and fatigue are considered to contribute to the frequency of human error. The first section of this report lays the ground work for a Coast Guard Research and Development Center project on human errors in marine operations. Operational and Organizational Dimensions (OODs) - which define aspects of the ship operations to include management's approach, labor's negotiated contract concerns, type of ship and area of operations - are defined and given applicable scales and ranges. Scales and ranges help further define the OODs and give the Coast Guard a way to measure the prevalence of these dimensions. Shipboard routines relevant to an on board evaluation of the human factor issues causing excess fatigue and stress are discussed to help in undertaking such on-site research.

This thesis continues in the second section to address human resource management concerns from a competitive basis with due regard to safety and work environment issues previously discussed. Different approaches, or paradigms, to vessel operations are reviewed. In particular, the option of operating a highly automated ship with a reduced number of crew members is discussed. Differing levels of this paradigm exist in the U.S. fleet, and these are reviewed as reflective of the OODs. Finally, as reduced crews call for the use of riding or maintenance gangs to be temporarily placed aboard vessels, current and optimal uses of these riding gangs are discussed.

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Acknowledgment

I would like to dedicate this work to my father, Robert J. Gerard, for motivating me in an exemplary manner through both his life endeavors and his academic endeavors.

I would like to thank Professor Henry S. Marcus for his assistance throughout this research and for making this academic year possible. Appreciation also goes out to the ship operating companies and the individuals in those companies who provided assistance and input to this project.
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Chapter 1.0 INTRODUCTION

This thesis will cover various operational aspects relating to the safe operation of merchant ships. Particularly, it will view operating parameters pertaining to a vessel's human resources, or front line operators. The focus of this paper is twofold. The first focus or section of this thesis will complement a current project undertaken by the U.S. Coast Guard Research and Development Center in Groton, Connecticut. The Center's project is titled "Human Resource Management for Commercial Vessels" and will address human factors as they relate to current practice and operation on U.S. merchant vessels. Specifically, Chapters 2, 3 and 4 will address the Coast Guard's concerns. These chapters cover Operational and Organizational Dimensions (OODs) of ship operations, safety issues and casualty data bases, and finally measurement tool development for surveying merchant ship crews. The second focus, or section, of this thesis will further investigate some human resource options for current and future ship operations. This section is slanted more towards competitive operations in today's shipping markets. These Chapters, 5 and 6, cover merchant fleet paradigms, and riding (or maintenance) gang options and scenarios. This second section should be considered with due regard to issues covered in the first section; the underlying agenda being safe vessel operations.

It has become apparent that many marine casualties (collisions, oil spills, groundings) are the result of human error. It is believed that these errors may have resulted from operator fatigue or other factors brought on by working and living environments on board merchant vessels. The objective of the Coast Guard's human resource project is threefold and is outlined as follows:

1. To identify and define merchant marine work environment characteristics that affect crew performance and safety.

2. To develop measurement tools for collecting data on board merchant marine
vessels and for weighing the effects of the above work environment characteristics.

3. To collect data during actual sea going voyages and to interpret that data from crew responses to the measurement tools.

The long term goal of the Coast Guard project is to measure the effects of the work environment on the crew of merchant vessels. This report will assist the Coast Guard achieve their objectives in the following manner:

1. WORK ENVIRONMENT CHARACTERISTICS: We will help define and categorize a list of Operational and Organizational Dimensions (OODs) that the Coast Guard has compiled. Industry sources have been surveyed in an attempt to establish whether a database on casualty and near miss incidents exists. With proper documentation, such a database would help relate the human factor influences and human errors to the OODs of ship operation, thus centralizing key underlying and contributing factors to marine accidents.

2. MEASUREMENT TOOL DEVELOPMENT: We will assist in the development of human factor measurement tools to be used aboard merchant ships by reviewing the tools formulated by the Coast Guard. We will comment on the practicality and use of the tools as well as insure proper phrasing, terminology and content. We will attempt to help ensure maximum participation and validity of the tools throughout the course of the our input.

3. COLLECTION AND INTERPRETATION OF DATA: This step in the project will be undertaken by the Coast Guard. They will, however, make use of our scaling and defining of the OODs in order to determine which ships to ride and survey.

The ultimate goal of USCG Research and Development Center's project will be to assist the Coast Guard, Maritime Administration and industry in determining safe
operational procedures, requirements and manning levels in an attempt to reduce vessel casualties and improve safe operation. In supporting that goal this thesis will hopefully lay some groundwork for the project by outlining the broad range of vessel operational parameters and some operating options. This will include defining and scaling those dimensions to help the Coast Guard team decide which ships to observe and what questions to ask.

In light of the concern for safety, the maritime industry is continually (although not rapidly) undergoing change. In order for U.S. ship operators to maintain competitiveness, they must have some degree of flexibility and opportunity to make dynamic changes to their operation. Some of the changes may be merely mimicking trends of more competitive maritime nations, but should be considered nonetheless. The second section of this report covers two concepts representing potential options for operators. The first is on merchant fleet paradigms which gives a perspective to operations involving fewer crew, higher technology and more flexible work rules. We will review the merchant fleet paradigms relevant to a shipping company's operating strategy. The paradigms may have a bearing on the more specific Organizational and Operational Dimensions (OODs) of merchant ship operations to be discussed in the first section. The second concept - which would be an integral part of the paradigm shift but is still applicable to status quo operations - is the use of riding (or maintenance) gangs on board merchant vessels. As temporary riding gang use is increasing in current operations, we will further outline the use of riding gangs on board merchant vessels to determine their relevance in the operation and effect on the crew. Input from industry will help define how these gangs are currently being used and give some insight as to how or if they may be optimally used to the competitive advantage of ship operators.
Chapter 2.0 OPERATIONAL AND ORGANIZATIONAL DIMENSIONS

The marine Operation and Organizational Dimensions (OODs) to be identified and defined include all facets of a merchant ship operation that may have fatiguing or fatigue-related effect on the crew. These dimensions are inherent to both company operation procedures and government regulation. They are more specific than the operating paradigms because they may be considered individually whereas an operating paradigm may encompass several of these dimensions. A preliminary list of OODs that the Coast Guard R&D Center has drafted includes the following:

- Crew cohesion
- Crew continuity
- Crew duties/tasks
- Crew size
- Crew work duration
- Crew work schedules
- Level of automation
- Operational trade route
- Organizational work procedures/requirements
- Sea-tour length
- Type of vessel
- Union affiliations
- Union requirements/restrictions
- Vessel's physical condition
- Vessel's officers' work procedures/requirements
- Vessel's maintenance concept
- Watch-keeping schedule

These areas must be considered in looking for ways to reduce the fatigue effect of the operation. They require definition and categorization, and our research involved how accurately they can be defined and measured. These dimensions may relate to the casualty

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1 Antonio Carvalhais, Ph.D., Coast Guard Research and Development Center; Fax to Professor Henry Marcus dated December 21, 1993.
database and to vessel operational paradigms. Recapping the big picture, the Coast Guard would like tie the OODs to the final tools used for measurement of fatigue as it relates work environment characteristics. The questions that the Coast Guard is asking are: Will there be any trends correlating these dimensions to casualties? How will the tools reflect these dimensions? What is the break point of these dimensions and how will they be scaled to relay significant impact? The first step to answer these questions is to define each dimension. These definitions will be given in section 2.1. The second step is to determine a measure of each dimension. These measures are given in section 2.2.

2.1 DEFINITIONS

In the following paragraphs, an initial definition is given to each of the listed dimensions. The definitions are general and make reference to each other where applicable. These definitions are written from a shipboard operational perspective. The stress or fatigue potential of each dimension will also be touched upon where applicable.

Crew Cohesion: Crew cohesion is a reflection of the crew's natural ability to get along socially. This includes both working and non-working encounters as the two are never very far apart. Crew cohesion for an individual may depend in part on the person's duration aboard the vessel and whether that person will be returning to the vessel. "Short timers" may not be accepted as part of the team. Personnel who are assigned to a vessel on a permanent status will transitionally become part of the team. That transition may be smooth or not so smooth as they learn to work with the permanent crew and vice-versa. All personnel on ships must learn to work with the entire crew whether personal conflicts exist or not. Poor crew cohesion leads to conflicts and stress among personnel. Crew cohesion is closely tied to the next dimension, crew continuity.
Crew Continuity: Crew continuity is a reflection of the number of crew members who remain on, or who always return to, the same vessel. Where high crew continuity exists, a returning crew member knows a majority or all of the other crew members with which he will be working. On the other hand, low crew continuity requires crew members to get to know the rest of the crew, learn their own job and learn the working practices of the ship as soon as possible after signing on the vessel. When a crew member joins a vessel for the first time, the job pressures and stresses may be amplified as this person is under the watchful eye of permanent crew. For officers, this period may be a testing ground to see whether or not they will be given a permanent job. I believe that high crew continuity contributes to good crew cohesion. This phenomena was alluded to by a 1992 Drewry shipping consultant report on Liquefied Natural Gas (LNG) carriers. The low turnover of officers on the global fleet of LNG ships has led to long term reliability and safer operations. ²

Crew Duties/Tasks: The duties or tasks of the crew are those items which might appear on a job description for each of the ratings on the vessel. Many of these duties are common to all vessels for each rating. For example, the Second Mate is considered the navigational officer. Knowing nothing else about a ship to which he is assigned, he can be sure that he will be standing eight hours a day of bridge watch (broken down into two four hour watches); will be in charge of correcting the charts, laying the course lines and maintaining the bridge equipment; in addition to supervising at the bow or stern during docking and undocking. These general items are fairly standard, but each ship will also have its own particularities about who does which (more specific) jobs. Particular duties and tasks will also be reflected in the organizational work procedures and the vessel's officers' work procedures.

² Drewry Shipping Consultants LTD, Trading in LNG and Natural Gas: Global Patterns and Prospects. (London 1992), 63-64.
Crew Size: On an international level crew sizes may vary greatly. On U.S. ships crew sizes are fairly standard and will depend on the ships, laws, regulations, and bargaining agreements. The trend may be slowly heading towards crews that reflect the minimum permissible by regulation. Depending on one's perspective, reduced crew sizes may detract from any social relationships because of the 24-hour rotating cycles of watch standing in addition to adding to each person's work requirements or responsibilities. If everyone is working during your off work period, then you will be spending your free time alone (or with others from your watch). However, fewer crew may also require a greater team effort by those remaining on board. This team effort could break barriers between departments and ratings and result in greater crew cohesion. Also, the number of crew will dictate the amount of hours a crew member will be expected to work in the course of a day. Fewer crew members may mean more hours of work for those remaining. Crew work schedules and watch keeping schedules may have to be adjusted to crew size, particularly in the case of reduced crew size.

Crew Work Duration: Crew work duration is the amount of time a crew member may be working during one particular call out. For instance, watches normally consist of four hour time frames, and those on watch will normally be off immediately preceding and following watch. The normal work duration is four hours. Work duration is most likely extended during odd hour call outs for evolutions such as docking or undocking. Under these circumstances crew members may spend several hours working overtime and then immediately commence their four hour watch cycle. The vessel's unlicensed crew are normally allowed rest periods or breaks during their assigned period on watch due to bargaining agreements. Officers may not be afforded the time for breaks, especially while in port. Crew work duration is an integral part of crew work and watch keeping schedules.
Crew Work Schedules: Work schedules basically consist of time on and off watch. Crew work schedules are likely to be one of the greatest contributors to fatigue, in addition to being the most difficult dimension to address due to the 24-hour operation on ships. This section will address this sleep deprivation and fatigue concern along with defining/outlining the work schedule. Watchstanding crew will stand two 4-hour watches per day, which makes up their eight hour work day. Any overtime work that the crew performs revolves around their watch schedule. The standard three watch system consists of six watches daily broken down as follows (starting at midnight - 0000):

0000 - 0400  
0400 - 0800  
0800 - 1200  
1200 - 1600  
1600 - 2000  
2000 - 2400

The three watches are referred to as the 12 to 4, the 4 to 8, and the 8 to 12. Crew members may have a preference as to which watch they stand as some watches are more conducive to a good night's sleep. The unlicensed personnel are sometimes given a choice of watch depending on seniority or time on board. The Officers are assigned watches specific to their position. Usually, the Chief Mate (& First Asst. Engineer) stands the 4 to 8, the Second Mate (Second Engineer) stands the 12 to 4 and the Third Mate (Third Engineer) stands the 8 to 12. On ships where the Chief Mate and First Assistant Engineer are day workers, there will be two Third Mates and two Third Assistant Engineers to stand the 8 to 12 and the 12 to 4 watches while the Second Mate and Second Engineer will stand the 4 to 8 watch. Most crew members will work the maximum amount of overtime that they are allowed. This both adds to their paycheck and keeps them busy during less eventful sea transits. Working overtime also requires the crew members to
schedule sleep between watches and the work day (0800 to 1700). In particular, the 12 to 4 watch standers will break their sleep into two periods during the night instead of one long period of sleep. This will increase this watchstanders' susceptibility to fatigue. A crew member's ability to cope and adjust to the watch and work schedule he will be keeping will affect the stress and fatigue levels that he experiences.

**Level of Automation:** The level of automation varies widely in the U.S. merchant fleet. This is largely due to the working life of ships. Older ships (20 to 30 years) certainly do not have the automation that recently built ships have. Levels of automation are outlined in the following section and they certainly have a bearing on several of these dimensions. Automation is reflected in labor-saving devices. As long as this automated equipment is working well, it will make many jobs easier to accomplish. Automation primarily saves both time (man hours) and physical exertion, hence reducing fatigue.

**Operational Trade Route:** The operational trade route will influence the crew's physical and mental status by the number of port calls in a given period and by the climate or weather encountered during the course of a voyage. Both of these aspects have the potential to reduce the amount of sleep or rest that the crew members receive, in addition to adding to their levels of stress and fatigue.

**Organizational Work Procedures/Requirements:** These procedures and requirements are most likely outlined by the company and should be found in the company's operating manual. These will affect more particular tasks and duties and will represent the company's way of doing things. These procedures will normally fit into the generic job description of the ratings aboard most vessels.
Sea-Tour Length: The sea-tour length is the amount of time that a crew member will spend signed onto a vessel. This time, from the seaman's perspective, often goes hand in hand with vacation time. A standard sea-tour length is hard to define because it varies from company to company and from union to union. Although personal preferences will vary, most vessel personnel would consider four months (120 days) a full or complete assignment. Depending on the vacation earned, sea tour lengths along with vacation may vary from 4-months on/4-months off, to 4-months on/2-months off, to 2-months on/2-months off (to name a few). To measure the effect of sea tour length I think an evaluation early in a crew member's tour followed by an evaluation later in the tour would be required. During a four month tour for example, most personnel consider themselves "burned out" during the final month.

Type of Vessel: The type of vessel will certainly influence the amount of work and the condition of the crew. Tankers are generally considered more labor intensive than container ships. Tankers will also vary regarding work load depending upon trade route and type of tanker. Product and chemical tankers, which require frequent tank cleaning and cargo configuration calculations plus frequent loads and discharges, are more labor intensive than crude tankers, which are normally on a two port trade route and have a standardized load plan and homogenous cargo.

Union Affiliations: Union affiliation is a requirement for many of the jobs in the U.S. merchant fleet. Opinions will vary widely regarding the need and purpose of the unions. Many personnel support and back the union and its functions. Others consider the union just a required aspect of the job and participate in no other way except paying required dues. It is unlikely that a crew member’s union affiliation will affect his stress and fatigue level on board a ship. In light of this, a large percentage of sea-going personnel may
experience stress regarding the stability of their job due to the increased scarcity of U.S. ships and sea-going jobs regardless of which union they are affiliated with.

**Union Requirements/Restrictions:** The union representing the personnel on board will have some bearing on the work practices of that vessel. The union will normally have some limits or restrictions regarding the work its members will have to perform. These restrictions may have detrimental effects on the overall operation or on a specific job at hand. For instance, some jobs may be held up due to a union requirement that a certain crew member or rating is required by contract to perform a contributing function or to simply be present. The frustration this causes to a crew member who is more concerned with just finishing the job in a timely or efficient manner may lead to stress.

**Vessel's Physical Condition:** The physical condition of the ship relates to everything on the ship from cargo gear to crew amenities. A common anecdote on ships is that the gear required to fix something will have to be fixed prior to starting the original project which was set out to be done. A vessel that is in poor condition definitely has an adverse effect on the crew. Nobody likes to work on a rust bucket. The physical condition may be a reflection of the company's maintenance concept, the age of the vessel, or conditions (weather or frequency of port calls) under which the vessel operates.

**Vessel's Officers' Work Procedures/Requirements:** The officer's work procedures and requirements are generally similar from vessel to vessel. These will vary according to the type of vessel (i.e. container or tanker) and according to the Master's and the Chief Engineer's way of doing things. In lieu of overbearing senior officers or the personalities of those officers, this would not measurably contribute to crew fatigue.
**Vessel's Maintenance Concept:** The maintenance concept is determined by the operating company and is inherent in its operating paradigm. At one end of the spectrum, the company may be highly dedicated to vessel maintenance; time and money will be spent to maintain the vessel at all times. At the other end, the company may plan to operate the vessel only for a given number of years. In this situation, the effort given towards maintenance decreases as the vessel nears its termination point with the operator. As that operating period comes to an end, the vessel may be in extremely poor physical condition due to scaling back maintenance (spending). This ties back to the vessel’s physical condition, and a vessel in poor physical condition detracts from the human (or operator’s) interface with that ship.

**Watch Keeping Schedule:** Watch keeping schedules are outlined under crew work schedules. Currently, the three watch system is required by law on U.S.-flag ships. As stated in 46 USC §8104:

> (d) On a merchant vessel of more than 100 gross tons...the licensed individuals, sailors, ... and water tenders shall be divided, when at sea, into at least 3 watches. A licensed individual or seaman in the deck or engine department may not be required to work more than 8 hours in one day.

For categorizing the dimensions in the next section, the watch keeping schedule and the crew work schedule have been incorporated into one dimension.

### 2.2 CATEGORIES / MEASUREMENT / SCALES

Currently, there are little or no data regarding these dimensions and their effect on merchant vessel crews. These dimensions need to be categorized and reduced to 2 to 3 critical OODs (those with the greatest adverse effect on crew fatigue and performance) in
order to increase their utility in the Coast Guard’s study. In this section the dimensions are given measurement values and scales where applicable and possible in an attempt to allow prioritization of the significance of their relation to safe vessel operations. Due to the qualitative and/or diverse nature of some of the dimensions, no attempt is made to give them quantitative measurement values. The nature of these dimensions are discussed in the next section, section 2.3.

**Crew Continuity:** Crew continuity can be directly measured as the number of crew members who return to the same vessel. These crew are considered permanent crew members. This number will depend to a large degree on union requirements for job rotation. Therefore, on union manned ships this number will generally be lower than for non-union (or “independent” or “company” union) ships. Nearly all ships, including union vessels, will maintain a permanent roster of 3 to 5 persons. This will be the starting point for comparison. The top four echelon positions will generally be permanent: this includes the Captain, the Chief Mate, the Chief Engineer and the First Assistant Engineer. Variance will normally occur with the First Assistant Engineer who may rotate through the union hiring hall. A fifth permanent person may include the (Chief) Steward.

The next category for continuity would be maintaining 5 to 8 permanent personnel. This category generally involves the next step down the echelon ladder. This would (with some variance) include the Second Mate, the Second Assistant Engineer and perhaps the (Chief) Cook. Variance from this scheme might occur where different unions - with different job rotation requirements - are representing the deck and engineering officers. For instance the deck officers union may allow stipulation for permanent assignments to vessels where as the engineers are required to rotate through the union hall. With the Captain, Chief, Second and Third Deck Officers plus the Chief Engineer, First Assistant Engineer and the Steward permanent, we still have a permanent crew of 7.
A final category of permanent crew members would be 8 or more. With most crew levels at 21 or greater, this allows for a multiple of variations. However, this may represent the smallest category in terms of number of ships with permanent crew and is therefore grouped together. At the lower end of this scale it is likely that all the officers on the vessel are permanent with the crew rotating because of company policy or union requirements. The next step up from this level would include the Steward and the Cook plus the Bosun (foreman of unlicensed deck crew members) as permanent crew members. The high end of this category would include the entire crew assigned to a particular vessel.

Crew Continuity may exist and also be reflected on ships where a minority of the crew are designated to a certain vessel, but where all crew members are employees of the same company and rotate among several similar vessels in that company’s fleet. Under these circumstances, the top echelons in each department may be permanent to the ship, but over time the crew members will get to know each other from past assignments and will be familiar with equipment and operating practices from experience on the Company’s other vessels. For our purposes, this situation will be reflected in the last category of 8 or more permanent crew members and should resemble the high end of this category.

In summary we have the following break down of crew continuity:

<table>
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<th>CATEGORY</th>
<th># PERMANENT CREW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>3-5</td>
</tr>
<tr>
<td>Average</td>
<td>5-8</td>
</tr>
<tr>
<td>High</td>
<td>8 or more</td>
</tr>
</tbody>
</table>

Crew Duties/Tasks: The duties and the tasks of the crew vary according to the paradigm approach of the operator, regulations, and union requirements. One legal stipulation limiting the diversification of work roles is that members of the deck and engine department can not work in the other department. In part, 46 USC §8104 states:
(d) On a merchant vessel of more than 100 gross tons... the licensed individuals, sailors,... and water tenders shall be divided, when at sea, into at least 3 watches. A licensed individual or seaman in the deck or engine department may not be required to work more than 8 hours in one day.

(e) On a vessel designated by subsection (d)

(1) a seaman may not be -

(A) engaged to work alternately in the deck and engine departments; or

(B) required to work in the engine department if engaged for deck department duty or required to work in the deck department if engaged for engine department duty;

As mentioned under the definition section, duties and tasks are generally outlined according to the crew member's rating on board the ship. This may vary however, for some members of the ship. The difference will likely involve only approximately three individuals. If the ship is run in a traditional manner with traditional labor unions aboard, than there will be no crew duty and task flexibility. If, however, the operator is utilizing some of his crew in a "maintenance" department (not the deck or engine department as per above USC), then those in the maintenance department will be able to work in either the deck or engine department depending upon where they are needed. The crew duties/tasks therefore can only be measured as traditional or flexible. Remember, a flexible duty/tasks structure will likely involve 3 to 5 unlicensed (and likely the least skilled) crew members who would be able to work in both the deck and engineering departments.

Crew Size: On an international level, crew sizes are ranging from 10 to over 30. In 1992 the average number of jobs per ship for the U.S. fleet was 26.0.³ The breakdown of crew

³ U.S. Department of Transportation. Maritime Administration. U.S. Oceangoing Merchant Fleet
sizes in the Maritime Administration’s report *U.S. Oceangoing Merchant Fleet Operators and Crewing Levels* is compatible with the intent of this report. A breakdown of these crew sizes and some particulars for the U.S. fleet are given below in Table 1. Note that in the “Less than 21” category the average jobs per ship is low by U.S. standards at 15.82. This is because integrated Tug/Barge units were included in the report. Also the average number of jobs in the “Greater then 30” category is driven up by the two U.S. cruise ships which have crews of three hundred.

**TABLE 1: BREAKDOWN OF CREW SIZES ON U.S. VESSELS**

<table>
<thead>
<tr>
<th>Crew Size</th>
<th>No. of Ships in this Category</th>
<th>Average No. Jobs per Ship</th>
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<tbody>
<tr>
<td>Less than 21</td>
<td>51</td>
<td>15.82</td>
</tr>
<tr>
<td>21</td>
<td>66</td>
<td>21.00</td>
</tr>
<tr>
<td>22-24</td>
<td>70</td>
<td>23.23</td>
</tr>
<tr>
<td>25-26</td>
<td>73</td>
<td>25.40</td>
</tr>
<tr>
<td>27-30</td>
<td>58</td>
<td>28.26</td>
</tr>
<tr>
<td>Greater than 30</td>
<td>58</td>
<td>42.48</td>
</tr>
</tbody>
</table>


**Crew Work Duration:** Crew work duration is difficult to define in a scalar fashion. Differences will be found in the amount of overtime that the crew is working aboard different ships, in addition to the occasional use of two watch standing deck or engine officers instead of three. Non-watchstanding crew members will work a standard eight hour day with a one hour break for lunch. Four scenarios exist which will outline different

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work durations for the watch standing crew. These scenarios are; no overtime, standing 6
and 6 watches, overtime call out immediately prior to or following watch, standing 6 and 6
watches and working additional overtime.

If there is little or no overtime being worked by the crew, then the normal work
duration will be four hours. The watchstanding crew will stand four hours on watch
followed by eight hours off watch.

Occasionally watchstanders will rotate the watches in a six-on, six-off manner in
order to cover for temporary loss of a watchstander. This may occur if a watchstander
becomes incapacitated to stand watch, there is a shortage of crew, or if the Chief Mate or
First Assistant Engineer - normally watchstanders - are temporarily excluded from the
watch standing cycle to attend to other duties. In this scenario, those standing the
watches will work for six hours straight.

When a crew member turns to for overtime immediately before or after watch, it is
likely that he or she will work for an eight hour duration. Most call outs for overtime will
involve four hours of work, excluding arrivals and departures which are job completion
dependent.

A final scenario may exist where a crew member standing a six hour watch cycle is
required to complete off watch work. Potentially, this could extend the work duration to
ten hours. This crew member will also be returning to work with less time between call
outs. For example, if he works four hours after watch, he will only have two hours to rest
prior to returning to work for a six hour watch.

In light of these scenarios, the work duration can most practically be measured in
two hour increments of 4, 6, 8, or 10 hours. For a more general measurement, the
average number of hours worked per day could be used.

Crew Work Schedules and Watch Keeping Schedule: As discussed previously, a crew
member’s work schedule will depend on whether he is a day worker or watch stander, and
then, if a watchstander, which watch he is standing. Table 2 below outlines a twenty-four hour day showing the work and rest periods for each of four categories (day worker, 12x4 watch, 4x8 watch, 8x12 watch). The entries in the chart may be defined as follows:

**IDLE** - crew member is either sleeping, resting, eating or any other activity outside of assigned work.

**WORK**- these are the times during which the crew member is performing his watch or day work duty for his eight hours per day.

**O.T.** - **OVERTIME** - at these times the crew member is working hours in addition to his eight hour day.

Note that "IDLE" or "O.T." in the chart indicates that theoretically it is the crew member's choice as to whether or not he will work overtime. During an "all hands" scenario all crew members are required to turn to for overtime. An "all hands" situation occurs during docking, undocking or an emergency situation. The following table outlines a routine day at sea or in port. An "all hands" call out may happen at any time of day or night, but is excluded from the following chart as it is not a day to day evolution. Also note that breakfast, lunch and dinner meal hours are from 0730-0830, 1200-1300, and 1700-1800 respectively. No one other than watch standers work during these periods.
There is no clear cut method to measure how the work schedule will affect the crew member’s fatigue or stress level. What is more important is knowing to which category the crew member belongs. However, individuals will split their sleep according to their preference. Normally, one would find that the day workers and the 8x12 watch get their sleep in one shot at night. The 12x4 normally will split his night sleep into two periods and the 4x8 practice may vary between these two norms. To narrow the above categories it may be easier to consider only whether the crew member sleeps for one period or two shorter periods during the night. Shift work and its implications are difficult to account for as individuals have varying thresholds to adjustment.

**TABLE 2: DAILY CREW WORK SCHEDULES**

<table>
<thead>
<tr>
<th>DAY WORKER</th>
<th>12 X 4 WATCH</th>
<th>4 X 8 WATCH</th>
<th>8 X 12 WATCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000-0100</td>
<td>IDLE</td>
<td>WORK</td>
<td>IDLE</td>
</tr>
<tr>
<td>0100-0200</td>
<td>IDLE</td>
<td>WORK</td>
<td>IDLE</td>
</tr>
<tr>
<td>0200-0300</td>
<td>IDLE</td>
<td>WORK</td>
<td>IDLE</td>
</tr>
<tr>
<td>0300-0400</td>
<td>IDLE</td>
<td>WORK</td>
<td>IDLE</td>
</tr>
<tr>
<td>0400-0500</td>
<td>IDLE</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>0600-0700</td>
<td>IDLE</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>0700-0800</td>
<td>IDLE</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>0800-0900</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
<td>WORK</td>
</tr>
<tr>
<td>0900-1000</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
<td>IDLE OR O.T.</td>
</tr>
<tr>
<td>1000-1100</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
<td>IDLE OR O.T.</td>
</tr>
<tr>
<td>1100-1200</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
<td>IDLE OR O.T.</td>
</tr>
<tr>
<td>1200-1300</td>
<td>IDLE</td>
<td>WORK</td>
<td>IDLE</td>
</tr>
<tr>
<td>1300-1400</td>
<td>WORK</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
</tr>
<tr>
<td>1400-1500</td>
<td>WORK</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
</tr>
<tr>
<td>1500-1600</td>
<td>WORK</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
</tr>
<tr>
<td>1600-1700</td>
<td>WORK</td>
<td>IDLE OR O.T.</td>
<td>WORK</td>
</tr>
<tr>
<td>1700-1800</td>
<td>IDLE</td>
<td>WORK</td>
<td>IDLE</td>
</tr>
<tr>
<td>1800-1900</td>
<td>IDLE OR O.T.</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>1900-2000</td>
<td>IDLE OR O.T.</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>2000-2100</td>
<td>IDLE OR O.T.</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>2200-2300</td>
<td>IDLE OR O.T.</td>
<td>IDLE</td>
<td>WORK</td>
</tr>
<tr>
<td>2300-2400</td>
<td>IDLE</td>
<td>IDLE</td>
<td>IDLE OR O.T.</td>
</tr>
</tbody>
</table>
The physical difficulties in dealing with shift work are prevalent in a multitude of industries, and the drawbacks have been well documented. First, shift workers (shoreside) are likely to have low levels of well being, poor social life's, in addition to increased family and social problems. Difficulties in shiftwork are compounded during night work involving vigilance, tasks under relative perceptual isolation or monotonous surroundings. A report titled “Fatigue at Sea” written by Circadian Technologies, Inc. of Cambridge, Massachusetts focuses on lack of sleep and fatigue issues prevalent in the operation of marine vessels. The report points to Automatic Behavior Syndrome, Microsleep, Sleep Inertia, and Chronic Fatigue as common experiences (and underlying contributors to casualties) by watch standing personnel. Definitions of the above sleep disorders are given in the report along with approaches to measure and combat fatigue. Unfortunately, fatigue caused by sleep, work cycles, and shifts has different effects on different people. Some crew members’ bodies can simply adjust easier to the watch and work rotation on ships. The Circadian Technologies report recommends Alertness Surveys, to measure the extent of alertness problems; Medilog, a walkman like device to continuously record physiological data; Multiple Sleep Latency Test (MSLT) a simulation that serves as benchmark for evaluating alertness; and Attitude Surveys, to gain insight to individuals circadian rhythms.

Level of Automation: The level of automation is both a primary indicator of the operator's paradigm as well as a key issue to investigate regarding Organizational and Operational Dimensions. Automation dictates, to a degree, the manning level of a vessel

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5 Ibid.
7 Ibid.; 3.
and the work characteristics of the vessel. To scale this dimension the automation levels that can be found on board ships as outlined in the Maritime Administration (MARAD) report PRC '93 (published but not released) will be used. 8 PRC '93 is the latest MARAD report to survey shipboard manning levels on a modern containership. These levels incorporate the shipboard task analysis model derived in Crew Size and Maritime Safety and are used to determine a merchant ship manning chart as a function of technology level. 9 The following explanations of technology levels are taken verbatim from PRC '93. As defined by PRC, five levels of automation and technology have been identified for commercial ship application. The five levels are: (A) Engine Room Automation: (B) Navigation/Ship Control Automation: (C) Human System Integration: (D) Advanced Maintenance Concepts, and (E) Artificial Intelligence.

Level A: Level A has been available for ships since the 1960s. Level A measures engine room automation and permits unmanned engine room operation, leaving the engineers and unlicensed staff to work during the day on routine maintenance. Alarms in the on-duty engineer's stateroom and bridge notify the crew in the event of the need for engine room attendance during off-daywork hours. The alarm will spread to common crew spaces and then specific staterooms if no acknowledgment of the alarm is made. Specific examples enabling Level A automation include, but are not limited to:

- Bridge fitted remote control of propulsion machinery, and monitoring and alarm devices for propulsion machinery and its direct auxiliaries.
- Automatic start of lube oil, fuel oil, and cooling water standby pumps for propulsion machinery.

8 Sealift Technology Development Program. Assessment of Advanced Manning Techniques, PRC, MARAD, August, 1993
- Propulsion machinery safeguard system (excessive revolution and loss of lube oil pressure)
- Automatic temperature control of propulsion machinery fuel oil, lube oil, and cooling water.
- Automatic control of electrical generation and distribution system including load shedding under casualty conditions.
- Generator safeguard system (overspeed and reverse current protection).
- Automatic temperature control of generator lube oil and cooling water.
- Shielding of main engine fuel injectors (diesel powered ship).
- Automatic start of fire pumps to maintain fire main pressure set point.
- Engine room machinery alarm installed in each of the engineer's quarters.
- Remote control level gauge and high level alarm for all fuel oil tanks.
- Automatic data logging device for main propulsion machinery.
- Remote control system for fuel oil injectors (diesel propulsion plant).

**Level B:** Level B has been available since the late 70s and early 80s, but was not prevalent until 1990. Level B automation deals with the Navigation/Ship Control System. Essentially, this permits a bridge watch of two persons. An electric chart display is driven by a touch screen and shows the ship's location. Navigation charts for each of the waterways and harbors the ship visits are aboard and have been digitized into the onboard computer. The collision avoidance system, operated by the mate, is a reliable enough detection system to permit only 1 lookout. Steering can be done manually, although the autopilot is frequently used. Stateroom call systems eliminate the need of a mate making rounds waking each member of the ensuing watch. Automatic alarm systems linked to the bridge replace the need for any monitoring through a roving watchman. Specific examples of Level B include, but are not limited to:
• Satellite Navigation System/Global Positioning system (GPS), Loran, electronic charts, ARPA and auto pilot systems constituting an integrated navigation system. The GPS system has an imbedded training capability (i.e. simulation).
• MARISAT satellite communications capability, providing reliable worldwide real-time communications, between ships at sea and home base.
• Global Maritime Distress and Safety System (GMDSS), which automatically alerts land based search and rescue agencies, as well as ships at sea, when a ship is in distress.
• Remote control devices for mooring winches (bow and stern) which provides automatic tensioning control, along with an enclosed operating space.
• Control and monitoring of the water ballast and clean bilge system both on the bridge or in the engine room, plus a monitoring capability in the deck office.
• Power driven sideports, cargo rampways, and hatch cover handling devices.

Level C: Level C entails the integration of Levels A and B into one user-friendly unit. A single operator has all the ship controls at his finger tips: engine controls, rudder controls, internal and external communications equipment, fire and flooding alarms, and a radar based collision avoidance system supported by a back-up low visibility system. Examples of Level C technologies include, but are not limited to:
• Loran
• Electronic charts, (Individually digitized by the crew)
• Infrared search and track for low light navigation and surveillance
• ARPA
• Auto pilot systems which constitute the integrated navigation component and the main engine control which constitutes the propulsion component. The system also has an imbedded training capability.
**Level D:** Level D describes advanced maintenance concepts that are only recently finding commercial shipboard applications. The purpose of Level D automation is to prevent catastrophic failures, and eliminate unneeded preventive maintenance. Examples include, but are not limited to:

- **On-line Readiness Test System (ORTS)** which automatically monitors the performance and trends of critical on-line systems (electronic, electrical, and mechanical) and reconfigures the appropriate system around faults or activates redundant systems as required. ORTS alerts the watch when any system or equipment performance falls to a specific level.

- **Vibration Analysis** sets a baseline level for rotating machinery and monitors change over time. Vibration analysis prevents unnecessary maintenance and gives ample warning of impending catastrophic failure. The function can be automated and tied into the ORTS.

- **Automated Fuel Oil Analysis** provides assurances that propulsion and auxiliary prime movers are not damaged by fuel impurities.

- **Spectrograph Lube Oil Analysis** provides another early warning of rotating machinery's impending failure. The process will be automated through ORTS.

**Level E:** Level E covers advanced concepts in artificial intelligence. Ideally, all ship systems would be computer controlled and the operator's only function would be to override for safety or maintenance reasons. The closest date for commercial shipboard implementation would be beyond 2000. Level E examples include but are not limited to the following:

- The Navy's AEGIS Combat System (ACS) is the seaborne system which comes closest to the levels of automation/artificial intelligence envisioned for overall ship control beyond 2000. Once the ship's location and system operation parameters are...
determined and entered, ACS automatically meets these parameters, identifies, analyzes, and counters threats, updates itself from shipboard sensors and remote data feeds, monitors its material condition and automatically reconfigures itself around faults. ACS's range of operations is from fully automatic to local manual.

- Mitsubishi Heavy Industries (MHI) has developed a bridge operation support system that uses artificial intelligence to automatically navigate a ship and prevent collisions, strandings, and groundings. The system is called Super Bridge and is an enhanced version of MHI's Super TONAC integrated navigation system. The fully automatic alarm and monitoring systems are designed to permit one-man bridge operation. MHI also developed Super Plant, an advanced engineering plant monitoring and maintenance system, and Super Cargo, an advanced cargo handling system. Together, the bridge, plant, and cargo systems make up what the company calls Super ASOS, the Super Ship Operation Support System. The first ASOS is being installed in a very large crude carrier (VLCC) under construction at MHI's Nagasaki shipyard.

**Operational Trade Route:** There are two ways in which the operational trade route may affect the condition of the crew. The first is the number of port calls in a given period of time. Because port calls normally represent the busiest and most intense period for vessel operations, the crew ideally would receive sufficient rest between ports. However, this is not always the case. For instance, a typical voyage for a U.S.-flag containership trading in the Far East consists of a 10 to 14 day Pacific transit from the West Coast followed by approximately eight or more port calls in a two week period, and then a return trip across the Pacific. The two weeks of port calls in the Far East requires frequent "all hands" operations such as docking and undocking. These operations may take place at any time
of day or night. Also, because the docking or undocking evolutions depend on berth availability, cargo completion time or harbor pilot availability, these call outs are subject to extended periods of time or last minute notification. Additionally, arrivals and departures from port, plus coastal legs of the voyage, are the most stressful periods for the ship's officers. During these periods the deck officers have to deal with greater traffic density and more navigational hazards. The engineering officers must monitor the main engines and machinery more closely due to varying vessel speeds, engine warm up or cool down and the increased possibility of emergency maneuvering. The crew members are now dealing with not only higher stress operations, but they are doing so with less than normal sleep or rest.

The operational trade route may also affect the stress and fatigue of the crew if the route is in areas of consistently poor weather. Operations in poor weather may adversely affect the crew's stress or fatigue level by interrupting sleep or by making daily and routine tasks more difficult. A good example of this is the tanker trade in and out of Alaska, especially during the winter months. The Gulf of Alaska is notoriously rough during the winter months, and this is the final leg of the tanker's voyage before entering port. Following perhaps one or two days of the vessel rolling and/or pitching excessively, the ship's crew will dock at Valdez and commence the critical operation of loading crude oil irregardless of the amount of sleep that they have had.

The operational trade route will apparently have some influence on the condition of the crew. Measuring this effect should involve tracking the number of arrivals and
departures per week. The difficulty in weighing these values will be that they will vary for certain legs of the voyage.

Weather will also be difficult to account for as its influence may be segmented. Wind Force may serve as a simple measurement of adverse weather. For example a wind of Force 5 or greater may be considered a starting point at which weather will start to adversely affect the comfort of the crew (for most vessels). This value, or a greater value of wind force, would than have to be related to a period of time or percentage of time that those conditions are encountered.

Another option would be to use the vessel’s load line restrictions which determine to what draft a vessel may load in accordance with the season and the intended route of the vessel. These regions and seasons are reflective of the expected weather and could be used to define the boundaries of varying influence of adverse weather on a crew’s normal area of operation. 46 CFR §42.30 outlines the zones, areas, and seasonal periods for the International Maritime Organization’s (IMO) International Convention on Load Lines (the regulating convention). The convention breaks the seasons and the oceans into tropical, summer, winter and winter North Atlantic geographic areas. The winter North Atlantic consistently has the roughest weather and is the most restrictive Load Line. Globally, the oceans were divided into the following regions for Load Line purposes:

- Northern winter seasonal zone
- Southern winter seasonal zone
- Tropical zone
- Seasonal tropical areas
- Summer zones
- the Winter North Atlantic
46 CFR §42.30 delineates these areas by parallels of latitude, longitude and geographic
land masses. The applicable seasonal dates are also given. The Load Line ocean regions
are illustrated in Figure 1.
**FIGURE 1: LOAD LINE CHART OF ZONES AND SEASONAL AREAS**

Sea Tour Length: In the previous section the various sea tour length scenarios were described. Crew members will typically sign on board the vessel for two, three or four (or more) months. When surveying crew members, it may suffice to just inquire the amount of time - in days - that the person has been on board.

Type of Vessel: The type of vessel can be described as in the following list.

- Crude Tanker
- Product Tanker
- Chemical Tanker
- General Cargo
- Intermodal (container or RoRo)
- Bulk Carrier

As of December 1, 1992 there were 35 general cargo vessels, 128 intermodal vessels, 18 bulk carriers, and 175 tankers in the active United States oceangoing merchant fleet.10 As mentioned earlier, the vessel, the cargo, and the trade route are all integral parts of how the vessel may differ in fatigue and stress inducing environments. Tankers, due to the nature of the cargo and the greater involvement of the crew in ensuring safe loading and discharging, may introduce greater levels of stress to the responsible personnel. Three types of tankers are listed above because in general, one will find the assortment of cargoes on board will add the number of port calls and the amount of time spent loading and discharging and hence, the level of stress. Chemical tankers carry more diverse cargoes, up to forty different grades at a time, and are the "busiest" vessels to work.

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Noting the type of vessel, along with its schedule immediately preceding and following a port call will give some indication of the crew’s susceptibility to exhaustion.

Union affiliation and union requirements/restrictions are also variable and difficult to quantify. Nearly all shipboard personnel are part of a maritime union or a company employee association. Due to the large number of maritime unions, differentiating between the unions and their negotiated rules would be impracticable. Company associations are handling fewer personnel than the unions and they are closer to their ship’s concerns and requirements. For survey purposes, one may simply look into whether the crew belongs to a national union or if they work for the company in an “independent” or “company” union.

2.3 NON-MEASURABLE / NON-SCALEABLE OODs:

The following OODs have not been given measurable or scaleable definition. They are however important to the overall evaluation of a ship’s operation and play a role in the condition of the crew. The dimensions are:

- Crew Cohesion
- Organizational work procedures/requirements
- Vessel’s physical condition
- Vessel’s officer’s work procedures/requirements
- Vessel’s maintenance concept
Crew cohesion, organizational work procedures, vessel’s physical condition, and vessel’s maintenance concept are all covered in depth in the previous Section 2.1. Definitions and qualitative parameters are covered and should be noted as qualitative asides to any direct survey or evaluation on the condition of merchant ship crews.
This chapter will cover the prospects of marine casualty data recorded by various shipping companies and other sources, and how this data may be related to a quantitative measure of human error. The scrutiny of the human error factor as causing the majority of marine casualties is growing. For instance the UK Club, who insures over 25% of the world's merchant fleet, contends that human error is the biggest fault underlying protection and indemnity claims. As illustrated in the following Figure 2, the UK Club blames human error for 90% of the $200 million annual cost of collisions; 80% of the $400 million of property damage claims; 65% of the $360 million spent on injuries and 50% of both cargo and pollution claims ($600 million and $250 million respectively). If the UK club figures are correct, then human error is costing an annual total of $1.159 billion in claims each year.

12 Ibid., 16.
FIGURE 2:  HUMAN ERROR CAUSED P&I CLAIMS
(figures in million of dollars)

The focus of this chapter is twofold. The first objective, covered in section 3.1, is to outline an attempt to establish the existence of pertinent casualty data that may incorporate human factor elements and how they played a role in the casualty. The second objective is to review other attempts at studying and organizing the human element in marine operations to better understand its role in marine casualties, section 3.2. Section 3.2 is further divided into three subsections. Subsection 3.2.1 reviews the Marine Transportation Research Board’s study of human error completed in 1976. Subsection 3.2.2 reviews a 1993 doctoral dissertation on human and organizational error in marine systems. Subsection 3.2.3 summarizes the existence of existing marine casualty databases outlined in the doctoral dissertation.

3.1 SURVEY ON CASUALTY DATA

In order to get a handle on what casualty data collection exists and whether any of the information is in database form, seven shipping companies were solicited for relevant information. The companies were sent a copy of the questionnaire shown in APPENDIX NO. 1. All seven of the companies responded and contributed either by telephone interview or written responses to the questionnaire. The responding companies will all remain anonymous, but a brief outline of each company follows.
• **Company A** is a U.S.-flag tanker company. The company operates coastal product and crude tankers.

• **Company B** is a U.S.-flag diversified company. The company owns and operates tankers and dry bulk ships world wide.

• **Company C** is a large U.S.-flag company operating tanker and dry bulk vessels world wide.

• **Company D** is a U.S.-flag tanker operator. The company's product tankers operate primarily coastwise.

• **Company E** is a large foreign-flag chemical tanker company and operates ships world wide.

• **Company F** is a U.S.-flag container ship company operating ships in various liner trades.

• **Company G** is a U.S.-flag container ship company operating ships in various liner trades.

Each company has a varying definition of “casualty”. Most define an incident by the term casualty depending upon monetary or other significant repercussions. The responses by the companies illustrate that a broad and general spectrum of data is gathered during a casualty or near casualty investigation. The amount and the specifics of that data vary from company to company as do their reasons for the casualty data collection. Some companies indicate that the collected data is part of a Total Quality Management effort and is used to reduce errors and costs. Other companies investigated casualties -
depending on the size or costs - for insurance or liability purposes. Some investigations, depending on the nature of the incident, are conducted for regulatory requirements.

46 CFR §4 - Marine Casualties and Investigations - outlines the reporting and investigating of marine casualties in addition to the submittal of marine casualty investigation reports. A marine casualty or accident is defined by 46 CFR §4.03-1 as follows:

(b) The term marine casualty or accident includes any accidental grounding, or any occurrence involving a vessel which results in damage by or to the vessel, its apparel, gear, or cargo, or injury or loss of life of any person; and includes among other things, collisions, strandings, groundings, founderings, heavy weather damage, fires, explosions, failure of gear and equipment and any other damage which might affect or impair the seaworthiness of the vessel.

Subpart 4.03-2 continues to define a serious marine incident as any marine casualty or accident as defined above which is required to be reported on a Form CG-2692 and which results in any of the following:

(1) One or more deaths;
(2) An injury ... which requires professional medical treatment beyond first aid ... which renders the individual unfit to perform routine vessel duties;
(3) Damage to property ... in excess of $100,000;
(4) Actual or constructive loss to any vessel subject to inspection under 46 USC 3301; or
(5) Actual or constructive loss total loss to any self propelled vessel ... of 100 gross tons or more.

Chapters (b) and (c) of this subpart continue to include an oil discharge of 10,000 gallons or more plus the discharge of a reportable quantity of a hazardous substance into the navigable waters of the United States as serious marine incidents. Subpart 4.05 calls for the submittal of a written report on Form CG-2692 “at the port which the casualty
occurred or the nearest port of first arrival.” Form CG-2692 must be submitted for all of the above listed reasons in addition to the following and more limiting reasons as per 46 CFR §4.05-1:

(b) Loss of main propulsion or primary steering, or any associated component or control system, the loss of which causes a reduction of the maneuvering capabilities of the vessel ...;
(f) An occurrence not meeting any of the above criteria but resulting in damage to property in excess of $25,000. Damage cost includes the cost of labor and material to restore the property to the service condition ...;

The substance of regulatory reporting of marine accidents is not human factor related and does not satisfy database collection requirements. The Coast Guard reporting and investigating authority has a regulatory and policing bent. Much of their effort is focused on who is at legal fault for law enforcement purposes.

The format for collecting data range from detailed company issued forms to non-standard written reports by a senior vessel officer recounting the details of the incident. There are no industry-wide data collection or casualty investigation forms. There appears to be limited knowledge and a limited collection of details outlining human factor dimensions which could have contributed to crew members’ mental or physical fatigue at the time of an incident or casualty. Casualty data that is collected by the companies is put to little use after the incident has been addressed (often company-wide) and corrected. Although recorded information may be kept on file, it would provide little insight in narrowing the potential human factor issues into an equation for addressing living and working conditions on board ships. The companies that do maintain more formal records and investigations do so for Total Quality purposes. These efforts are done to better their...
competitive position in the markets, and these companies are not likely to share their information or disclose their internal investigation and/or remedial procedures.

Outlining the responses to the Questionnaire will give further insight to the extent of casualty investigation currently undertaken by various merchant ship operators. The questions from Appendix No. 1 are repeated for convenience.

CASUALTY DATA QUESTIONNAIRE: RESPONSES

1. Does your company maintain records of all casualty and/or near casualty incidents?

2. Does the company use a standard form or format for recording casualties?

<table>
<thead>
<tr>
<th>Company</th>
<th>Records of casualties?</th>
<th>Standard form to report Casualties?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Company B</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Company C</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Company D</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Company E</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Company F</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Company G</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Company B claimed that near casualty or near miss information is also recorded. Company D stated that recording near miss incidents was strongly encouraged, and
Company G stated that near miss reporting program was getting started. One or two other companies verbally stated that near misses may be addressed if they were significant, but most did not report these. All of the companies had a common policy of a senior or supervisory vessel officer filling out the reports. If an incident was “serious enough” then management would come in and take over the reporting and investigation. Company G has stated that currently a standard form is used for the shipping component of their corporation; however, they are in the process of going a step further and will soon have a corporation-wide (all transportation modes and departments) standard accident reporting form.

3. What qualifies as a casualty or near casualty incident?

All companies interviewed expressed that a number of incidents could qualify as a casualty. Most revolved around those previously mentioned by regulation. No list would be all inclusive as the environment on board ship and in any shipping operation may be susceptible to numerous personnel, vessel, or external environment casualties. Company F had no hard and fast rules, and they considered a casualty “any major incident”. Company G stated that for recording purposes, the key to what is reported is the “loss potential”. The other companies listed casualties as follows.

Company A - collision, grounding, spill, personal injury, allision, weather damage.

Company B - damage to vessel or others exceeding $25,000, delay to vessel in excess of 24 hours (other than normal weather/berthing delays), customer complaint,
pollution incident of any type, serious injury, grounding, death, collision, near miss.

Company C - collision, grounding, fire, death, man overboard, cargo contamination, weather damage, intoxication, fighting on board the ship, illegal use of drugs, spill.

Company D - injury, any unplanned or uncontrolled occurrence.

Company E - collision, grounding, spill, cargo contamination, injury, delay, pollution, regulation violation, inspection deficiency.

4. Do casualty records indicate human factor or fatigue related issues?

Company A - No, but the company is “getting around to that”.

Company B - Human factor issues may or may not be identified in the incident report. There is no question or prompts on the form checking for human factors.

Company C - No.

Company D - Yes, monitor human factors and fatigue, but find no significant trends.

Company E - Yes, the reporting form addresses 20 to 40 possible human factors that may have contributed to the incident.

Company F - If a report is filled out, then human factors may be addressed. Human factors contributing to incidents are not tracked for trends or reoccurrence.

Company G - No, the forms are not that sophisticated yet, but the company is gearing in that direction. New forms will look at basic and underlying causes and not just the direct cause.
5. What is the basis of recorded information?

Company A - insurance; Coast Guard, federal, state agencies; company investigation.

Company B - required for TQM process and for permanent elimination of a problem.

Company C - company use only, regulatory reports are separate and are filed to the appropriate authority.

Company D - for company use to prevent reoccurrence.

Company E - insurance and liability, company investigation, TQM (tracking cause in process), fleet wide distribution for awareness and future prevention.

Company F - internal investigation.

Company G - Basis of recorded information is insurance and litigation. Coast Guard and other agency forms are filled out when they apply.

6. Does the company further utilize the information after it has been reported and filed?

All of the companies answer in the affirmative to some degree. However, none of the companies have computerized database files in which recorded information can be organized, managed or tracked for trends in a logical order. Company G is focusing their attention in the right direction, and this is evidenced by their familiarity with the topic and current literature on the topic. Most of the companies responded in a manner which indicates that the information is used and/or distributed to prevent future reoccurrence and to improve overall operational procedures.
Company A - Yes, information is used for further study and to check for reoccurrence. Note that incidents may be addressed on a company-wide basis even if there has been only one occurrence.

Company B - The results of incident reporting are used to update company procedures, advise other company vessels of potential problems, and to eliminate PONC (price of non-conformance) on a permanent basis. Information is graphed and displayed for the vessel's and office staff's awareness.

Company C - Lessons learned are incorporated into operating policy and practices aboard our fleet. The company is in a constant state of upgrading and reviewing its fleet standing orders.

Company D - Yes, republish findings, examine for trends, put into company safety bulletins to prevent reoccurrence.

Company E - Recorded information is incorporated into cost control bulletins. These are distributed in an attempt to prevent future occurrence of any casualty that will result in costs.

Company F - Apparent trends are known and addressed without referring to the files. The ships should be tracking their own incidents and addressing them as required.

Company G - Not yet analyzing but gearing towards the establishment of a casualty and safety database. The forms are now in a rough format and the process will be implemented in approximately three months. This is part of a much
larger corporate effort and considerable outside help and consultation is being used to better their effort.

The results of the Casualty Data Questionnaire indicate that there is no formalized method for collecting and organizing the contributing factors to marine casualties. In particular, human factor dimensions are addressed minimally. Commercial ship operators are recording casualty information with their own agendas in mind, which appears to be operational improvement in their fleet. To truly address the underlying concerns, a standard, industry-wide investigating and reporting forum is required. The most complete information gathering and reviewing stems from conscientious efforts at Total Quality Management in which some companies are further along than others.

From the interviews and discussions with the above operators, it appears that attempts to review and sort through the casualty information that does exist at these companies in an effort to gain insight to human factor issues contributing to the casualties would be futile. Marine casualties aboard merchant vessels result from an iterative process of contributing factors some of which may or may not have been influenced by human factor issues (i.e. stress, fatigue, lack of sleep). The casualty data that does exist at the commercial ship operators level is provincial in that it addresses the incident itself and not the circumstances of the events leading up to the incidents. The actions by crew members immediately preceding or following the incident may be included in the reporting systems, but these do not provide the required spectrum of events and are more or less a piece of the incident itself. Another restriction in evaluating these records is that the
majority of incidents do not incorporate formalized investigations. Normally, the information that is reported is done so by one of the vessel officers. These officers are not trained in incident reporting and investigation. Also, there may be some motivational or cognitive biases and/or incompleteness in these reports. Finally, the companies that do record and file the most complete information do so for Total Quality process improvement. This is a strategic move by these companies and they are the least likely to release their methods or their collected information.

To satisfy the requirements of a complete casualty database that includes the human factor dimension, a formalized reporting and investigating procedure would have to be implemented. This would require a standard reporting form that prompts the appropriate questions and completeness of the investigation because of the difficulty in having trained investigators look into every casualty or incident. Furthermore, the system would require voluntary and diligent participation on the part of a solid number of ship operators.

3.2 PAST AND RECENT LOOKS AT THE HUMAN FACTOR ELEMENT

The human factor element in marine transportation has not been investigated nor regulated to the degree of other transportation industries. However, it has been reported upon to varying degrees over the years. Unfortunately, only the severest casualties may initiate the interest and produce thorough investigations and reports. Two of the studies
that have been conducted may be useful in organizing efforts to update the casualty reporting system and in the development of a industry wide casualty data base with human factors tracked in a quantifiable manner. The first was a five year study by the Maritime Transportation Research Board (MTRB) titled Human Error in Merchant Marine Safety. The second, more recent study, was a doctoral dissertation by William Henry Moore, Jr. titled “Management of Human and Organizational Error in Operations of Marine Systems” submitted to the Naval Architecture and Offshore Engineering graduate division of the University of California, Berkeley.

3.2.1 THE MARITIME TRANSPORTATION RESEARCH BOARD, 1976

The MTRB study was initiated as a result of an internal 1970 report on merchant marine safety. This first report detailed the extent to which human error played a role in marine casualties. The Human Error in Merchant Marine Safety report was published in 1976 following investigations and data collection from 1971 to 1976. The report relied on interviews and an in-depth survey mailed to marine industry personnel. The survey, however, was overly extensive and consisted of 192 questions. Limitations to this report resulted due to the self-reporting style of the questionnaire (which would lead to biases) and because only 25.6% of the 1400 questionnaires were returned.

The report was successful in isolating fourteen factors that are major or potential causes of casualties. Some of the factors parallel aspects of the OODs such as poor operation procedures and excessive personnel turnover. The fourteen factors are:

- Inattention
- Ambiguous pilot-master relationship
- Inefficient bridge design
The factors listed by the board unfortunately do not address the real concerns of their investigative purpose nor concerns that still exist today. Many of the factors are either an effect or a cause of another underlying factor which needs to be addressed. For example, inattention may be the result or effect of inefficient bridge design which might be the cause. Many of the factors can (and have been) addressed by company operating policies, national and international maritime organizations and by regulation. Nevertheless, the report is significant because it narrows the scope of current efforts to strictly human factor issues which are the result of operational procedures. Today the operational practices that cause these effects need to be better understood and addressed. Four of the factors listed above (inattention, poor physical fitness, excessive fatigue, and excessive personnel turnover) are indicative of present concerns. Additionally, the study demonstrates the difficulties faced in collecting data and inherent industry wide practices which make reporting difficult. These include degree of motivation of personnel in completing self-reporting questionnaires, underlying biases of shipboard personnel, and possible attitude changes in personnel depending on whether they are on vacation or

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currently signed on a ship. The major conclusions of the report were that existing databases are inadequate, that an industry-wide data collection program is needed, and that existing data is useful only in evaluating overall safety performance. The 1970’s and 1980’s did show improvements in shipping safety and concerns for safety; however, since this report, little or no progress has been made in addressing their conclusive evidence of a lack of data and concerns focusing on the human element in marine operations. We have made little progress in our ability to track and address the root causes leading to human error in marine operations.

3.2.2 WILLIAM H. MOORE, JR., DOCTORAL THESIS, 1993

In William Moore’s dissertation, “Management of Human and Organizational Error in Operations of Marine Systems”, the human factor element has been isolated from the operational factors contributing to marine accidents. Accidents, however, may be and usually are the result of a combination of both human and organizational error. Moore further points out the deficiencies in current documentation of marine casualties or near misses. Existing data bases that list a single input for “human error” or “operator error” are not sufficient to attack the root causes. The objective of Moore’s dissertation is to create a methodology to assess the interactions between humans and organizations that lead to human error in the operation of marine systems. Moore points out that errors may result from inattention, carelessness, inadequate training, and physical limits (to name a few), and all of these are compounded during periods of stress and panic. The organizational structure may influence many of these errors and a breakdown in the
organizational and human elements may result in a system failure or casualty. Moore used two past casualties (the Exxon Valdez grounding and the Occidental Piper-Alpha platform explosion) as a basis for setting up his framework methodology. The following outlines his methodology.

For the human element to be integrated into a Quantitative Risk Analysis (QRA) it must be modeled similar to any other component in the system. In modeling the human element, one must consider how various "states" (i.e. fatigue, folly, laziness, bad judgment) are reached as a result of internal and external environmental factors such as adverse weather, darkness and heat. Influence diagrams are used in modeling the human and organizational errors (HOE) to various error contributors. These influence diagrams provide an analytical framework which provide simplified "templates" that preserve the causative mechanisms for casualties in marine operations. This framework allows underlying, direct, and compounding contributors to be incorporated into the model. The components of the influence diagram are (1) decision or chance nodes represented by circles or ovals, (2) arrows to indicate relationships between nodes in the diagram, (3) deterministic nodes, whose outcome is determined deterministically from the preceding nodes, represented by double lined ovals, and (4) value nodes represented by a rounded edge rectangle for a distribution of values, or a rounded double border rectangle for expected values.14 Two examples of influence diagrams are shown in Figure 3 and in Figure 4. Figure 3 shows how human errors can be shown in an simplified influence

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diagram as a result of contributors such as human factors, organizational errors, system errors and environmental factors. Without reviewing the details, Figure 4 shows an influence diagram of the events, decisions, and actions leading to the Exxon Valdez grounding. As the time frame and levels of contributing factors are expanded, the diagrams quickly become more dense.
FIGURE 3: SIMPLIFIED INFLUENCE DIAGRAM MODELING HUMAN ERROR

FIGURE 4: INFLUENCE DIAGRAM; EVENTS, DECISIONS, ACTIONS LEADING TO EXXON VALDEZ

GROUNDING

Using this scheme, Moore sought to quantify the human errors conditional on the error contributors by developing a measuring technique (computer program) called the Human Error Safety Index Method (HESIM). The HESIM measures organizational, task and systems complexities, and environmental factors that may influence an operator's ability to make decisions and to take actions in preventing a casualty event. The HESIM relies on measurements from a "safety index". The "safety index" would be formulated from expert judgments, experiences, and objective data. The worksheet user interface for the HESIM is shown in Figure 5. The ten buttons across the top of the HESIM worksheet are used for providing quantitative measurements for human errors conditional upon various operating conditions.

To collect the objective data for the HESIM, Moore developed a second computerized database program called the Human and Organizational Error Data Quantification System (HOEDQS). The HOEDQS may be updated and refined and permits less reliance on judgmental indexing and more on objective data. The spreadsheet user interface for inputting or analyzing data for the HOEDQS is shown in Figure 6. The buttons at the top of the spreadsheet are used for inputting casualty or near-miss information. Each of the buttons prompts questions or inputs regarding relevant aspects of that topic. The GOTO button allows the user the switch directly into the HESIM worksheet.

The HESIM and the HOEDQS are then used to update a failure event index. This index is then matched against the failure probabilities for a particular event. The probability of an accident event can then be determined under various human operator
conditions. A second purpose of the HOEDQS is to allow generation of quantitative measures of human and organizational errors to marine casualties and near misses. The HESIM-HOEDQS program is designed to run on Macintosh personal computers using the Microsoft Excel version 4.0 software package. A user's guide for both the HESIM and the HOEDQS programs and an operating guide for the influence diagram templates is provided in the Appendix to Moore's dissertation.
**FIGURE 5:** HESIM WORKSHEET USER INTERFACE WINDOW

<table>
<thead>
<tr>
<th>GOTO DATA INPUTS</th>
<th>Organizational Safety Index</th>
<th>Task Safety Index</th>
<th>Environmental Safety Index</th>
<th>UPDATE SAFETY INDICES</th>
<th>SELECT NEW DATA CRITERIA</th>
<th>Calculate Marginal HE/OE Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUIT</td>
<td>knowledge/training/exper MOE1</td>
<td>maintenance MOE2</td>
<td>violation MOE3</td>
<td>morale/incentive MOE4</td>
<td>job design MOE5</td>
<td>regulating/policing MOE6</td>
</tr>
<tr>
<td>human/system interface</td>
<td>HE1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>knowledge/training/experience</td>
<td>HE2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mental/physical lapse</td>
<td>HE3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>violation</td>
<td>HE4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>job design</td>
<td>HE5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>communication/interaction</td>
<td>HE6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.3 SUMMARY OF OTHER EXISTING DATABASES

In his dissertation, Moore also summarizes existing databases. Unfortunately, these existing databases do not provide sufficient information to model probabilities with the previously described mechanisms. The extensive reporting and investigations following the Exxon Valdez grounding and the Piper Alpha platform explosion allowed these incidents to provide a basis to Moore's techniques and to permit testing of the models. The existing marine casualty databases include CASMAIN Marine Casualty Database, the Marine Casualty Human Factors Supplement (a supplement to CASMAIN), the World Offshore Accident Database (WOAD), and the Institut Français du Pétrole (IFP). A brief summary of Moore's description and cited shortcomings of the databases follows.

CASMAIN is the US Coast Guard's vessel and personnel casualty database. In 1992 CASMAIN had more than 58,000 marine casualties recorded. For each casualty there are 71 vessel input fields and 37 personnel input fields, 3 fields to input the nature of the casualty, and 5 fields to input the accident cause. CASMAIN is the most extensive casualty database available. However in light of the difficulty in modeling human error, the database has many shortcomings. The format is single dimensional in that it does not account for the complete interaction of human errors and error sequences. The system is also task oriented and does not account for associated events and errors at different stages of the system failure. Finally, Moore also claims that much of the information is inaccurate and incomplete.
The Marine Casualty Human Factors Supplement was developed by the Coast Guard as a supplement to CASMAIN in order to take the human element into account. Casualty error information is related to the role, position, and education of the personnel involved in the marine casualty. This system is a modified alternative to the Annotated Human Factors Taxonomy (AHFT) developed by the Dynamic Research Corporation to identify complex interactions related to marine casualties. The shortfall of the Coast Guard’s modified system is that it does not capture the interactions leading to the accident and still does not allow for the documentation of errors at different stages of the scenario.

The World Offshore Accident Database (WOAD) is the world’s largest offshore casualty database. This system allows for the analysis of time dependent trends in offshore safety for various operations to include drilling, fixed platforms, mobile offshore drilling units. The database provides what events initiated the accident but little or no other causes of the accidents.

The final existing database is the Institut Français du Pétrole (IFP). This database is divided into two categories: one for platform accidents and the other for tanker accidents resulting in spills of at least 500 metric tons. It includes worldwide data since 1955. The system is limited in that it records oil spill incidents only and excludes other marine accidents. An advantage of this system however is that it includes both a digitized input field and a field for informational inputs. The digitized field permits well defined statistical inputs similar to the other databases, while the informational field allows for inputs particular to the case that are not easily captured in the digitized field.
3.3 CONCLUSIONS

It is, and has been, apparent that human error is the underlying cause to a large percentage of marine accidents and casualties. However, pinpointing the contributing factors that cause these human errors is less apparent. Analytical study must go beyond the immediate events triggering a casualty. In the past, casualty investigations and reports did not unveil the multitude of causative mechanisms. A survey was undertaken to determine if industry was accounting for or tracking the issue of human error on board their merchant ships. The companies interviewed are all concerned with the human element in their operation; however, their agendas are primarily driven by regulation and by insurance considerations. A few companies are more cognizant of the human factor element and are in the early stages of tackling and evaluating the problem.

Other concerned parties and institutions have addressed this human factor issue, but no one has come up with an action plan for reducing this contributory element in marine operations. Several of the studies have come to the same conclusion. That conclusion is that a well documented database of marine casualties or near misses is required to evaluate and focus on the underlying human element causes of these incidents. The database needs to be designed specifically for this purpose. The companies surveyed have not yet made progress in this direction, and their past records are not complete enough or are not available to initiate this database. The latest study of marine casualty databases and of applicable quantitative analysis in evaluating databases was addressed in...

In closing, although recorded data on casualties does exist, it does not provide the necessary information to incorporate into a complete database for modeling the probability of marine casualties based on human error. The models and database format for a comprehensive view of how the human element contributes to marine casualties does exist. For this know-how and these techniques to be useful, a centralized effort will be required to standardize and implement an industry-wide casualty data collection and reporting system. Until this is done, and an original database with appropriate inputs has been developed, efforts to quantitatively evaluate human factor effects on marine casualties will be difficult.
Chapter 4.0 MEASUREMENT TOOL DEVELOPMENT

To better understand the fatiguing and stress related aspects of the living and work environments on board ships, the Coast Guard’s project will eventually lead to actual on site surveys and evaluations using measurement tools. The Coast Guard R&D personnel (or contractors) will ride various vessels to better acquaint themselves with the OODs of ship operations. Human factor measurement tools will be tested and used at this time - under actual work conditions - to collect data on current conditions relating vessel personnel to operating dimensions. These data will be the base of investigation by the Coast Guard in studying the effects of OODs on crew fatigue and performance, hence allowing them to assess whether the OODs exert differential effects on how well crews adapt or cope with merchant marine work requirements. The difficulty in these measures will derive from both the on location measurement plus particularities in shipboard phrasing, terminology and standard practices. Hopefully, this report has shed some light on a few routine shipboard regimes. This chapter will review some generalizations about testing crew members on ships, thereby assisting in how to best administer the study to achieve maximum cooperation and completion from the personnel aboard the vessels.

The survey and measurement of fatigue issues on board merchant ships was addressed in 1990 by the Volpe National Transportation Systems Center (VNTSC) in Cambridge, Massachusetts. Their report, Shipboard Crew Fatigue, Safety and Reduced Manning, discusses the difficulties they faced and the lessons they learned in evaluating ship crews. The focus of this report was on the attention span and depth of the personnel
while carrying out routine vessel operations. Inattention is indicative of excess stress and fatigue and can lead to operational error. Standard measurement of attention performance is accomplished either through physiological indicators or behavioral approaches. Physiological tests for fatigue include brain electrical activity, heart rate, heart rate variability, and core body temperature.\(^{15}\) Physiological indicators, however, were found to be impracticable for shipboard use for the following reasons:\(^{16}\)

- invasive
- time-consuming
- require specialized and sophisticated equipment
- require calibration of the individuals tested
- require sophisticated analysis of the collected data
- are often done "off-line" rather than "real time"

Behavioral tests for fatigue - which include looking behavior, subsidiary task performance and control movements - were also found impracticable.\(^{17}\) The behavioral approaches were found unsuitable for the following reasons:\(^{18}\)

- not unequivocally related to fatigue
- require a training and calibration period
- not self-administering
- results may be impacted by factors other than fatigue

The fact that these two standard approaches were found impracticable may be suggestive of the obstacles in gathering significant data.

However, the VNTSC team was successful in narrowing the issues regarding measurement tool implementation. Due to limitations in their early work on this area, they


\(^{16}\) Ibid., 4-2.

\(^{17}\) Ibid., C-1 to C-3.

\(^{18}\) Ibid., 4-2.
resorted to in-depth interviews and observations taken on board various merchant vessels. From an operational viewpoint, they found objective assessments of behavior to be the most valid.\textsuperscript{19} Most significant was their eventual use of the \textit{Mariner's Fatigue Survey Form}. This self-reporting combined survey form covered both activity and fatigue/sleep data on a daily basis for the seaman. A 24-hour schedule is listed in rows, at one hour per row, down the left hand side of the report, with nine columns across the top covering various shipboard/living activities.\textsuperscript{20} The reporting personnel simply has to draw a line under category of his activities respective to the hour(s) the day. The activity categories include:\textsuperscript{21}

- watchstanding
- maintenance (scheduled and unscheduled)
- supervising/training
- other operations
- off-watch paperwork
- leisure, eating, personal
- sleeping
- unusual conditions

Additionally, these survey forms allow brief, check-off inputs regarding the vessel location (open-water, pilot-waters, anchored, berthed), amount of trouble falling asleep, and waking and current rest status.\textsuperscript{22} This format for surveying personnel's activities was successful because it was brief (2 to 3 minutes to complete, one page only) and because it was a once-a-day reporting format.\textsuperscript{23} Additionally, any self-reporting forms should not require timed responses (i.e. just before going to bed or just after waking up). Although

\textsuperscript{19} Ibid.
\textsuperscript{20} Ibid., 6-4.
\textsuperscript{21} Ibid.
\textsuperscript{22} Ibid.
\textsuperscript{23} Ibid., 5-10.
these are critical times, waking crew members usually have limited time to prepare and wake themselves for watch. Following watch, especially a night watch, many crew members will only be concerned with going STRAIGHT to bed. Time requirements for filling out forms will serve to lessen valid participation.

Along with the VNTSC team’s conclusions, a few other aspects of shipboard routine should be pointed out. As previously mentioned, interviews and observations may prove useful in evaluating dimensions of the operation. The timing of these interactions may be difficult to schedule, but an extended period of time may be required within reason. A full one week visit would prove far more useful than a few day trips between ports. Port time, to include arrival and departure, is the busiest period for ship operations. During this time observations should be made, and interviews held off until the vessel is at sea or under routine watches and work schedules. During routine days at sea, most personnel will take a coffee break from 1000 to 1020 and from 1500 to 1520. This time may provide an opportunity to talk to several crew members at one time. It does not provide sufficient interview time, but it will allow an interviewer time to meet members of the crew. In terms of number of people, the largest turnouts are in the engine control room for engine room personnel and in the crew’s mess room for unlicensed deck personnel. The senior officers may take their coffee breaks on the bridge, and the watchstanding deck officers could likely be interviewed during a less eventful bridge watch. Once a week, the entire crew - excluding those necessary for continued vessel operation - will be gathered for about one hour for fire and boat drill. This drill is required by law. This time is designated for emergency and fire drills, but again may allow an
interviewer an introduction to most of the crew if this is deemed necessary. A cooperative ship operator with cooperative crew may give researchers some of this time to conduct business.

In closing, it is likely that objective data collection is most practicable. However, more formal data collection techniques may prove more valid if active participation could be obtained. The personality types found at sea will vary greatly, as will their motivations for working at sea. However, one underlying incentive for personnel to work at sea is a good wage and the ability to put money in the bank due to lightened costs of living on board ship. Most of today’s seamen, officers and unlicensed crew, identify with this motivation.24 With this in mind, it is possible that more complete data collection could be collected with monetary incentives. Another approach may be to reimburse participating companies the cost of the personnel’s overtime if on board surveys and analysis will detract from their work schedule.

Chapter 5.0 REVIEW OF MERCHANT FLEET PARADIGMS

The competitiveness of the shipping industry has stimulated a variety of operating strategies (or operational paradigms) to increase efficiency. These paradigms reflect both corporate and national trends. The operating paradigm of the shipping company may have direct relation to the human factor issues to be addressed. These paradigms will be outlined and defined, but our primary consideration in paradigms consists of the vessel's use of automation as it relates to the man-hours required for operation and the company's approach to crew assignments and working practices. Highly automated ships for example may require fewer crew members (e.g. less "manhandling") to perform various tasks. At present, the crew size of relatively modern U.S. vessels is nearing a standard of 21 to 24 persons. Some strategies, however, used by other nations in their reduced crew paradigms are being incorporated by U.S. operators. The Operational and Organizational Dimensions (OODs) that were covered in Chapter 2.0 may be dependent or inherent upon these paradigms.

5.1 INTERNATIONAL PERSPECTIVE

Joel Barker defines a paradigm as "... a set of rules and regulations (written and unwritten) that does two things: (1) it establishes or defines boundaries, and (2) it tells you how to behave inside the boundaries in order to be successful."\textsuperscript{25}

In a merchant fleet there are different types of paradigms. For example, each type of vessel might have a paradigm unique to its function: a passenger ship would require different activities from its crew members than a tanker (and would be affected by different regulations). A paradigm might be affected by the trade route, including such

\textsuperscript{25} J. A. Barker, Future Edge, Discovering the New Paradigms of Success, (William Marrow and Co., Inc., 1992), 32.
factors as the number of days per round trip, the number of port calls and the climate. Although these examples of paradigms cannot be ignored, this section of this thesis will focus on what we call operational paradigms: those that describe the ship owner’s/operator's overall operating strategy. One example of an operational paradigm deals with crew assignments. If a ship owner/operator is employing permanently assigned crews dedicated to a certain ship or class of ship, he can consider certain types of training, whether technical or managerial (TQM), to increase the operational efficiency. If his paradigm is driven by transient crews that may never sail his vessel again, then such training would be outside the boundaries of his operational paradigm.

The operational paradigm of the ship owner must be addressed in its initial design. Length of ownership/operation, amount of crew accommodations, size and continuity of the crew, the extent of reliability and redundancy of equipment, and the maintenance strategy can all affect the design of the ship's operational paradigm. A maintenance strategy involving whether temporary maintenance gangs or temporary technicians riding aboard the vessel, or shore-based personnel, will be included in the overall operational paradigm.

Operational paradigms will likely fall between one of two extremes. At one end would be a high number of low-paid seafarers. (Note that this option is not available to owners of U.S.-flag ships since hiring of U.S. crews represents the highest cost in the world.26) With a high number of low-paid seafarers, nearly all preventative and routine maintenance is performed onboard. Savings for the company might be realized through the avoidance of purchasing sophisticated, automated equipment.

At the other end would be a small number of highly skilled, highly paid, seafarers onboard a ship with highly sophisticated, reliable, and redundant equipment. Maintenance

would be taken care of, in part, by maintenance gangs riding aboard the vessel and shore-based personnel, and thus, in principle, allow for a reduction in crew size.

Ship owners flying flags of traditional maritime nations are heading in the direction of the latter - a low number of highly trained personnel on a highly technical and highly automated ship with some maintenance performed by maintenance gangs and/or by shore based personnel. Examples include the COLLEEN SIF, a Danish-flag containership under Knut I. Larsen (KiL) in the international trade and operating with a 10-man crew.27 (In contrast, a typical modern U.S.-flag containership has a crew of 21.)

Crew continuity is essential for reduced manning of vessels. Ships with a small number of highly paid seafarers are characterized by low personnel turnover, high levels of familiarity with the ship and their duties, and crew operations that are not hindered by contractual restrictions. Cross trained deck and engine department unlicensed personnel are the standard on reduced-crew international vessels. (Such crew members are sometimes designated as a maintenance department.)

The current operating paradigm for U.S.-flag containerships provides a dramatic contrast to those of the foreign flag competitors. Table 3 compares the typical U.S.-flag containership operating paradigm with the foreign-flag paradigm containing a small number of highly paid seafarers (typical of traditional maritime nations using a high percentage of its citizens.) One of the few common factors is the level of sophistication of technology aboard the ships. In both cases use is made of the latest in reliable and/or redundant technology. While the manning level on a U.S.-flag containership has decreased over the years to 21, the foreign competitors are putting even fewer people on their ships. The foreign-flag ship owner has the ability to have crew members permanently assigned to vessels. Therefore, if the owner spends money on training, whether for specialized technical activities, team building, or total quality management, he knows these

people will be returning to his containership, or at least a similar ship in his fleet. In the U.S.-flag containership paradigm, only four to seven persons would be permanently assigned to a ship. It is interesting to note that on the U.S.-flag containership there is high P&I insurance costs, high personal injury cost not covered by P&I insurance, and no physical fitness for duty testing.28 The foreign-flag containership, however, has lower costs related to personal injury claims and P&I insurance.29 There appears to be no need for physical fitness testing. With a small crew if someone is not performing his or her job, it is immediately noticed and the person is replaced. The sum effect of the reduced crew scenario may be better crew cohesion and working practices aboard that vessel.

**TABLE 3: COMPARISON OF HIGH PAID FOREIGN-FLAG WITH TYPICAL MODERN U.S. CONTAINERSHIP PARADIGM**

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>U.S.-FLAG</th>
<th>FOREIGN-FLAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Technology</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Number of Crew</td>
<td>Not so Low</td>
<td>Low</td>
</tr>
<tr>
<td>Cross utilization of Unlicensed Crew</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Maintenance Gang Riding Aboard</td>
<td>Limited Use</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of Permanent Crew</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Physical Fitness for Duty Testing</td>
<td>No</td>
<td>Not Necessary</td>
</tr>
<tr>
<td>Personal Injury Claims</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>P&amp;I Insurance</td>
<td>High</td>
<td>Not as High</td>
</tr>
<tr>
<td>Repair Costs</td>
<td>High</td>
<td>Not as High</td>
</tr>
<tr>
<td>H&amp;M Insurance</td>
<td>High</td>
<td>Not as High</td>
</tr>
</tbody>
</table>


28 Ibid., 80.
Table 4 shows that the operating paradigm for non-containership U.S.-flag vessels, such as tankers and roll-on roll-off vessels, differs considerably from the operating paradigm for U.S.-flag containerships described above. While the technology and manning level are similar, some aspects of the operation reflect the reduced crew paradigm of traditional maritime nations. Permanent crews tend to lead to lower personal injury claims. More flexibility exists with cross utilization of unlicensed personnel and the use of maintenance gangs and/or shore-based personnel for maintenance as appropriate. One oil company has started physical fitness for duty testing for its new seafarers. On an oil company tanker, it is more likely that unlicensed crew members would be available to work in either the deck or engine department. One might expect that such flexibility and other characteristics of that work environment might reduce stress and fatigue.

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>OTHER U.S.-FLAG SHIPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Technology</td>
<td>Similar</td>
</tr>
<tr>
<td>Number of Crew</td>
<td>Similar</td>
</tr>
<tr>
<td>Cross Utilization of Unlicensed</td>
<td>Yes</td>
</tr>
<tr>
<td>Maintenance Gang Riding Aboard</td>
<td>Yes</td>
</tr>
<tr>
<td>Permanent Crew</td>
<td>Yes</td>
</tr>
<tr>
<td>Physical Fitness for Duty Testing</td>
<td>Starting</td>
</tr>
<tr>
<td>Personal Injury Claims</td>
<td>Lower</td>
</tr>
</tbody>
</table>


In visiting ships one should look for certain elements of the operating paradigm. A key set of factors will be continuity, the relationship of the crew with the particular ship and the terms of employment. On board U.S. tankers owned and operated by oil companies, one would expect that the crew would be members of an independent (i.e. company) union and fully employed by the oil company (with allegiance to it). The crew
has typically worked in the company fleet and maybe on this particular ship for many
years. Little or no time on board should be used for training or retraining. Crew may
have received some special company training as well.

With the exception of the oil company ships, most other U.S.-flag ships have
crews that come through the union halls (and may owe their allegiance to the union, not
the company). Although 4 to 7 persons may be permanent on the ship, the rest will
probably change relatively often. No company training will have been provided for these
"transients", who may be new to the ship as well as to the other crew members. One
would expect more time aboard the ship would be spent on training and retraining.
Typically, there would be no cross utilization of unlicensed personnel. Operations under
this paradigm may increase the stress and fatigue experienced by the crew.

It will be very difficult to compare operating paradigms aboard different vessels,
because of differences in vessel type, age, propulsion plants, technology, and trade route.
However, when comparing the "oil company paradigm" with others on U.S.-flag ships,
one would expect - relatively speaking - to see on the oil company tanker crews with less
stress about keeping their jobs, more comfortable about dealings with their ship and crew
members, and more comfortable with the flexibility of using unlicensed personnel where
needed. They should view their job as a career with their employer (although if their
employer is cutting back on the number of ships, this won't help). On the typical non-oil
company ships, one would expect to see more time being spent getting acquainted with
equipment and crew members, less flexibility with work roles, and possibly a higher level
of stress.

5.2 OODs RELATIVE TO U.S. PARADIGMS

It is apparent that several OODs are key concerns regarding the ship operator's
operational approach or paradigm. These key OODs are crew continuity, crew
duties/tasks, type of vessel, and some union requirements/restrictions inherent on union affiliation. Two other OODs, crew size and level of automation, are also critical to the paradigm, but these two may be more difficult to differentiate under analysis of U.S. ships. On U.S.-flag vessels crew sizes are concentrating toward 21 crew members and comparisons may be invalid for small variances. The level of automation is likely reflective of the age of the vessel. This aspect will be difficult to use discerning an operator’s paradigm because the depressed shipping markets have left most operators with a broad age range of vessels and hence, varying levels of automation.

The other key OODs mentioned will show some variance and significance in the U.S. fleet. Looking at the progressive side for instance, a vessel may have eight or more permanent crew. This crew will have some flexibility in their work roles (i.e. some deck and engine cross over, or shared responsibilities). The progressive vessel will also likely be a tanker for the simple reason that these vessels (to include operators and crew) have been more receptive to the crew continuity and job flexibility changes. Finally, on this vessel, the crew will either work directly for the company, or, if affiliated with a union, will be permanently assigned to this ship or operating company. The five OODs described for this vessel all fit within the definitions and measurements as outlined in Chapter 2.0.

The OODs are more specific than the paradigms, and varying mixes of the dimensions exist throughout the U.S. fleet. Many of the dimensions will also be contingent upon each other. However, some general trends are apparent and parallel those trends corresponding to the paradigms. The following Table 5 outlines three paradigms by the OODs that they encompass. These paradigms are prevalent in the US. merchant fleet.
TABLE 5: U.S. VESSEL PARADIGMS DEFINED BY OODs

<table>
<thead>
<tr>
<th>OODs</th>
<th>TRADITIONAL</th>
<th>STATUS QUO</th>
<th>PROGRESSIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew Continuity</td>
<td>3-5 permanent</td>
<td>5-8 permanent</td>
<td>8+ permanent</td>
</tr>
<tr>
<td>Crew Duties/Tasks</td>
<td>traditional/fixed</td>
<td>some variability</td>
<td>flexible</td>
</tr>
<tr>
<td>Type of Vessel</td>
<td>Cargo/Container</td>
<td>Cont./RoRo/Tanker</td>
<td>RoRo/Tanker</td>
</tr>
<tr>
<td>Union Affiliation</td>
<td>established and strong</td>
<td>newer unions or company unions</td>
<td>company employees</td>
</tr>
<tr>
<td>Union Req./Restricts.</td>
<td>strict job functions and restrictions</td>
<td>some job functions determined by ship</td>
<td>none</td>
</tr>
</tbody>
</table>

When surveying ship crews for stress and fatigue related to the job, trends in these operational paradigms and their respective operational dimensions may become apparent. These dimensions should be looked at qualitatively and collectively. Underlying contributors to human error on merchant vessels may result from an operator’s conglomerate approach, and not just one or two dimensions of that approach.
Chapter 6.0 RIDING GANG OPTIONS AND SCENARIOS

6.1 CURRENT CREW AND MAINTENANCE PRACTICES

Taking into account the paradigm options and the individual OODs, the growing trend in international shipping operations is to build ships with more advanced technology and automation. This allows a reduced number of highly trained crew members to operate the vessel. A smaller crew with better training and more continuity may provide higher quality vessel management and safer operations. This paradigm differs from traditional and third world practices of using a high number of lower paid and trained seafarers.

A primary concern of the vessel operators and the personnel on the ships for reduced manned vessels is the proper maintenance of the ship. As crew size decreases, more maintenance duties must be shifted from the vessel crew to others including riding or maintenance gangs and port maintenance gangs. Maintenance is necessary not only for the cosmetics of the ship, but also to maintain the ship in a seaworthy and safe condition. Traditionally, with larger crews, maintenance was performed by unlicensed vessel personnel while they were off watch. This work constituted overtime work and pay and usually entailed labor intensive tasks. The riding gangs would allow operators to reduce the number of crew members who simply provide labor to the ship. This would allow the Chief Mate, who normally oversees vessel maintenance, and other vessel personnel, time to tend to other duties as may be required or time to rest.

There is now a further consideration in regards to working hours and the necessary jobs that a vessel's crew is able to complete. As a result of the Oil Pollution Act of 1990 there exists a work hour limitation on board U.S. merchant tankers. Specifically, 46 USC §8104 states:

(n) On a tanker, a licensed individual or seaman may not be permitted to work more than 15 hours in any 24-hour period, or more than 36 hours in
any 72-hour period, except in an emergency or a drill. In this subsection, 'work' includes any administrative duties associated with the vessel whether performed on board the vessel or ashore.

The reduced crews may allow the U.S. companies to be more competitive, but the question now is not only whether ships operated with fewer people will be as safe as past operations with more crew members, but whether the ships operated with fewer personnel can abide by OPA 90.

It is apparent that riding gangs and port gangs may become or are becoming an integral aspect of vessel operations. This chapter will investigate the objectives of using these gangs, the operational aspects of these gangs, the current situation regarding their use, and some human factor impacts. Several companies using riding (and port) gangs have been interviewed to assist in this study. The types of questions to be asked are shown in APPENDIX NO 1.

Seven shipping companies were contacted and all seven responded. These same seven companies were solicited for input on casualty data for Chapter 2.0. The companies responded either in writing or by telephone interview. Each will remain anonymous, but a brief outline of the seven companies will be repeated here for convenience.

- **Company A** is a U.S.-flag tanker company. The company operates coastal product and crude tankers.

- **Company B** is a U.S.-flag diversified company. The company owns and operates tankers and dry bulk ships world wide.
• **Company C** is a large U.S.-flag company operating tanker and dry bulk vessels worldwide.

• **Company D** is a U.S.-flag tanker operator. The company’s product tankers operate primarily coastwise.

• **Company E** is a large foreign-flag chemical tanker company and operates ships worldwide.

• **Company F** is a U.S.-flag container ship company operating ships in various liner trades.

• **Company G** is a U.S.-flag container ship company operating ships in various liner trades.

### 6.2 RIDING GANG OBJECTIVES

1. What are the objectives of hiring a riding gang or port maintenance gang?

2. What would be your primary use of riding gangs?

There are several common objectives in the use of riding gangs. None of the companies are using riding gangs for normal (or daily) operation requirements. **Company G** does not use labor type riding gangs due to crew labor relation and contract reasons. For the other companies, the objective is to bring on board extra hands in busier than normal times such as during preparation for the shipyard, or for large cosmetic projects, or tank maintenance projects that are outside routine ship operation. The vessel’s unlicensed
crew are still used for cosmetics and vessel maintenance. Two major uses of riding gangs stand out above the rest. The first use, which represents the larger percentage of the work done by riding gangs, is labor intensive and/or dirty work. Some of these jobs include descaling (physically scraping rust and old paint), painting, mucking and cleaning tanks or void spaces. A few of the companies mentioned that the ship’s crew often find these types of jobs undesirable. The cleaning and mucking jobs are also more frequently done in preparation for the shipyard, which may occur only every two or three years. This preparation work saves shipyard time and expenses. A second frequently mentioned objective of using gangs is to carry out specialized work such as welding or pipefittings. It would be unusual to find certified specialists in the crew for these jobs. All of the companies emphasized that the riding gangs when used were not freeing up the Chief Mate’s or crew’s time as was suggested in the questionnaire. However, the gangs did allow the ships to maintain some continuity during busy periods. Some of the specific objectives in using riding gangs and particular company responses are listed below.

Company A - Outside (the company) gangs are used once in while and are beneficial from a time standpoint. Occasionally 2 or 3 extra company crew members are put aboard the vessel for tank cleaning. The purpose of the riding gangs is to maintain continuity while undertaking big projects or during busy periods. Primary use would be for a specific sand blasting or big paint job.

Company B - Gangs are hired for either a specific repair job to reduce or eliminate offhire
or down time, or for the upgrading of a company vessel cosmetically or otherwise. Primary use would be specialized work to reduce or eliminate offhire time.

Company C - Foreign riding gangs are placed aboard the vessels, U.S. or foreign flag, when a major job has to be carried out. In port, gangs would be used for tank cleaning for grain cargoes and tank cleaning for high grade petroleum cargoes, or to build rose boxes on tankers when prepping to carry grain. Primarily used for skilled labor (hotwork) and for dirty labor intensive work.

Company D - They are not used to free up the Chief Mate’s time. Primary use is for labor intensive or dirty work (mucking, chipping, painting).

Company E - Objectives are for more specific jobs such as retrofit, adding equipment, and double bottom/void space maintenance. Gangs will do shipyard prep such as scaling while the yard will do the final work. Chief Mate’s and crew’s time is not a concern. Primarily used for skilled or unskilled labor.

Company F - Primary use would be for shipyard preparation, specialized work (welding, pipefitting), and dirty work.

Company G - Riding gangs are not used for vessel cosmetics for labor relation and contract reasons. Technical specialists only are used for machinery and auxiliary equipment maintenance.
6.3 RIDING GANG OPERATIONAL ASPECTS

The survey questions on the operational aspects of riding gangs look into when and where they are used, and how they fit into the vessel operation.

3. Where and when would a riding gang best be utilized in your shipping operation?

Where a riding gang is used is mostly dependent upon where the ships operate, the frequency of their port calls, and the nature of the work to be done by a riding gang. Coastwise vessels will use the gangs during a coastal transit, or when they have several days between port calls. Coastwise vessels may transit an ocean every two to three years for a shipyard period and these times provide time for riding gang work to be accomplished. Often this work is done in preparation for the shipyard or following the yard for clean up. Vessels on foreign trade, but using American riding gangs will likely use the gangs when the vessels are on the U.S. coast. This keeps travel and logistics costs down. For tankers the majority of work is done outside of port because port time is used for critical cargo operations and is not conducive to extraneous work. Some specifics of the companies interviewed are outlined below.

Company A - In port contractors are used, not riding gangs, for port projects. Riding gangs are used coastwise and for an occasional ocean transit.

Company B - Riding gangs would be used on the transit leg of a voyage.
Company C - Riding gangs are mostly used when the vessel is gas free. It is imperative that the vessel wash and gas free tanks as soon as is possible in order to maximize the gas free time prior to the next load. The most cost efficient time to employ riding gangs is on a U.S.-flag vessel working overseas with a foreign (i.e. Indian) riding gang.

Company D - Riding gangs are best utilized on coastwise transit leg.

Company E - 90% of the work is done in transit and not normally in port. Often work is prohibited in port for safety reasons.

Company F - An effort is made to match the riding gang’s time on board equal to the amount of time needed to complete the job. This is usually on a coastwise or shorter leg of the voyage.

Compete G - Not applicable.

4. Would the company have preference of company employed or contracted riding gangs?

5. Would the ships have a preference?

The preference of company employed riding gangs and contracted riding gangs varies by company and there are advantages of each. This option is highly dependent on the labor and crew arrangements for the particular company. The labor pool arrangement used by Company E is the most efficient. In this case, both crew and outside labor are taken from the same foreign labor source. For the U.S.-flag vessels, this type of labor source is not normally available or congruent with current labor agreements. Additionally,
the size of the company and the number of vessels being operated has some bearing on this decision. If riding gangs are used only occasionally, then it is not cost effective for the company to support a labor force that is not fully utilized. Another economic concern is that if outside contractors are used, there may be some down time after their job is complete or the weather may exclude them from working everyday while on board. If company employees are used there is more flexibility in keeping them working on various jobs while they are on board. The preference of the ships also may vary to some degree, but it is felt that the crew on board the ships is mostly indifferent as to where the riding gangs come from. Feedback on this issue follows.

Company A - The company would like to see both company employed and contracted. Employees of the company can be used for other projects which is beneficial. Contractors will only do what they are contracted to do.

Company B - The preference for employing a riding gang is to obtain the best workers you can who will work long hours (up to 15 hours a day) at a reasonable cost. The vessel’s input is considered important.

Company C - This corporation has a minority position in the ownership of a foreign ship management company and has access to that company’s riding gang resources. This foreign company’s gangs are mostly used. The foreign manpower used (Indians) have always proven to be highly experienced and very easy to work with.
Company D - Union contracted labor is used for ship crew and riding gangs. The ship does not have a preference as long as they have bodies.

Company E - Gangs are company hired from a Philippine labor pool, which is made up of approximately 2500 Filipino junior officers and crew. The ship’s crew and riding gangs are taken from this pool, except for the European senior officers. Ship does not normally have a preference, but for some jobs they may prefer to see a European foreman.

Company F - At the present time the company prefers the use of contracted riding gangs. It is not efficient to have company gangs if they are only used occasionally and for short periods. The contracted employees parallels the use of union (not company) personnel on the ships.

Company G - Not applicable.

6. What control would the ship desire over a riding gang? (supervisory or hands off?)

7. What type of supervision would the company want to see over riding gangs?

Supervision of the riding gangs is usually the responsibility of the ship to varying degrees. Supervision may range from total control to simply being reported to regarding progress. Depending on the number of people in the gang, they should have their own supervisor, but he should be a working supervisor. The companies expect the ships to maintain supervision over the riding gangs. The Chief Engineer or Chief Mate will be
responsible for the work according to the job at hand and/or the location of the work. Some particulars of the companies' feedback are outlined below.

Company A - The company expects the Chief Engineer or the Chief Mate to oversee the work of the riding gangs.

Company B - The riding gang foreman will either report to the Master or the Chief Engineer. The company's policy is for licensed officers to oversee the riding gangs.

Company C - The vessels would enjoy having 100% control over the riding gangs because they are highly skilled and motivated workers. Thus, the vessels do not report the completion of the project that the gang was put on for and put them on another project. The vessel is hoping that the office forgot about the gang. This is possible with a large fleet of ships where a gang is placed aboard for an eight month project. These workers typically receive $600 per month salary and earn $1.25 per hour overtime. The vessels maintain supervisory control and the office determines what work will be done. The Chief Mate and the Chief Engineer are charged with ensuring that the gang is furnished with the necessary tools and supplies necessary to complete the job. Supervisory personnel must ensure that the work is carried out properly.

Company D - Ship would desire supervisory control. The Chief Mate or First Assistant Engineer will supervise depending on where the job is located.
Company E - The ship prefers to keep hands off. The company desires a European skilled foreman of licensed ship officer qualifications or higher to accompany the gang.

Company F - The ships want and have supervisory control over the riding gangs similar to their supervisory role over the crew. The gangs also have a designated foreman or supervisor. Chief Mate or Chief Engineer supervise according to the job at hand.

Company G - The technical gangs have their own expert in charge of supervising.

8. Would riding gangs be more beneficial on a time hire basis or on a specific job hire basis?

Ideally, riding gangs can be hired on a combined time and job specific basis. If there are three days between ports and there is a three day job to be done, then this would be the ideal time to use the riding gang. However, due to scheduling, possible weather delays, possible cargo delays and the difficulty in estimating the required time to complete a job the ideal time and job specific basis is difficult to obtain. This again points toward advantages of company employed riding gangs that can be used on various jobs. The greatest problem in hiring outside contractors would be having to pay them for lay days at sea after they have completed their work. The different perspectives on this issue follow.

Company A - Gangs are more beneficial on a time hire basis.
Company B - In actuality you hire a riding gang on a time basis. If they are employed to perform a repair to a specific item and complete say two days before entering a port they are paid for the days they just sit idle.

Company C - If American labor is used than it is more cost efficient to hire on a specific job basis. Foreign labor would be more cost effective on a time basis since foreigners produce more then their American counterparts. Hiring Americans purely on a time basis would be counter productive since the workers would tend to coast through the contract. Foreigners tend to give a good hard day's work everyday.

Company D - Riding gangs are hired for a specific job.

Company E - Both, but as gangs are internal it negates this problem. There is some flexibility in the use of these gangs.

Company F - The gangs are hired to do specific jobs. Their time on board should equal the time to finish the job. The riding gangs however are hired on a time basis. It is up to them to get finished the job in the allotted time. They will work 12 hours a day or whatever it takes to finish the job. Their embarkation and debarkation is scheduled in advance.

Company G - Not applicable.
9. Would the company and ship prefer to supply equipment and supplies or hire a completely outfitted riding gang?

Whose equipment and gear will be used also varies slightly from company to company, but the more deterministic issue is what gear is required by the riding gang. If they are doing work that requires specialized equipment not normally carried on board, then it is likely they will have to bring along their own equipment. Paint and other consumables will normally be supplied by the shipping company in an effort to control their costs.

Company A - Company would prefer the riding gang to have their own tools to avoid squabbles over turf and tools.

Company B - Normally have a gang supply only specialty tools which will be needed. Using company supplied consumables keeps costs down as the company usually can purchase for less cost. Plus the vendor will add 15% to cost for handling charge (may or may not be indicated on invoice).

Company C - The riding gang company would most likely charge the owner for furnishing its own equipment. This is an unnecessary cost.

Company D - For small jobs the company supplies, for large jobs the contractor supplies.

Company E - Again internal gangs negate this to some degree. Heavy equipment shared by ships may travel with the riding gangs (i.e. HP water blasters for scaling,
or coating equipment). Smaller and normal ship equipment items are used from the ship supply.

Company F - A concern for non-outfitted gangs is the liability of the ship’s equipment working properly (company debate).

Company G - Not applicable.

6.4 CURRENT SITUATION REGARDING RIDING GANGS

The questions regarding the current situation delve into how riding gangs are utilized today.

10. Are riding gangs presently used only on foreign flag vessels?

This question is applicable only to companies operating both foreign-flag and US-flag vessels and was based on the author’s presumption of significantly less use of riding gangs than are actually in use today. The answer, where applicable, is that riding gangs are used on both U.S. and foreign-flag vessels.

11. Under what circumstances might riding gangs be used on U.S. ships?

From the interviews and responses to this question, it appears that although the riding gangs are used on U.S. ships, they are not used to the extent that they are used on foreign-flag vessels. When used, the circumstances reflect those for the primary uses of the gangs inquired about under “Objectives”. These uses include specialized jobs, dirty jobs and shipyard preparation. Two particular answers to this question follow.
Company B - US-flag vessels using riding gangs for the reduction of down time (offhire) and for upgrading work.

Company C - Foreign gangs are used only when the vessel is in disrepair and only when the vessel is outside US waters.

12. Are there any difficult legal stipulations to the use of riding gangs?

On the operator's part, there is some doubt as to all of the legal aspects on the use of riding gangs. The primary concern is over the use of foreign gangs on U.S. ships in U.S. waters, which is not allowed. Foreign ship operators do not have this concern. The other legal stipulation would be the number of persons permitted on board as dictated by the Certificate of Inspection (COI). Depending on a vessel's accommodations and on the amount of safety equipment on board (usually certified for a specific number of people), the number of persons permitted to ride the vessel in addition to the crew will vary. The responses from several of the companies outline the relevant parameters.

Company A - Perhaps under workman's comp or Jones Act regulations.

Company C - US law stipulates that foreigners are not allowed to work on US ships within US waters if they do not possess work visas. Obtaining work visas for foreign riding gangs is a difficult process, plus it draws bad labor publicity onto the ship owner. Therefore, this ship owner does not obtain work visas for its foreign riding gangs.

Company F - No legal stipulations to the use of gangs. Only limit is given by the COI for the number of people on board. However, waivers from the Coast Guard can be granted by giving prior notice and requesting approval. Approval will likely require the operator to place additional life rafts and other safety gear temporarily aboard the vessel.
13. Are there any labor stipulations to the use of riding gangs?

On the US-flag vessels, labor concerns appear greater than legal concerns. The most frequent response was that if riding gangs (U.S. or foreign) are employed aboard the vessel, then the crew must be given the opportunity to work their maximum amount of overtime or at least be turned to work anytime that the gang is working. Labor is interested in ensuring that the riding gangs do not take their “bowl of rice”, which is mostly touch up maintenance. Responses follow.

Company A - This is dependent on the job being done. If the job could be done by the crew, they better be turned to for the same amount of time on a different job.

Company B - The riding gang can not take work away from the crew.

Company C - The union requires that the sailors receive the opportunity for unlimited overtime if foreigners are being used to supplement the crew.

Company D - Must be union labor only for U.S. vessels.

Company E - No.

Company F - The crew has to get their normal amount of overtime or they can file for overtime for the work being done by the gang. Again, the gangs are usually doing specialized work or work that the crew does not want to do.

Company G - Unlicensed labor agreements would have to be used to use riding gangs.

14. Do the riding gangs become an integral part of the ship operation?

How well accepted the riding gangs are is reflective of how, and how often, they are used. Companies that use riding gangs on a regular basis seem to have more integration with their crews. Companies that infrequently use the gangs may have a suspicious concern from their crew members; the primary concern being over jobs, or loss
of jobs. Much of the acceptance of the gangs is reflected from the work that they do, whether it be dirty work or specialized work. In the case of dirty work, the crew is glad to see others doing it - often instead of themselves. For specialized work, if it improves the appearance or utility of the vessel, the crew is glad to see the company spending money on vessel improvement. In some instances, the acceptance is viewed as indifferent. With respect to operations, how the riding gangs are used comes into play. When the gangs are used less frequently and only for specialized jobs, then they are not viewed as an integral part of the operation, but perhaps as just a temporary tool. Some of the significant responses follow.

Company A - No, they are not an integral part of the operation, but they are received and do live with the crew.

Company B - The riding crews fall under the command of the Master, and they are treated as unlicensed crew members except for the foreman, who is treated and dines with the officers. But they are not an integral part of the ship operation: they are on for a specific need.

Company C - Yes, very much so. They are often used for routine ship operations such as tank cleaning, mooring, steering, and anchoring. The caliber of the gangs that are used ... is high. The foreign riding gang earn respect from the crew and the officers. The only feedback is positive.

Company D - Yes, they are received because they are an extra body doing dirty work, but the vessel crew want to make sure the riding crew is union.

Company E - Riding gangs are well received and there is positive feedback from the ships, but they are not used for normal ship operation (company policy).

Company F - The crew likes to see the company concerned with the upkeep of the ship.
15. Have any comparisons been made between riding gang costs and crew O/T costs?

The costs in the use of riding gangs is certainly a significant aspect in determining whether or not they will be used. The interviewed companies agreed to the largest extent on the fact that the gangs may be more efficient due to their specific role (job assignment) and that they are not distracted with the other operational aspects of the vessel. A strict cost analysis is difficult, because some companies are using less costly foreign gangs, and others are using highly skilled, American technical gangs. The varied extent of use, of the riding gangs, is not conclusive in an overall cost analysis. Rather, the varied use indicates that certain types of vessel, types of operation, areas of operation, and labor contracts and agreements are sometimes more, and sometimes less, easily integrated with the use of riding gangs. The following listed responses illustrate the companies' perspective on riding gang costs.

Company A - The riding gangs are better productively because they are given a specific job and specific instructions. They do not need to go the watch or concern themselves with other duties. They may cost more in absolute dollars, but they show a better return in efficiency (i.e. no half hour coffee breaks or 1.5 hour lunches).

Company B - We have done a study in the cost of riding gangs versus overtime costs. Overtime is the preferred method of work as it is the cheapest cost compared to a riding gang. The problem is that the riding gang usually has a skill or trade to do work that the crew is not skilled in or able to do due to watch keeping and/or other normal ship board duties.

Company C - The foreign riding gangs are overwhelmingly cost efficient compared to the high cost/low performance U.S. crews. The cost savings is very high!

Company D - Ridings crews are more efficient due to lack of benefits and work
restrictions on hours (from OPA 90). Economically sound from company standpoint.

Company E - Not applicable.

Company F - Yes. A cost analysis has been done and the riding gangs are cost efficient and do provide a savings to the company. For instance, a certified welder's hourly rate is about $8.50, which is less than the crew overtime rate.

16. If the OPA 90 work hour stipulation (crew can only work 15 hours per 24 hour period, or 36 hours per 72 hour period) were applicable on dry cargo/container ships, how would this affect your operation with respect to riding gangs?

This question was asked exclusively to the operators of dry cargo and container vessels (Company B, F and G). All these companies responded that the work hour stipulation would have little or no effect on their use of riding gangs.

6.5 RIDING GANG CONCLUSIONS

Temporary riding or maintenance gangs have found a place in most ship operations. These gangs have found functional use in both labor intensive and highly skilled aspects of marine operations. Riding gangs can and have become an integral part of some ship operators' routines. Increased utilization of these gangs leads to increased acceptance and integration to daily and project based operations. Currently, riding gang utilization appears to be on the rise, and most operators would like to see trends continue in that direction. The benefits of using these gangs outweighs their costs.

The largest advantage of using riding gangs is their economic practicality. Two ship operators found through cost analysis that the riding gangs provide savings over shipyard costs and some crew overtime costs. Nearly all of the interviewed operators
found the efficiency of riding gangs and the amount of work that they accomplish well worth their monetary costs. On board the ships, the advantages of the riding gangs was also perceived. Assuming that the riding gangs are competent, the ships' crew like to see the upkeep of the vessel and are pleased to have extra hands when tank cleaning or other dirty and labor intensive jobs are undertaken. With increased automation, technical gangs are becoming more of a necessity, but the crew and the operators are interested in the safe and efficient operation of the vessel to which these technical gangs contribute. Skilled labor gangs also are finding greater use and are advantageous in cost and efficiency.

In light of the advantages, riding gang use is still limited in today's merchant fleet. Port gangs especially have limited use due to quick turnaround times, other in port priorities, and - on tankers - the limited work that can be done due to cargo loading or discharging. In port gangs are best utilized for engine room repairs and maintenance. Other drawbacks to the riding gangs revolve around labor issues. Most companies are contractually bound to work their employees while the riding gangs are being used. Also, labor may view riding gangs as stealing or competing for their jobs. This may create tensions and lead to less acceptance and integration of the riding gangs.

The companies interviewed expounded on a variety of approaches toward the use of riding gangs. Some were more efficient than others, and some operations are simply more conducive to the temporary use of riding gangs. Combining the advantages of these approaches may provide some insight to the future use of riding gangs. The gangs proved most efficient and practical when drawn from a common labor pool. The one foreign-flag ship operator was able to draw both crew and riding gangs from the same pool which encompasses the ideal utilization of shipboard operating personnel. This type of arrangement, however, is easier for operators with a large number of ships and, presently, for those operating under foreign-flag. The pooling arrangement for crew and gangs allows high level of integration between all employees and permits the easy transfer of personnel and equipment. Concerns over whose tools are whose, and spreading capital
for large maintenance expenditures (i.e. heavy equipment) are negated. Flexibility of the riding gang is also enhanced, because the gangs are less likely to be job dependent and are more likely to be capable of undertaking other jobs on the ships. In fact, a member of the ideal pool might be a vessel's crew member during one assignment and part of a riding gang working several vessels on another assignment. With a large pool and a large fleet of vessels drawing from the pool, technical and highly skilled labor could also be utilized in this fashion.

In closing, it is likely that riding gangs will become an integral part of vessel operation. Gradual reductions in the size of crews and continued improvements in shipboard technology and automation are defining the boundaries of future ship operations. Riding gang use appears to be increasing and many companies are in the early stages of implementing their utilization. As the benefits and efficiency of temporary and external labor riding the ships for maintenance and repair services continue to increase, so will their acceptance as part of standard operation. Progress in this area is not without obstacles. Some U.S. labor contracts may preclude the efficient use of these gangs. However, the use of riding gangs fits well into the operational paradigm of lesser crew and higher automation. Riding gangs are capable of externalizing some of the labor intensive and fatigue inducing job requirements taking place on most vessels. Additionally, the members of riding gangs will not be concerned with watchstanding and other duty requirements on board the vessel. From a safety, and human factor standpoint, these issues support the presumption that riding gangs will further enhance safe vessel operation.
Chapter 7.0 SUMMATION AND CONCLUSION

The focus of this report is on the management of the front line operators, the human element, of merchant ships in the U.S. fleet. A primary concern regarding the carriage of goods by sea is the safe operation of the vessels, with due regard to the protection of the ship, cargo, personnel and environment. Evidence indicates that a high percentage of marine casualties are caused by human error. Investigation shows, however, that this error is not strictly limited to the vessel operating personnel. Contributing and underlying factors to the operation and how they may have added to the error potential must also be considered. Chapters 2, 3, and 4 of this report were written to assist the Coast Guard Research and Development Center further investigate how to address and eventually minimize the human errors contributing to marine accidents. The primary concern is how vessels' operational work environment affects the fatigue and stress level of the crew, as fatigue and stress are likely fundamental causes of the human error. In addition to work environment characteristics, these chapters discuss the evaluation of vessel personnel in actual operating situations and the collection and interpretation of casualty data. Chapters 5 and 6 of this report investigated some operational alternatives for managing the vessel and its personnel. These sections reviewed a pending trend of utilizing higher automation on ships along with a reduced number of highly qualified individuals to operate the vessel.
For the Coast Guard's study, vessel operational parameters have been narrowed to specific aspects which would allow measurement and comparison in order to determine their influence on the vessel personnel. The narrowed parameters have been termed Operational and Organizational Dimensions (OODs), and their influence may improve or detract from safe vessel operations. Each dimension was defined from an operator's perspective. A majority of the dimensions were also given measures or scales that will allow them to be categorized in an effort to determine which are the most critical with respect to safe vessel operations. The measures also help give further definition to the OODs.

One way to determine the influence of the OODs and their contribution to marine casualties would be to investigate past casualty data. This however has proved difficult if not impossible to do. Seven ship operators were contacted to determine to what degree they record past casualty information and, in particular, whether that data would be sufficient to assist in analyzing the influence of the previously defined dimensions. The data maintained by the companies appears insufficient. For an in depth study of the OOD's influence on casualties, data bases accounting for the depth of these dimensions would have to be specifically designed and put into use. Varying degrees of human factor considerations were taken into account by the operators in their casualty investigations. Some operators, however, are in the early stages of proper investigation of underlying and contributing factors.

Due to the lack of casualty data sources, a brief investigation into other marine casualty investigations was undertaken. It appears that the lack of proper casualty data
was also a conclusion of earlier reports. Casualty databases have been improved and the human element is accounted for, but it is usually only considered in light of the immediate decisions and actions causing or related to the reported incidents. One study that merits further investigations and possible implementation is a Ph. D. dissertation by William H. Moore titled "Management of Human and Organizational Error in Operations of Marine Systems" submitted to the University of California at Berkeley. Moore’s study has modeled casualty scenarios, or “templates”, to account for the underlying, compounding and direct causes. Moore has written a program using two interrelated PC based spreadsheets to analyze casualty data based on various human operator and organizational conditions. The programs allow for probability risk analysis and quantitative measures of human and organizational errors leading to marine casualties and near misses.

To further get a handle on how the OODs are contributing to the fatigue level of merchant ship crews, the Coast Guard, or their contractors, will ride aboard vessels in order to obtain real time measurement and observations of the fatigue level of the crew. Earlier investigations and attempts to utilize onboard evaluation has concluded that standard physiological and behavioral tests may be hard to implement or may be inconclusive. Interviews and on-site observations may be the most practical tools to gain insight to the human element. Any self-reporting surveys or techniques should require minimal time and effort. The Mariner’s Fatigue Survey Form used in the VNTSC’s study proved very useful. For personal interviews and observations researchers need to spend more time on the vessels than just a few days due to the varying level of activities between
in port and at sea operations. Incentives may be useful in obtaining shipboard personnel’s cooperation on the more intrusive measurement tools.

The ship operator’s concerns lie not only in safe operations, but also in efficient and competitive operations. Some alternative operational approaches may in fact prove safer than current operations. The second section of this thesis looked at the paradigm or operational approach of using highly automated vessels with fewer, highly qualified and technical crew members. Some traditional maritime nations are headed in this direction and account for safety by utilizing more cohesive and flexible crewing and working practices. This alternative approach was compared to a typical U.S. paradigm of larger crews operating under restrictive regulation and union-negotiated work practices. There are some variances to U.S. operational approaches and these paradigms were reviewed under consideration of the OODs. For the U.S. fleet three operational paradigms could be defined as traditional, status quo and progressive. These slightly differing paradigms may reflect a combination of OODs that can all be related to the working environment of the vessel.

As international trends are heading toward the reduced number of highly trained crew members, a primary concern is over the vessel maintenance and repair. With fewer crew, less maintenance can be performed by the crew. This leads to the use of temporary riding or maintenance gangs working aboard the vessel. Riding gangs can be used for service in skilled and unskilled labor projects. Skilled jobs include welding, pipefitting, electrical or even control systems work. Often the crew is unable to perform these jobs, or the engineers who may be capable, are too busy with other daily and routine operations.
Unskilled jobs mostly include dirty jobs such as tank cleaning on oil tankers which involves entering the tanks and mucking them out. Other jobs include steel surface preparation (chipping, scraping) and painting. Externalizing these jobs by using temporary gangs aboard the vessel will save the crew's time and effort. From a human factor and safety standpoint this will reduce the number of hours per day the crew will work, and allow more rest time. From an operator's standpoint, using riding gang labor instead of the crew may prove more efficient. First, day working crew members who simply provide labor could potentially be removed as not all seasons and routes are conducive to daily vessel maintenance work. Also, riding gangs will not be faced with the time constraints of the crew who are shifting between the jobs at hand and other vessel duties such as watch standing.

The seven companies contacted for casualty data information were also questioned regarding their use of riding or maintenance gangs, the objectives in the use of these gangs and the operational aspects of these gangs. Responses to the inquiry varied greatly, but nearly all of the companies agreed on the efficiency and practicality of these gangs. Maritime labor contracts are perhaps the biggest obstacle in implementing the riding gangs as a more efficient and integral component of the operation. A pooling of labor sources for both crew needs and riding gangs needs appears to be an efficient system used by one foreign-flag operator. The U.S. unions may want to consider pooling themselves to provide a source of alternative labor for both crewing needs and temporary maintenance needs of vessel operators. As increased technology allows for highly automated ships, and rising costs are bearing on the competitiveness of all traditional maritime nations, ship
operations are pointing in the direction of the paradigm of highly automated ships with fewer crew. Crews will have to be highly trained and qualified; and labor in the form of riding gangs, although more temporary and mobile in nature, will still be required to maintain ships in a safe and seaworthy condition.

The common thread throughout this report is the necessity to operate ships in a safe and responsible manner. In continuing this study, the Coast Guard will look into the underlying and contributing causes of marine accidents by evaluating the work environment which results from the Operational and Organizational Dimensions. These dimensions are inherent in the vessel particulars, the vessel’s route, the vessel’s crew and the operator’s approach toward running the vessel. Collectively these dimensions will have a bearing on the physical and mental fatigue and stress experienced by the crew. Different combinations of the controllable dimensions may stimulate safer and more efficient work environments on board ships. In undertaking this study, the Coast Guard Research and Development center must keep in mind the possibility for changes in the industry and operational approaches which could ultimately enhance the safe operation of merchant ships.
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APPENDIX NO. 1

CASUALTY DATA QUESTIONNAIRE:

1. Does your company maintain records of all casualty and/or near casualty incidents?

2. If so, is this information recorded on a standard company form?

3. What qualifies as a recordable casualty (or near casualty) incident?
   i.e. - collision, grounding, spill, cargo contamination?

4. Do casualty records indicate human factor or fatigue related issues?
   i.e. - hours worked by personnel involved in incident?
     - amount of sleep or rest personnel received prior to incident?
     - time on board of personnel involved in incident?

5. What is the basis of the recorded information?
   i.e. - required for insurance purposes?
     - required by Coast Guard, federal or state agencies?
     - for company investigative purposes?

6. Does the company analyze or make further use of the information after it has been recorded and filed (other than for liability purposes)?
   i.e. - database?
APPENDIX NO. 2

RIDING GANG QUESTIONNAIRE:

OBJECTIVES.

1. What are the objectives in hiring a riding gang (or a port maintenance gang)?
   i.e. - general vessel maintenance or cosmetics (touch up work)?
   - specific maintenance projects perhaps in order to avoid shipyard costs of these projects?
   - to prepare for shipyard?
   - to 'free up' Chief Mate's or crew's time for other duties?

2. What would be your primary use of riding gangs?
   i.e. - specialized work such as welding?
   - labor intensive or dirty work such as mucking tanks?

OPERATIONAL ASPECTS

3. Where and when would a riding gang best be utilized in your shipping operation?
   i.e. - port?
   - coastwise?
   - transit leg of voyage (coastwise or trans ocean)?

4. Would the company have a preference of company employed or contracted riding gangs?

5. Would the ships have a preference?

6. What control would the ship desire over a riding gang?
   i.e. - supervisory or hands off?

7. What type of supervision would the company want to see over riding gangs?
   i.e. - licensed ship officer for instance?

8. Would riding gangs be more beneficial on a time hire basis or on a specific job hire basis?

9. Would the company and ship prefer to supply equipment and supplies or hire a completely outfitted riding gang? (paint, air hoses, needle guns, paint brushes)
APPENDIX NO. 2 - CONTINUED

CURRENT SITUATION

10. Are riding gangs presently used only on foreign flag vessels?

11. Under what circumstances might riding gangs be used on U.S. ships?

12. Are there any difficult legal stipulations to the use of riding gangs?

13. Are there any labor contract stipulations to the use of riding gangs?

14. Do the riding gangs become an integral part of ship operation while on board?
   i.e. - are they well received by the crew?
   - is there any specific positive or negative feedback from the ships crews?

15. Have any comparisons been made between riding gang costs and crew O/T costs?
   i.e. - are the riding gangs considered cost efficient?
   - do they provide a tangible savings for the company?

16. If the OPA 90 work hour stipulation (crew can only work 15 hours per 24 hour period, or 36 hours per 72 hour period) were applicable on dry cargo/container ships, how would this affect your operation with respect to riding gangs?