THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 Pavonia Avenue, Suite 400, Jersey City, New Jersey 07306 USA
Paper presented at the Marine Structural Inspection, Maintenance, and Monitoring Symposium
Sheraton National Hotel, Arlington, Virginia, March 18-19, 1991

Report on the Trans-Alaska Pipeline Service Tanker Structural Failure Study

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I . EXECUTIVE SUMMARY

1. Scope

A. Structural Casualty Study. The study of tankers engaged in the TAPS trade is the culmination of related initiatives dating back to April 1988. The first of these initiatives, the Structural Casualty Study, dated April 27, 1988, reported that TAPS tankers comprised 13 percent of U.S. flag oceangoing vessels over 10,000 gross tons between 1984 and 1988, but accounted for 59 percent of the structural failures, i.e., cracking in the hull plates and connecting structural members, that had been reported to Coast Guard Headquarters. That finding lead to the conclusion that TAPS tankers suffered a disproportionately higher number of structural failures when compared to vessels in other trades.

B. TAPS Study Work Plan. Following a significant fracture in the main deck of the EXXON NORTH SLOPE on March 5, 1989, the investigation of structural failures on TAPS vessels was formally undertaken by Commandant(G-MVI) and (G-MTH). A Work Plan was developed with the following objectives:

(1) Development of short and long-term solutions to structural failures;
(2) Development of Critical Areas Inspection Plans; and
(3) Review of ABS rules and development of guidance and requirements.

C. The Tanker Accidental Oil Outflow Study Group. Following the grounding of the EXXON VALDEZ on March 24, 1989, in Prince William Sound, the members of the TAPS Study Group were temporarily redirected to other issues related to that grounding. Rear Admiral J. D. Sipes, Chief, Office of Marine Safety, Security and Environmental Protection, assembled a working group to review and assess issues related to tank vessels. This group, chaired by Captain J. C. Card (USCG), was called the Tanker Accidental Oil Outflow Study Group. In its report titled Development and Assessment of Measures to Reduce Accidental Oil Outflow from Tank Ships, dated May 1989, the Group recommended several items for further review, including, but not limited to:

(1) review of structural failures by trade;
(2) elimination of tankers from certain waters;
(3) providing for more Coast Guard inspections of tank vessels; and
(4) dedication of more Coast Guard resources to the analysis of casualty and inspection data.

D. Tanker Safety Study Group. On October 6, 1989, a separate study group chaired by Rear Admiral H. H. Bell (USCG Ret.) issued recommendations in its Report of the Tanker Safety Study Group, related to tank vessels in general and to TAPS tankers specifically. As a result, the scope of the TAPS Study was expanded to investigate matters related to inspection efficiency and the methods used to conduct inspections of large tank vessels.

2. Meetings With TAPS Operators

In an effort to get information from the operators of TAPS tankers, letters were sent to the operators of TAPS vessels with documented structural failures. The letters advised the operators of our findings and requested one-on-one meetings to discuss operating and maintenance philosophies, and programs they use to document and track structural failures. Meetings were held with 14 operators between January 16 and May 30, 1990.

3. Interim Policy

Initial findings by the TAPS Study Group showed that the Coast Guard's database was incomplete. In addition, inconsistent repair procedures and heightened environmental concerns created a need to change the classification and reporting criteria for structural failures. MVI Policy Letter No. 23-89, dated 20 December 1989, was issued changing the classifications and reporting criteria for structural failures. Emphasis was placed on locating Class 1 failures. The definition for a Class 1 failure was changed, and a "structural failure" was distinguished from "structural damage" for reporting purposes.

4. General Findings by the TAPS Study Group. Findings by the TAPS Study Group were based on an evaluation of the data that was assimilated from 200 Coast Guard vessel files, information contained in the Marine Safety Information System (MSIS), and data from the operators. In the assimilation, this information was used to identify vessels with cracking histories and to determine possible causes. Information in MSIS identified 69 U.S. and 7 foreign flag tank vessels that had made at least 1 port call at Valdez since 1984, were still in service, and thus subject to this Study. Each operator we met with recognized the need to properly address structural failures not only because of the threat to vessel structural integrity, but also because of heightened environmental concerns. The meetings validated the Coast Guard's data showing that specific vessels and classes of vessels were performing worse than other vessels and vessel classes. The operators also indicated a need to change the way the Coast Guard documents and evaluates structural failures. Figure II-1 lists the U.S. flag vessels, their respective class, and the operating company as of 29 September 1989. Each of the U.S. flag vessels were classed by ABS.

A. Time of Year. Analysis indicated that significant and potentially serious failures can occur on TAPS vessels at any time of the year. In general, the more harsh the environment the more serious the event, i.e., all four Class 1 events were documented between October and March.

B. Vessel Construction (materials and configuration). Analyses showed:

(1) vessels with cargo blocks constructed of a combination of mild and high tensile steel or solely of high tensile steel experienced disproportionately higher numbers of structural failures than vessels built solely of mild steel;

(2) single hull vessels, regardless of the type of steel, comprised 62.3% of those studied and accounted for nearly 80% of the failure events; and

(3) vessels built to full scantlings, regardless of type of steel, suffered the same proportion of failures as vessels built to reduced scantlings.

C. Vessel Class (design). Data in MSIS showed that the 69 vessels subject to this Study comprised 28 separate vessel classes (27 established classes and one special "Not In A Class" category, set up only for this Study, for three vessels not in an established class). The six vessels in the Atigun Pass Class, whose entire cargo block section is constructed of high tensile steel, accounted for 26.3% of the failure events. Five classes, comprising 23 vessels, accounted for 66.9% of the documented failures. The vessel MOBIL ARCTIC (Not In A Class) accounted for 8 of the failure events, making a total of 24 (34.8%) vessels accounting for 72.9% of the documented failure events. The following vessels have been identified as requiring special inspection, monitoring and/or reporting measures:

(1) The Atigun Pass class vessels have experienced the most frequent occurrence of cracking, including two of the four documented Class 1 events reviewed by the TAPS Study Group. These vessels are presently experiencing active cracking for which effective detail retrofits have not been devised.

(2) The Seatrain Class vessel STUYVESANT experienced two Class 1 events, both of which exceeded 17 feet in length in the main shell plating and resulted in significant pollution incidences. These incidences have been attributed to poor workmanship at the time of construction. It is our belief that the potential exists for similar type cracking to recur on this vessel or occur on the other vessels in this class.

(3) The American Sun Class vessels are experiencing active cracking for which repair solutions are being pursued. Much of the past cracking has been attributed to poor initial design and construction, for which effective repair have been made.

(4) The MOBIL ARCTIC has had several Class 2 fractures in recent years. The vessel was built with numerous structural deficiencies including misalignments of support members by as much as 3 inches, poor transitions, missing brackets, etc. Deficiencies have not become apparent until after a fracture has occurred.

(5) The COVE LEADER was not included with the original 69 vessels reviewed by the TAPS Study Group. It entered the TAPS trade in April, 1990, after undergoing extensive structural repairs required by MSO Portland, and requires special attention due to the vessel's age and past history.

(6) Although the vessels in the ARCO Anchorage and Sansinena classes accounted for a significant number of documented failures, measures have been taken to analyze the failures and to develop long term permanent solutions for repair. In most cases, the repairs have already been performed and the incidences of hull cracking is considered to be under control. As a result, these vessels require only special monitoring.

D. Place of Build (construction and workmanship). Analyses showed that four shipyards built 40 (57.9%) of the vessels under study, and that those 40 vessels accounted for 86.5% of the failure events. Regardless of how well designed a vessel may be, or how thoroughly a detail is analyzed and engineered for a particular arrangement, poor welding technique or a poor weld will negate the best of detail designs and possibly lead to a structural failure.

E. Design of Details. The primary concern of most companies is the poor design of details, i.e, the transition pieces such as brackets that connect the main transverse and longitudinal strength members where structural discontinuities exist. A vessel with poorly designed details will be subject to a high incidence of cracking regardless of environmental conditions. Analysis must not necessarily be aimed at increasing the strength (scantlings) of the vessel, but in reducing stress concentrations and in providing a better load path for he stresses.

F. Corrosion Control. Coating existence and maintenance significantly affects vessel structural performance and safety, particularly as tankers age. Proper surface preparation is the key to maximizing the service life of tank coatings, which normally last from 7 to 15 years, depending upon whether zinc or an epoxy-based coatings are used.

G. Internal Examinations. Analysis indicates that some vessels need more frequent internal inspections than presently required. Several operators indicated that our drydock internal inspections may be improved by attending ABS "close-up" or pre-drydock internal surveys frequently done by them. Surveys are usually done by either rafting tanks, or by climbing the internal framework. Although rafting is not an absolutely safe method due to problems with tank cleanliness and related personal hygiene concerns, and with ship motion and fluid surge in the tank, it is generally accepted as the best, and most cost effective, method for surveying the entire tank.

5. General Conclusions

A. Actions by Vessel Operators. A wide variety of maintenance and philosophical views were expressed by the TAPS operators. Many operators take a proactive role in addressing fractures as they occur, with analyses being performed, and in discussing/collaborating with operators of similar-class vessels. Many operators already have programs which are the essence of critical areas inspection plans.

B. Cause of Structural Failures. Poorly designed details, poor weld workmanship, and fatigue appear to be the major causes of structural failures, especially in association with the use of high tensile steel. Corrosion is also one of the primary types of structural degradation that can lead to structural failures. When employed and strictly maintained, coating maintenance can be an effective way to slow corrosion and, hence, stress corrosion cracking. There is no clear, single failure mechanism, and each and every structural failure must be evaluated on a case-by-case basis.

C. Future Actions. The variety of views and vessel performance, taken in concert with limited Coast Guard resources, necessitates that we target our attention on specific operators and specific vessels that require the most attention and oversight. We must limit impact upon available Coast Guard resources and rely on the responsibilities entrusted in the operators and classification societies. Many policy changes that we are requesting should be developed jointly with ABS and industry. Coast Guard participation in Joint Industry Projects (JIPs), along with close association of ABS, is an excellent vehicle for addressing and resolving many of the issues raised in this report. One such JIP already begun is the University of California project titled "Structural Maintenance for New and Existing Ships".

II. INTRODUCTION

A. Marine Structural Casualty Study. A 27 April 1988 report by the Marine Structural Casualty Study and a follow up report dated 19 July 1989 by G-MTH highlighted tankships engaged in the TAPS trade. The results of these studies indicated that:

(1) Between 1984 and 1988, TAPS tankers comprised 13 percent of U.S. flag oceangoing vessels over 10,000 gross tons, and

(2) the TAPS tankers accounted for 59 percent of the structural failures, i.e., cracking in the hull plates and connecting structural members, that had been reported to Coast Guard Headquarters.

B. TAPS Study Work Plan. Following a significant fracture in the main deck of the EXXON NORTH SLOPE on March 5, 1989, the investigation of structural failures specifically on TAPS vessels was formally undertaken by Commandant (G-MVI) and (G-MTH). A Work Plan was developed with the following objectives:

(1) Development of short-term and long-term solutions to structural failures, to be proposed by the TAPS operators and submitted for review and approval by the American Bureau of Shipping (ABS) and the Coast Guard;

(2) Development of Critical Areas Inspection Plans to monitor more closely the known problem areas of the TAPS vessels; and

(3) Review of ABS rules and development of joint industry, ABS and Coast Guard guidance and requirements.

C. Meeting With Industry and ABS. TAPS operators and ABS were notified by letter dated March 21, 1989, requesting a joint meeting at ABS World Headquarters in Paramus, New Jersey, on May 23, 1989. Despite a redirection of attention following the grounding of the EXXON VALDEZ on March 24, 1989, and thus a delay in TAPS study, the joint meeting was held. At that meeting, the findings of the 27 April 1988 study were presented for discussion. Additional information was needed before the Coast Guard could determine whether special inspection policy was needed for vessels engaged in the TAPS trade.

The TAPS Study was formally undertaken on August 1, 1989, to review the Coast Guard files of TAPS tankers in an effort to collate all documented structural failures, both reported and unreported. The intent was to establish an historical database that would provide an indication of the extent of the failures, whether there were any common causes, and what actions could be taken to mitigate future failures. Follow up action could then be taken with ABS and the operators of those vessels noted as being prone to structural failures.

Only those structural failures that had occurred since 1984 on vessels calling on the Port of Valdez were reviewed. Failures that had occurred within the last five years were the only ones considered since they likely to be active repair areas with repair procedures either still under analysis or being monitored.

Initially, 69 U.S. and 7 foreign flag tank vessels still in service were identified as TAPS vessels subject to review by the TAPS Study Group. Figure

II-1 lists the vessels, their respective class, and the operating company at the time this information was developed. Those vessels actively trading in the TAPS route as of the date of this report are marked by an asterisk. The Marine Safety Offices in Portland, OR, Long Beach, CA, and Honolulu, HI, were visited between 23 and 30 August 1989. All information on file at those ports related to structural failures was reviewed, including 200 Coast Guard drydock exam records, independent surveyor reports, CG-2752's (Reports of Structural Failure) and damage surveys. This information established the raw data upon which our analyses were conducted.

One-on-one meetings were held between January 16 and May 30, 1990, with 14 companies who had operated, or were operating, the vessels with documented structural failures. The purpose of these meetings was to discuss our findings and to solicit company background information on their TAPS vessels, their philosophies regarding the maintenance and operation of their vessels, and programs they have established to document and track structural failures as well as what they have done to prevent or minimize their occurence. The information obtained from these meetings has been used to confirm the identity of those vessels that are actively engaged in the TAPS trade and to develop active repair areas for each vessel.

Figure II-1

CLASS	VESSEL	OPERATOR
America Sun	AMERICAN TRADER*	American Trading Transportation Co.
	GLACIER BAY*	Trinidad Corp.
	ADMIRALTY BAY*	Trinidad Corp.
	ASPEN*	Trinidad Corp.
ARCO Anchorage	ARCO ANCHORAGE*	ARCO Marine, Inc.
	ARCO JUNEAU*	ARCO Marine, Inc.
	ARCO FAIRBANKS*	ARCO Marine, Inc.
	OVERSEAS JUNEAU*	Maritime Overseas Corp.
Atigun Pass	ATIGUN PASS*	Keystone Shipping
	KEYSTONE CANYON*	Keystone Shipping
	BROOKS RANGE*	Interocean Management
	THOMPSON PASS*	Interocean Management
	EXXON NORTH SLOPE*	Exxon Shipping
	EXXON BENICIA*	Exxon Shipping
Chevron GT	CHEVRON OREGON*	Chevron Shipping
	CHEVRON WASHINGTON	Chevron Shipping
	CHEVRON LOUISIANA*	Chevron Shipping
	CHEVRON ARIZONA	Chevron Shipping
Dynachem	OMI HUDSON	OMI Corp.
Exxon Baltimore	EXXON BOSTON	Exxon Shipping
Exxon Charleston	EXXON CHARLESTON	Exxon Shipping
Exxon Gettysburg	EXXON JAMESTOWN	Exxon Shipping
Exxon Houston	EXXON NEW ORLEANS*	Exxon Shipping
Exxon San Francisco	EXXON SAN FRANCISCO*	Exxon Shipping
	EXXON BATON ROUGE*	Exxon Shipping
	EXXON PHILADELPHIA*	Exxon Shipping
Exxon Valdez	EXXON VALDEZ	Exxon Shipping
	EXXON LONG BEACH*	Exxon Shipping
Golden Gate	GOLDEN GATE	Keystone Shipping
La Jolla	CHESAPEAKE TRADER	American Trading Transportation Co.
	POTOMAC TRADER	American Trading Transportation Co.
Massachussettes	OCEAN WIZARD	Boston Ocean Carriers
	ARCO SPIRIT*	ARCO Marine, Inc.
	ARCO INDEPENDENCE*	ARCO Marine, Inc.

* Vessel is actively engaged in TAPS trade as of date of this report

Figure II-1 (Cont'd)

CLASS	VESSEL	OPERATOR
Montrachet	COASTAL MANTEE	Coastal Tankers USA, Inc.
Petersburg	PETERSBURG	MARAD
San Clemente	LIBERTY BELLE	Liberty Maritime Corp.
	OVERSEAS NEW YORK	Maritime Overseas Corp.
	OVERSEAS WASHINGTON	Maritime Overseas Corp.
San Diego	B. T. SAN DIEGO*	Marine Transport Lines
	B. T. ALASKA	Marine Transport Lines
	ARCO ALASKA*	ARCO Marine, Inc.
	ARCO CALIFORNIA*	ARCO Marine, Inc.
Sansinena	SANSINENA II*	West Coast Shipping
	ARCO PRUDHOE BAY*	ARCO Marine, Inc.
	ARCO SAG RIVER*	ARCO Marine, Inc.
	CHEVRON CALIFORNIA*	Chevron Shipping
	CHEVRON MISSISSIPPI*	Chevron Shipping
Santa Paula	SABINE	Sabine Towing & Transport Co.
Sealift	SEALIFT PACIFIC	Marine Transport Lines
Seatrain	BROOKLYN	Texaco Marine
	WILLIAMSBURGH**	Laid-Up
	STUYVESANT	Bay Tankers
	BAY RIDGE	Bay Tankers
Sunship TAPS	PRINCE WILLIAM SOUND*	Sun Transport
	TONSINA*	Keystone Shipping
	KENAI*	Keystone Shipping
Texaco New York	TEXACO CONNECTICUT	Texaco Marine
	TEXACO FLORIDA	Texaco Marine
Western Sun	SYOSSET	Mobil Oil Corp.
Reflagged	COVE LIBERTY	Cove Shipping
	OMI COLUMBIA	OMI Corp.
	OVERSEA BOSTON	Cambridge Tankers, Inc.
20-Year Old	BALTIMORE TRADER	American Trading Transportation
	COVE TRADER	Cover Trader, Inc.
	MOBIL MERIDIAN	Mobil Oil Corp.
	PENNSYLVANIA TRADER	American Trading Transportation
Not In A Class	MOBIL ARCTIC*	Mobil Oil Corp.
	ARCO TEXAS*	ARCO Marine, Inc.
	EXXON BAYTOWN	Exxon Shipping

* Vessel is actively engaged in TAPS trade as of date of this report
** Vessel listed for Class identification only - not engaged in TAPS trade

III. FINDINGS BY THE TAPS STUDY GROUP

1. Overview of the TAPS Study

The TAPS Tanker Structural Failure Study comprised two phases.

A. Phase I covered the period from 21 March 1989 to 15 January 1990 and included the following actions:

(1) A joint meeting with TAPS operators and ABS on May 23, 1989, at ABS World headquarters in Paramus, New Jersey.

(2) Review of all Coast Guard files of tank ships having called on the port of Valdez since 1984 and development of structural failure history databases from the reports of structural failures contained therein.

(3) Evaluation of the structural failure databases to determine which vessels were experiencing the most numbers of failures and why.

(4) The establishment of new, interim policy via G-MVI Policy Letter 23-89, dated 20 December 1989, changing the definitions of structural failures and the reporting criteria for same.

(5) Notification of the operators of TAPS vessels apprising them of the preliminary findings and scheduling one-on-one meetings with them.

B. Phase II of the TAPS study covered the period from 16 January to 31 May 1990 and included one-on-one meetings with TAPS operators between 16 January and 30 May 1990 to

(1) present the preliminary findings of the TAPS Study group;

(2) discuss the changes that the Coast Guard had made in its inspection policies for the inspection of large tank ships; and

(3) solicit information from the operators that would supplement the databases developed during Phase I and either corraborate and explain, or refute the preliminary findings of the TAPS Study.

2. Supected Causes of Structural Failures

The structural failure histories developed during Phase I of the TAPS Study were evaluated to determine whether possible causes for structural failures could be related to one or a combination of

(1) the increased use of high tensile steels in the cargo block, either fully constructed with high tensile steel or in combination with mild steel;

(2) the reduction of scantlings based upon the use of protective coatings in tanks;

(3) lighter scantlings due to the use of high tensile steels;

(4) poor weld workmanship, including fabrication and fit-up, during the

construction of the vessel, resulting in stress risers in butt and seam welds;

(5) poor design of details, resulting in hard spots and extreme stress risers; and

(6) exposure to an extremely harsh environmental climate in the Gulf of Alaska

3. Meetings With TAPS Operators

During Phase II, meetings were held with the 14 companies listed below:

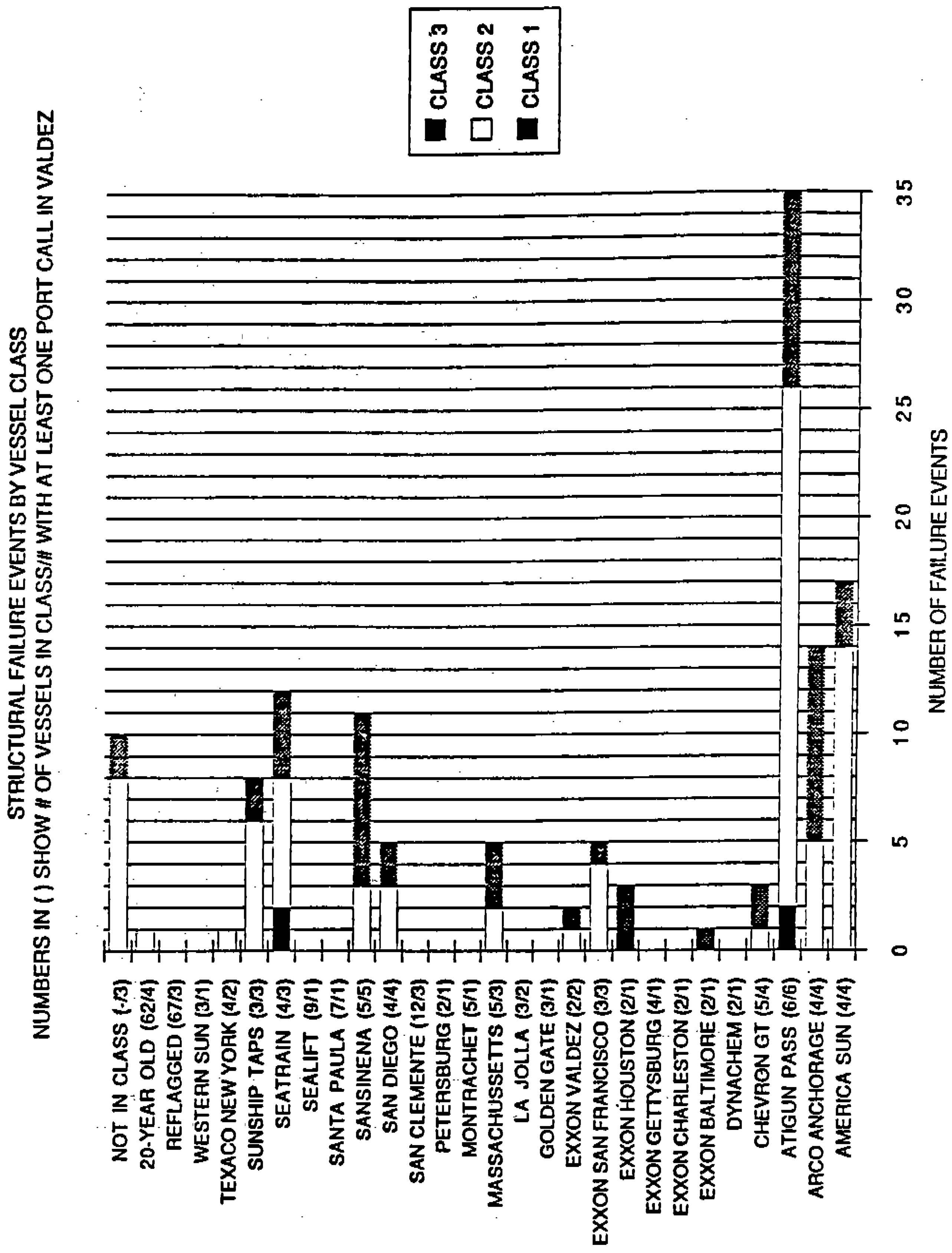
- Exxon Shipping Company	17 January 1990
- Chevron Shipping Company	18 January 1990
- ARCO Marine, Inc.	24 January 1990
- West Coast Shipping Company	26 January 1990
- Sun Marketing and Refining, Inc.	30 January 1990
- Texaco Marine Services, Inc.	01 February 1990
- Keystone Shipping Company	13 February 1990
- Interocean Management Corporation	15 February 1990
- Mobil Oil Corporation	20 February 1990
- Trinidad Corporation	27 February 1990
- Maritime Overseas Corporation	28 February 1990
- American Trading and Transportation	16 March 1990
- Cove Shipping Company	11 May 1990
- Marine Transport Lines	30 May 1990

These meetings provided valuable insight into operating and maintenance philosophies, which varied considerably between companies, and into the reasons why the structural failures were occuring. The information obtained from the operators was used to enhance our data analyses and to assess the correlations between failures and causes listed in paragraph 2 above. The information provided by the operators indicated that some of the preliminary findings of the TAPS Study group should be adjusted to take into account other factors and information that was either not available or not apparent from the raw data contained in the initial structural failure databases.

4. Vessels Requiring Special Inspection and Reporting Measures

Figure III-1 shows that the 69 vessels subject to this Study comprised 28 separate vessel classes (27 established classes and one special "Not In A Class" category, set up only for this Study, for three TAPS vessels not in an established class). Of those 28 classes, the Atigun Pass Class, consisting of 6 vessels whose entire cargo block section was constructed of high tensile steel, alone accounted for 26.3% of the documented structural failure events. Five classes, comprising 23 vessels, accounted for 66.9% of the documented failures. In addition, the vessel MOBIL ARCTIC (Not In A Class) accounted for 8 of the failure events, making a total of 24 (34.8%) vessels accounting for 72.9% of the documented failure events. Therefore, as a result of our analyses and information provided by the operating companies, the following vessels were identified as requiring special inspection, monitoring and/or reporting measures, as indicated:

FIGURE III-1


STRUCTURAL FAILURE EVENTS BY VESSEL CLASS
NUMBERS IN ( ) SHOW # OF VESSELS IN CLASS/# WITH AT LEAST ONE PORT CALL IN VALDEZ
CLASS 3
CLASS 2
CLASS 1
NOT IN CLASS (-/3)
20-YEAR OLD (62/4)
REFLAGGED (67/3)
WESTERN SUN (3/1)
TEXACO NEW YORK (4/2)
SUNSHIP TAPS (3/3)
SEATRAIN (4/3)
SEALIFT (9/1)
SANTA PAULA (7/1)
SANSINENA (5/5)
SAN DIEGO (4/4)
SAN CLEMENTE (12/3)
PETERSBURG (2/1)
MONTRACHET (5/1)
MASSACHUSSETTS (5/3)
LA JOLLA (3/2)
GOLDEN GATE (3/1)
EXXON VALDEZ (2/2)
EXXON SAN FRANCISCO (3/3)
EXXON HOUSTON (2/1)
EXXON GETTYSBURG (4/1)
EXXON CHARLESTON (2/1)
EXXON BALTIMORE (2/1)
DYNACHEM (2/1)
CHEVRON GT (5/4)
ATIGUN PASS (6/6)
ARCO ANCHORAGE (4/4)
AMERICA SUN (4/4)
0
5
10
15
20
25
30
35
NUMBER OF FAILURE EVENTS

A. Atigun Pass Class

Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
ATIGUN PASS	173380	1977	Hi-St	NO	NO	NO
KEYSTONE CANYON	173619	1978	Hi-St	NO	NO	NO
BROOKS RANGE	176102	1978	Hi-St	NO	NO	NO
THOMPSON PASS	173320	1978	Hi-St	NO	NO	NO
EXXON N. SLOPE	175305	1979	Hi-St	NO	NO	NO
EXXON BENICIA	172573	1979	Hi-St	NO	NO	NO

The vessels in the Atigun Pass class have experienced the most frequent occurence of cracking, including 2 of the 4 documented Class 1 events reviewed by the TAPS Study Group. These vessels are presently experiencing active cracking for which effective detail retrofits have not been devised. This class therefore requires special attention with regard to inspection, the monitoring of repairs and follow-up action, and the reporting of structural failures. The first four vessels in this Class have experienced cracking in the areas listed below. These areas have been identified as active repair areas, i.e., repairs have either been made and are being monitored, or are undergoing analysis for a long term permanent fix that will involve a redesign of certain details.

ATIGUN PASS, KEYSTONE CANYON, BROOKS RANGE & THOMPSON PASS:

Bilge Keels, in way of the toe of the keel plate;

Side shell longitudinals adjacent to bulkheads 42, 52 and 58;

Bottom longitudinal limber holes; and

Frame 29, No. 1 port and starboard wing tanks. The underdeck forward of frame 29 was strengthened by Keystone and Interocean Management following weather damage. This could have moved stress aft into Frame 29, causing the cracks.

The KEYSTONE CANYON, BROOKS RANGE & THOMPSON PASS have experienced fewer fractures than ATIGUN PASS due to some structural members installed during initial construction that were not installed on the ATIGUN PASS.

Initial attempts to solve cracks in side longitudinals near bracketed ends that then propagated into side shell involved the installation of "inertia bars". Subsequent analysis and experience has shown that the inertia bars did not correct the problem. Brackets have since been added over several yard periods per the recommendation of the Oil Company International Marine Forum (OCIMF) tanker book Guide to the Inspection and Condition Assessment of Tankers.

In February 1990, the BROOKS RANGE experienced two fractures in the No. 3 center cargo tank - 1 in the base metal adjacent to the transverse erection butt joint at frame 52 near the center vertical keel, and the other outboard of the first crack in the weld erection joint in way of a longitudinal limber hole.

The THOMPSON PASS has had numerous side shell fractures in the #1 starboard cargo tank, the most recent being an 8" crack in January, 1990. In July, 1989, 3 individual fractures totaling 17 feet in length appeared along the toe of a transverse field-erection weld in the bottom plating of #3 center cargo tank.

EXXON BENICIA & NORTH SLOPE: These two vessels have a raised forecastle (the other four are flush deck) and have fewer documented structural failures than the other vessels in this Class.

The EXXON BENICIA has had problems with cracking of the underdeck longitudinals at frames 64 - 65, attributed to poor design details and fabrication defects. These longitudinals were originally flat bar with face plates added to provide additional support for bollards and other deck equipment. In some locations, the added face plates terminated short of connecting brackets at transverse bulkheads, resulting in stress concentrations which in turn led to cracking. Analysis has shown that the size of brackets could be increased to spread out stresses and fix the cracking problem on some of the longitudinal; however, this fix has no effect on other longitudinals. Repairs/mods have been effected by installing new, larger brackets, but since the analysis did not provide conclusive information for all the repair areas, they are being monitored. Subsequent analysis shows that fatigue life has not been improved for all fixes; thus additional modifications are planned, including removal of face plates and brackets where considered unnecessary and, where larger stiffeners are required, deeper and/or thicker slab longitudinals will be used.

The other Atigun Pass vessels have not had the same problem with poor flat bar/bracket design. Exxon may be experiencing more underdeck cracking because the number of possible problem locations is increased due to underdeck "strengthening" on the two Exxon ships.

These vessels had early cracking in the flange of cargo tank sluice gate valves in way of the corner bolt hole. This problem has apparently been corrected by modifying the flange to remove the bolt hole and inserting the flange with DH (high strength) steel.

B. Seatrain Class
Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
BROOKLYN	225280	1973	Mild	Yes	No	No
WILLIAMSBURGH	228701	1974	Mild	Yes	No	No
STUYVESANT	228274	1977	Mild	Yes	No	No
BAY RIDGE	224428	1979	Mild	Yes	No	No

The vessel STUYVESANT has experienced the other 2 documented Class 1 events, both of which exceeded 17 feet in length. Each of these cracks, one in the bottom shell plating between frames 55 and 56 in the No. 5 Port cargo tank, the other in the side shell plating of the No. 5 starboard cargo tank, resulted in the spillage of more than 100,000 gallons of crude oil. Since the potential exists for similar type cracking to occur on the other vessels in this class, the Seatrain Class requires attention similar to that for the Atigun Pass Class. Other significant fractures on the STUYVESANT include the following:

18" fracture in a weld in the bottom plating of the No. 1 center cargo tank, forward of frame 89.

Fractures in side longitudinals Nos. 24 and 25, forward of frame 60 in the No. 4 starboard cargo tank. Fractures propagated into the sideshell plating.

Multiple fractures at the tapered ends of bottom longitudinals Nos. 12 - 15 and 17 - 21 in wing cargo tanks 4 and 5 and the wing slop tanks, attributed to poor initial design.

This Class of vessels was built under a special work program at Seatrain Shipbuilding in Brooklyn, New York. As a result, many of the welders had neither the training nor the skills necessary to perform the welding tasks required for shipbuilding. At the time of this writing, the WILLIAMSBURGH and BAY RIDGE were both in lay-up status, the BROOKLYN was operating in the Middle East, and STUYVESANT had recently been returned to MARAD.

C. American Sun Class

Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
AMERICAN TRADER	82735	1969	Hi-St	Yes	No	No
GLACIER BAY	82055	1970	Hi-St	Yes	No	No
ADMIRALTY BAY	82069	1971	Hi-St	Yes	No	No
ASPEN	81862	1971	Hi-St	Yes	No	No

The vessels in the America Sun Class accounted for 12.8% of the documented events, and are experiencing active cracking for which repair solutions are being pursued. Much of the past cracking has been attributed to poor initial design and construction, for which effective repairs have been made. These vessels require less frequent inspection emphasis, but special monitoring of ongoing repairs and reporting of new or repeat structural failures. These vessels have experienced cracking in the areas listed below, which have been identified as active repair areas:

AMERICAN TRADER:

Cracking in bottom longitudinals and girders of tanks No. 2 Center, No. 3 Port & Starboard, and No. 4 Center following grounding.

Recurring cracks in way of limber holes, attributed primarily to poor welding details in way of the holes; however, analysis has shown that some cracks are fatigue cracks.

Fractures have occurred at the ends of panel breaker stiffeners, at approximately mid-height, of the deep bottom longitudinals. The cracks that occur are in the web of the longitudinals, and are semi-circle in shape. The owner is veeing out and welding up cracks, and sniping back the web and flange of the panel breaker.

Cracks have occurred in the flange and web of bottom longitudinals in way of the toe of the bracket connections with the vertical bulkhead stiffeners. The owner feels that these cracks are due to poor initial welds, so their fix is to vee out the crack and reweld.

ADMIRALTY BAY, GLACIER BAY & ASPEN:

Fractures in bottom longitudinals 26, 27, 29 and 30 in No. 3 Port and Starboard wing tanks at the bracket attachment to transverse girders and frames. Based upon the results of an ABS study, rider bars and web inserts of DH36 steel and reconfigured brackets, are being installed in 2s, 3s and 4s.

Cracking of horizontal stiffener endings on web of longitudinal girder at web frames and bulkheads. Toe pads had been fitted earlier but didn't work. Horizontal brackets have since been added to make the structure longitudinally continuous (as opposed to sniping back the bracket as performed on the AMERICAN TRADER).

D. Vessels Not In A Class

Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
MOBIL ARCTIC	124999	1972	Hi-St	No	No	No

The vessel MOBIL ARCTIC, not in a class, has had several Class 2 fractures in recent years. The vessel was built with numerous structural deficiencies including misalignments of support members by as much as 3", poor transitions, missing brackets, etc. Deficiencies did not become apparent until after a fracture occurred. This vessel requires attention similar to that for the Atigun Pass Class vessels.

E. Vessels In the 20-Year Old Class

Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
COVE LEADER	73034	1959	Mild	No	No	No

The vessel COVE LEADER, which was not included with the original 69 vessels reviewed by the TAPS Study Group, entered the TAPS trade in April, 1990. The vessel was required by MSO Portland to undergo extensive structural repairs prior to going into TAPS service. Due to the vessel's age and past history, this vessel requires attention similar to that for the Atigun Pass Class vessels and MOBIL ARCTIC.

F. Vessels To Be Monitored. Although the two classes of vessels listed below accounted for a significant number of documented failures, measures have been taken by the operating companies to analyze the failures and to develop long term permanent solutions for repair. In most cases, the repairs have already been performed. As a result, these vessels require only special monitoring of the specified areas.

Class: ARCO Anchorage

Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
ARCO ANCHORAGE	122249	1973	Mild	No	No	No
ARCO JUNEAU	122249	1974	Mild	No	No	No
ARCO FAIRBANKS	122520	1974	Mild	No	No	No
OVERSEAS JUNEAU	122410	1973	Mild	No	No	No

ARCO ANCHORAGE, JUNEAU & FAIRBANKS:

Cracking on transverse bulkheads in cutouts in way of through longitudinals. This is most pronounced in wing ballast tanks. Repairs made with soft bracket.

The JUNEAU struck a bridge several years ago, requiring extensive repairs and renewal of steel. There are concerns that locked in stresses created during repair of this damage may make their presence known within the next couple of years.

ARCO FAIRBANKS:

Fractures of side longitudinals 19 & 20 were repaired in 1987. These fractures were suspected as being caused by wave slap in the vicinity of the waterline, and are therefore not considered active repairs.

OVERSEAS JUNEAU: No documented structural failures.

Class: Sansinena
Service: Crude Carrier

Vessel	DWT	YEAR BUILT	STEEL	SCANTLINGS REDUCED?	DOUBLE SIDES?	DOUBLE BOTTOM?
SANSINENA II	71589	1971	Hi-St	No	No	P-85
ARCO PRUDHOE BAY	70738	1971	Hi-St	No	No	P-85
ARCO SAG RIVER	70215	1972	Hi-St	No	No	P-85
CHEVRON CALIFORNIA	71339	1972	Hi-St	No	No	P-85
CHEVRON MISSISSIPPI	70213	1972	Hi-St	No	No	P-85

SANSINENA II:

Fractures in web portion of transverse web frames in way of web lap joint and snipe in flange butt. Common in ballast tanks near both bottom shell and main deck. Cracks appear to start near face plate and travel towards shell. Appears to be result of fatigue and poor design. Lap (joggle joint) replaced by an insert plate as cracks appear. Also, since web face plate is in a transition from 6" to 12" in this area, the face plate is renewed to relocate butt/snipe location and to smooth width transition.

Fractures in side longitudinals at toe of bracket to transverse web frame. This occurs one web frame aft of the transverse bulkheads at the stringer plate levels. Here the side longitudinals stop one frame aft of the bulkhead and are bracketed off to the web frame. Cracks occurred in the web and flange of the side longitudinals. It appears that the brackets that existed were too abrupt. Softer brackets were installed.

Cracks and buckles in brackets between transverse bulkhead centerline stiffeners and the CVK. A suitable repair may be to just replace per original since these are generally associated with long term degradation. Analysis has shown slight overstress in the structure. Fix will improve load path by new bracket shapes that account for better transition between differing bulkhead and bottom structural configurations.

Fractures in vertical bulkhead stiffeners in way of cut-out near lap connection to bottom longitudinals. Bracket has been added to stiffen the intersection.

This vessel has not had problems with fractures in the side longitudinals in way of the transverse web frames that CHEVRON CALIFORNIA and CHEVRON MISSISSIPPI have experienced. During detail plan review, the owner made sure that lugs were placed in way of the cut-outs in the web frame for the side longitudinals (there were none on the Chevron ships).

ARCO PRUDHOE BAY & ARCO SAG RIVER:

longitudinals crack at bulkhead of ballast tank and stiffener.

CHEVRON CALIFORNIA and CHEVRON MISSISSIPPI:

Side shell cracks and side longitudinal cracks. (See illustration on page 63 of "Guidance Manual for the Inspection and Condition Assessment of Tanker Structures.") This is the result of poor detailing. In general it occurred in way of longitudinals in way of cross struts of the transverse web frames. Squence of failure: (1) crack in flat bar connection to stiffener; (2) crack in free edge of cut out; (3) crack in side shell; and (4) crack in radius openings of the cut-outs. Solution was to add bracket to back-up flat bar and provide lug in way of longitudinals.

Cracks in erection joint near frame 55. Cracks are the result of general corrosion. Erection joint rewelded.

5. Findings Regarding the Causes of Structural Failures.

A. High Tensile Steel (HTS)

There was a general consensus among the TAPS operators that modern vessels, built within the last 20 years, which contain HTS have more problems than the older vessels constructed solely of mild steel. Of particular note are the vessels in the Atigun Pass class, whose entire cargo block section consists of HTS. Some operators were quite vocal in their disdain for higher strength steels. Some felt that HTS has no place on large vessels because the technology employed in actual design and construction of these ships is not adequate to produce HTS vessels that will not have cracking problems.

A majority of the naval architects and structural engineers who attended the meetings in company with TAPS operators felt that HTS was the source of many of the cracking problems, but that the cause of these cracks was not from the innate properties of the steel itself. They felt that structural failures on vessels with HTS could be attributed to poor or inadequate design of details and workmanship, which contributes to an increased incidence of fatigue failure. The major concern with details is that those that are being used on high tensile steel vessels are the same as those that have been used traditionally on smaller, mild steel vessels without corresponding analysis to take into account the fatigue concerns associated with the higher allowable stress associated with higher strength steels.

B. Reduced Scantlings/Minimal Design

Figure III-2 shows that

(1) vessels whose cargo block section is constructed of either a combination of mild and HTSs or solely of HTS experienced disproportionately higher numbers of structural failures than vessels built only of mild steel;

(2) single hull vessels, regardless of the type of steel, comprised 62.3% of those studied and accounted for nearly 80% of the structural failure events; and

(3) The number of vessels built with full scantlings, regardless of type of steel, suffered the same proportion of failures as vessels built to reduced scantlings.

None of the companies provided information indicating that they believed that reduced scantlings were a problem. In our analysis, we came to the same conclusion, with one exception. The vessels in the Atigun Pass class, besides having 100% HTS in the cargo block, were also built to reduced scantlings. Another feature of these vessels that may contribute to their high incidence of structural failures is that they have transverse frame spacing of 16'-10", which is considerably larger than the frame spacing typically found on similar size tank vessels.

C. Poor Weld Workmanship/Fabrication/Fit-Up

Figure III-3 shows that the first four shipyards listed below built 40 (57.9%) of the vessels under study, and that those 40 vessels accounted for 86.5% of the failure events. The chart, in addition to the number of TAPS vessels built and the respective number of structural failure events, shows the ratio of failures per TAPS vessel built.

Shipyard	# of vessels & (%)	# of failures & (%)	Ratio
Seatrain	3 (4.3)	12 (9.0)	4.0
Sunship	9 (13.0)	33 (24.8)	3.7
Avondale	12 (17.4)	40 (30.1)	3.3
Bethlehem	16 (23.2)	30 (22.6)	1.9
National Steel	11 (15.9)	7 (5.3)	0.6
Newport News	7 (10.1)	5 (3.8)	0.7
FMC Corp	4 (5.8)	3 (2.3)	0.8
Maryland Ship	3 (4.3)	2 (1.5)	0.7
Quincy	1 (1.4)	1 (0.8)	1.0
Todd	1 (1.4)	0 (--)	0.0
Hiroshima	1 (1.4)	0 (--)	0.0
Tamano	1 (1.4)	0 (--)	0.0

Many structural failures were attributed to either poor welding in and of itself - undercut welds, lack of penetration, wrong amperage, etc. - or to poor design which did not provide sufficient room for a welder to physically position himself to properly perform a good weld. There were other instances where an improper root gap, component misalignment and/or poor edge preparation, such as a jagged edge caused by flame trimming, before welding caused problems. In other cases, brackets and other components were either not installed or not completely welded. Regardless of how well designed a

FIGURE III-2

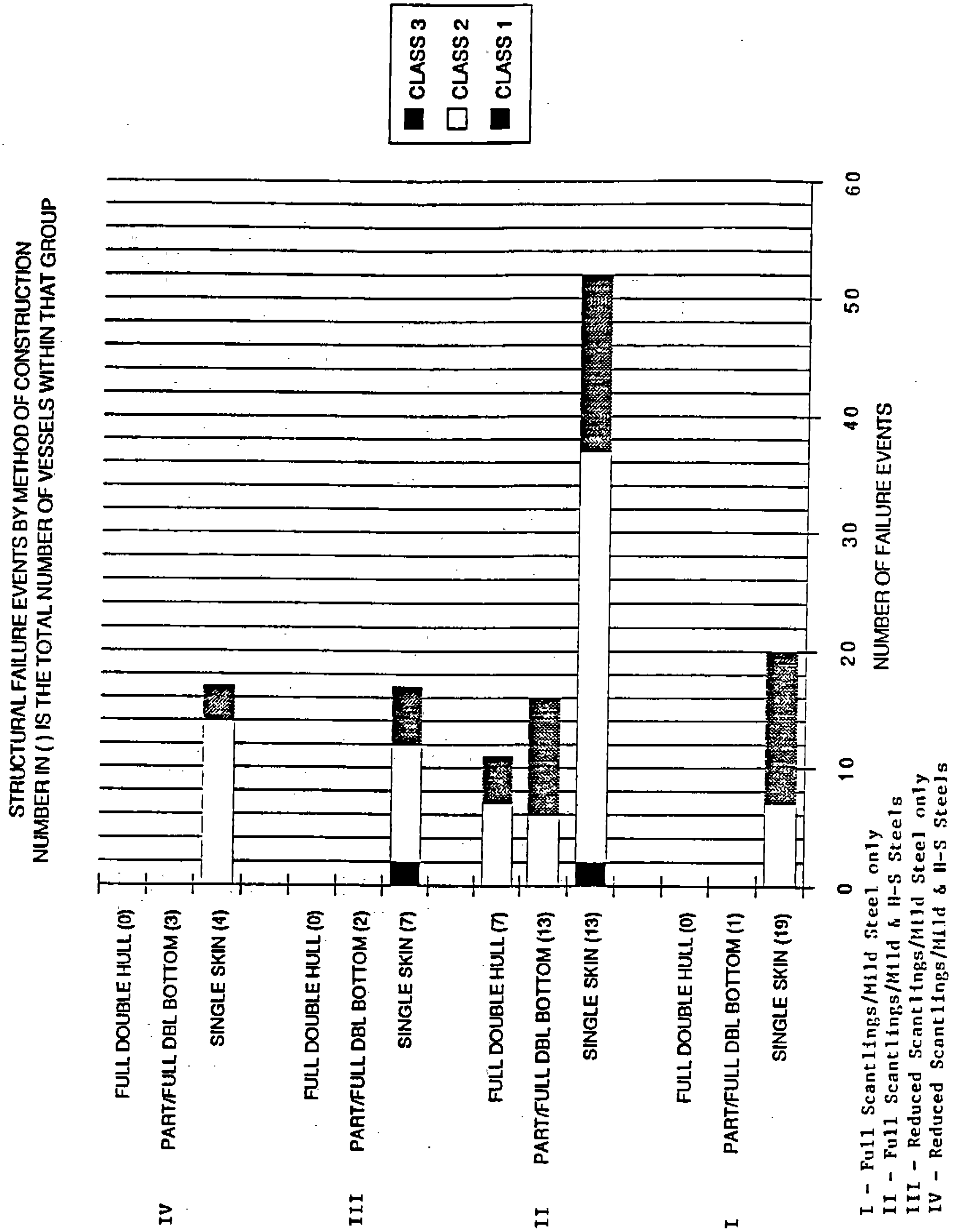
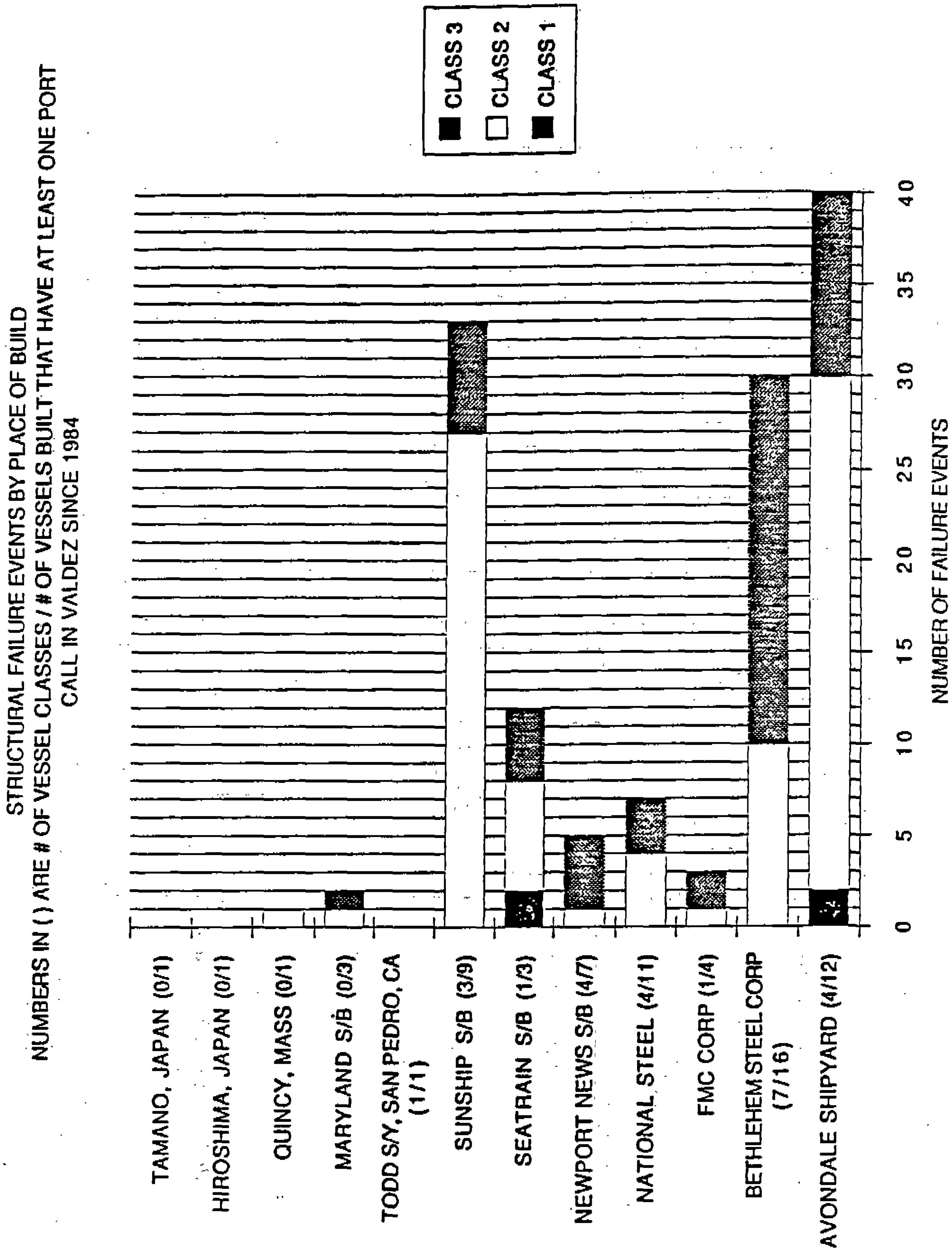

STRUCTURAL FAILURE EVENTS BY METHOD OF CONSTRUCTION
NUMBER IN ( ) IS THE TOTAL NUMBER OF VESSELS WITHIN THAT GROUP
CLASS 3
CLASS 2
CLASS 1
IV
FULL DOUBLE HULL (0)
PART/FULL DBL BOTTOM (3)
SINGLE SKIN (4)
III
FULL DOUBLE HULL (0)
PART/FULL DBL BOTTOM (2)
SINGLE SKIN (7)
II
FULL DOUBLE HULL (7)
PART/FULL DBL BOTTOM (13)
SINGLE SKIN (13)
I
FULL DOUBLE HULL (0)
PART/FULL DBL BOTTOM (1)
SINGLE SKIN (19)
0
10
20
30
40
50
60
NUMBER OF FAILURE EVENTS
I - Full Scantlings/Mild Steel only
II - Full Scantlings/Mild & H-S Steels
III - Reduced Scantlings/Mild Steel only
IV - Reduced Scantlings/Mild & H-S Steels

FIGURE III-3



STRUCTURAL FAILURE EVENTS BY PLACE OF BUILD
NUMBERS IN ( ) ARE # OF VESSEL CLASSES / # OF VESSELS BUILT THAT HAVE AT LEAST ONE PORT CALL IN VALDEZ SINCE 1984
CLASS 3
CLASS 2
CLASS 1
TAMANO, JAPAN (0/1)
HIROSHIMA, JAPAN (0/1)
QUINCY, MASS (0/1)
MARYLAND S/B (0/3)
TODD S/Y, SAN PEDRO, CA (1/1)
SUNSHIP S/B (3/9)
SEATRAIN S/B (1/3)
NEWPORT NEWS S/B (4/7)
NATIONAL STEEL (4/11)
FMC CORP (1/4)
BETHLEHEM STEEL CORP (7/16)
AVONDALE SHIPYARD (4/12)
0
5
10
15
20
25
30
35
40
NUMBER OF FAILURE EVENTS

vessel may be, or how thoroughly a detail is analyzed and engineered for a particular arrangement, poor welding technique or a poor weld will negate the best of detail designs and possibly lead to a structural failure. Further, with respect to missing details and poor workmanship and despite the presence of Coast Guard, classification society and shipyard personnel, there is insufficient manpower and time to conduct a thorough inspection of all welds and structural details to ensure that the vessel has been fully constructed to the approved plans.

D. Design of Details

Practically every operator attributed most structural failures to poor design of structural details and poor weld workmanship, including fabrication and fit-up. The biggest problem with detail design stems from the early designs in the late 60s and early 70s when tank vessels started to be designed using sophisticated analytical techniques that lead to very efficient, optimized structures. In many ways, these efficiencies brought about great advances in the ship building and operating industries and facilitated the extreme growth in tanker size. However, the general effects of structural optimization brought about a general lightening of scantlings, and problems with structural details have resulted.

Many of the structural details used in larger vessels have been designed from historical experience and fabrication preferences, and without any specific analyses requirements or guidance contained in classification society rules. It was the general consensus among the operators that studies have shown that details that had proven satisfactory for older vintage mild steel construction are not necessarily satisfactory for newer vessel designs, particularly those with HTSs. Some structural details on these larger vessels have proven to be inadequate and subject to failure.

One common detail that has been subject to failure on older vessels is lap joints. Fractures in lap joints are common in the transverse web structures in wing tanks. In general, operators are repairing fractured lap joints with butt-welded joints whenever possible.

Several of the operators attributed many fractures to metal fatigue. However, as one operator astutely noted, the word "Fatigue" doesn't identify the cause of a problem - it simply means that a structure has a lower safety margin; therefore, proper terminology should refer to cracks due to lower safety factors rather than fatigue. The assessment of fatigue life is extremely complicated and requires evaluation of environmental conditions combined with cargo and ballast loading and distribution.

Some operators have spent, and continue to spend, considerable resources to analyze details and have been successful in producing effective modification and repair solutions. Several operators supported the philosophy that careful scrutiny of structural details contained in the vessel during the design stages must be made to avoid structural problems after a vessel is built. The occurrence of fatigue damage on TAPS vessels, however, will continue to be a problem due to the inability of structural designers to remove all stress concentrations. Many structural components on ships have, and will continue to have, fatigue lives of only several years. Although considerable concern has been voiced concerning the amount of flexing that larger tank vessels undergo in a seaway, particularly those that are built with high tensile steels, there is nothing wrong with a vessel flexing in a seaway, provided the vessel has been properly designed to flex, just as an airplane is so designed.

E. <u>Environmental climate in the Gulf of Alaska</u>

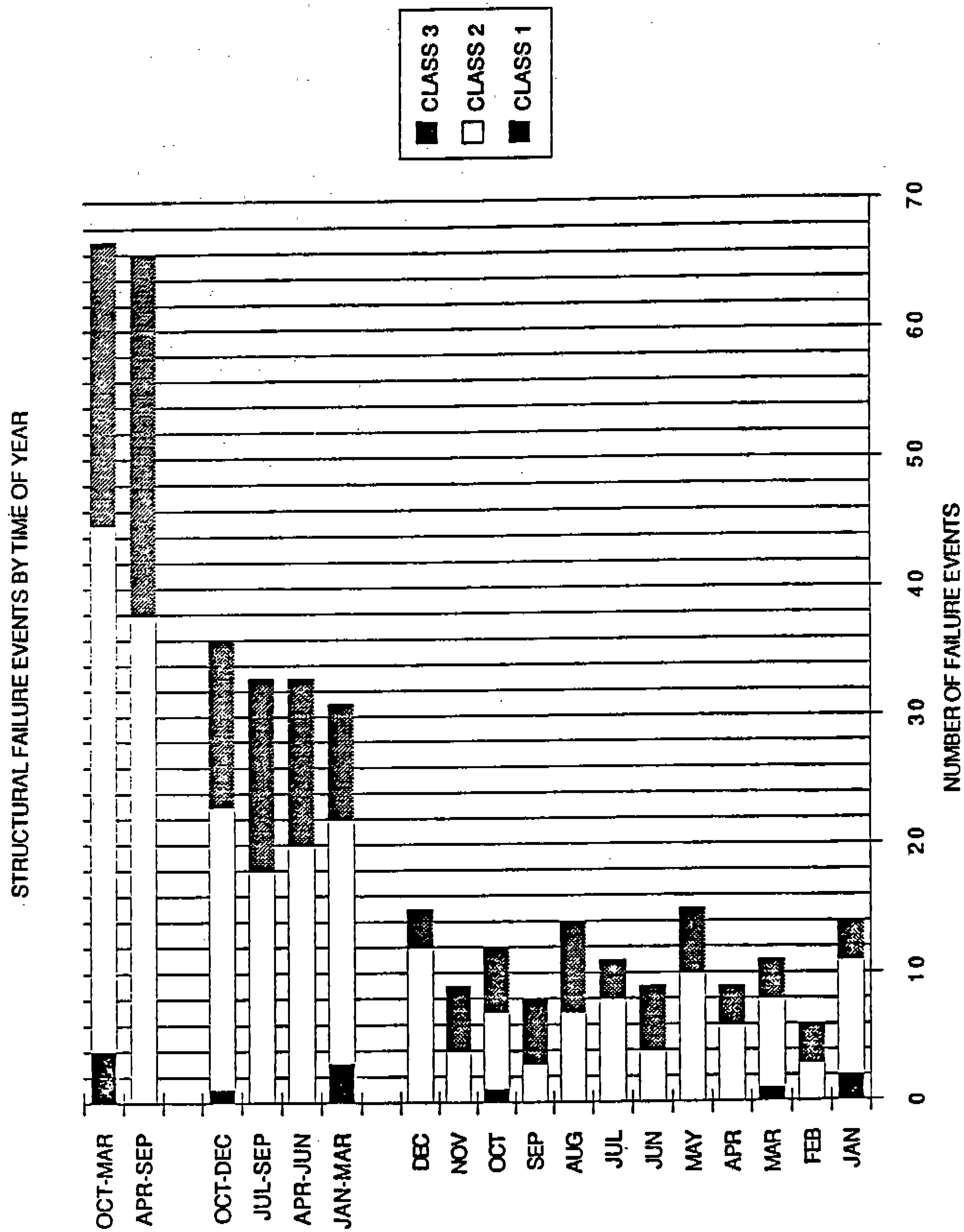
Figure III-4 shows that the overall reporting and documentation of structural failure events was evenly spread throughout the year, with a slightly higher number of events documented between October and December (thirty-six, or 27.1%); however, in the overall view, just a fraction more than half (sixty-seven, or 50.4%) of all events were documented during the months from October through March, the period when the most severe sea conditions would be expected. Our analysis did show that the more harsh the environment, in general, the more serious the event. All four Class 1 events were documented during the months from October through March, including two in January.

Some operators stated that the TAPS trade between the west coast and the Gulf of Alaska is extremely harsh on vessels, while others claimed that the route between the Gulf of Alaska and Korea and other far eastern countries was worse. The TAPS trade is highlighted due to the concentration of large ships built with HTSs currently trading out of Valdez. Also, the sea conditions most damaging to a vessel's hull may not necessarily be the most severe sea conditions that can exist. Depending upon a vessel's structure, loading, and course constraints mandated by its trading pattern (and thus direction of seas), sea conditions that are less than the most extreme can actually produce more severe racking forces on a vessel's hull. Although numerous companies subscribe to weather routing services, weather routing does not appear to be a feasible method for avoiding severe weather in the Gulf of Alaska due to the restricted trackline vessels must follow in transiting to and from Valdez.

The American Bureau of Shipping has conducted studies of wave data comparisons between two TAPS routes and a North Atlantic route. In a report titled <u>Enhanced Concerns Over Marine Pollution</u>, dated February, 1990, ABS discussed comparisons of wave data for the California to Alaska route, the Alaska to Yokohama route, and the New York to Rotterdam route. A most probable extreme wave height of approximately 33 feet, based upon data for the North Atlantic, was chosen as a norm for the comparison. While the wave severity for the New York to Rotterdam route nearly matched the norm of 33 feet, the wave severity for the Alaska to Yokohama route was approximately 39 feet, and that for the California to Alaska route approximately 40 feet. This data supports the view that the environmental climate in the Gulf of Alaska can be considered more of a problem for tankers on the TAPS route than those in North Atlantic service. Ships in the North Altantic service also have more routing options to avoid storms, whereas vessels in the TAPS trade do not.

Some operators felt that the TAPS trade is merely coincidental to cracking problems and that cracking problems are not specific to TAPS vessels. This group of operators felt that, since most failures are attributed to poorly designed details and/or poor welding, the natural working of a vessel's hull in any seaway will eventually result in a fatigue failure. The continously harsh sea conditions found in the Gulf of Alaska only exacerbates failures. Many felt that vessels that operate in international trades, extensively in tropical regions, experience structural failures that are also related directly to design of details.

FIGURE III-4



STRUCTURAL FAILURE EVENTS BY TIME OF YEAR
CLASS 3
CLASS 2
CLASS 1
NUMBER OF FAILURE EVENTS
0
10
20
30
40
50
60
70
OCT-MAR
APR-SEP
OCT-DEC
JUL-SEP
APR-JUN
JAN-MAR
DEC
NOV
OCT
SEP
AUG
JUL
JUN
MAY
APR
MAR
FEB
JAN

F. Ballasting Considerations and Tank Bulkhead Flexing

Most operators have instituted heavy weather ballast procedures, some more specific than others, whereby minimum amounts of additional (dirty) ballast is to be taken on in order to keep the vessel's hull down and reduce the amount of pounding it would otherwise be exposed to. At the same time, many operators acknowledged that ballast guidance is general, usually specifying only minimum amounts, and that the master has the discretion on how much ballast to take on. Masters even within the same company have different preferences and do not ballast in a uniform manner. One operator indicated that there is a need to overcome the mind set that minimum ballast is good from an operations point of view and instill the knowledge that more ballast is better for the vessel.

Bulkheads between cargo and ballast tanks undergo considerably more flexing than bulkheads between cargo tanks due to the reversal of forces, and thus stresses, between ballasted and loaded voyages. The flexing action accelerates the breakdown of tank coatings, and adds to corrosion rate already experienced in ballast tanks from the salt water environment.

Further discussions regarding the operating philosophies of the companies, including ballasting procedures, corrosion control practices and instructions to the master, are contained in the following section.

IV. PHILOSOPHY OF THE TAPS OPERATORS ON VESSEL OPERATION AND MAINTENANCE

The philosophies of the various TAPS operators regarding the operation and maintenance of their vessels vary considerably. Many companies indicated either verbally or in writing that they have some type of program in effect for conducting internal exams and for locating and tracking structural failures. While most of the programs have some degree of merit, some programs were judged to be far superior to others. One general problem operators are faced with is that reorganizations in recent years have frequently resulted in the downsizing of engineering and maintenance support staffs. Also, in some operating companies, because of smaller engineering staffs, it may be impractical to expect them to be able to cope with the administrative and technical requirements that are needed to effectively implement programs to reduce the incidences of structural failures. The following discussions summarize the various operating and maintenance philosophies and highlight the best programs established to deal with structural failures.

1. Tank Internal Surveys

A. Frequency of Surveys.

The frequency of internal exams of cargo and ballast tanks which operators establish is generally set by the operators' knowledge of their vessels' particular structural performance in conjunction with ABS surveys and Coast Guard required drydockings. Programs range from spot checks of ballast tanks after each voyage, to general surveys of all tanks once a year, to complete internal exams every six months (before and after winter). Many operators also conduct internal surveys of ballast tanks and, to a lesser extent, of cargo tanks 3 to 6 months prior to a vessel's scheduled drydock exam in order to find and document problem areas before the shipyard period rather than be caught short after the vessel enters the yard. These operators invariably stated that the cost of repairing cracks found after a ship is already in dock is considerably higher than those listed on a bid specification.

Other operators hold to the philosophy that the proper place to find cracks is in the shipyard, and therefore do not conduct pre-shipyard surveys. They believe that their yearly surveys will uncover any problems and that, since they correct the problems at the time they are found, an additional pre-shipyard survey will accomplish little. They also feel that there is economic incentive for shipyards to find cracks and, as a result, if a crack exist, the shipyard will find it.

The most aggressive program in effect involved a complete internal exam of every tank by raft every 6 months, both before winter and again after. A few operators had no program in effect other than conducting surveys only when required by the Coast Guard or ABS, or when repairs were conducted that required tanks to be cleaned and gas freed.

B. Scope of Internal Surveys.

The scope of internal surveys of cargo and ballast tanks varies widely among the operators. Some operators conduct complete surveys only in the ballast tanks, as those tanks undergo the most severe corrosion and wastage. Due to the duplication of design details throughout all tanks on a vessel, other operators inspect only a representative tank since a thorough inspection of details in one tank will provide a good indication of the condition of other tanks.

C. <u>Methods Used To Conduct Internal Surveys</u>.

Nearly every company agreed that conducting internal surveys on large tankers is a difficult undertaking. The most difficult areas to inspect on large tankers are the upper areas and underdeck structure of the cargo tanks. One company clearly expressed this by stating the opinion that finding cracks on large vessels takes a combination of good lighting, competent inspectors who know what to look for and where to look, and good luck.

To conduct internal examinations, nearly all of the companies use vessel crews, port engineers and/or contract surveyors who are familiar with their vessels. Using the same individuals is more productive as they know where the problems areas are and are more apt to find them. In general, the personnel of the company or contractor who performed the inspections have 20 to 30 years of experience in performing structural inspections.

The use of rafts was generally acknowledged by most companies as the best and most cost effective method for conducting up close surveys of the upper levels of a tank. Despite these apparent advantages, however, several companies do not use rafts to inspect tanks. They believe that it is an inherently dangerous method due to the sloshing of the water, even with the vessel at anchor. In addition, there are conflicting considerations that must be made with regard to tank entry procedures and the safety of personnel. The rafting of tanks conducted outside of a shipyard are usually done without the benefit of a marine chemist to certify tanks safe for entry, particularly with regard to benzene exposure limits. One company also stated that tanks <u>must</u> be dry and clean before conducting an inspection; otherwise, cracks will not be found unless the crew or inspector knows exactly where to look.

Some companies selectively stage certain tanks if there are known problem areas or when required for an ABS close up survey. A unanimous opinion was that complete staging of all tanks during a drydock is both cost and time prohibitive. Estimates to stage 100% of tanks ranged from $250 thousand to "unthinkable". In addition, few, if any, shipyards would have enough staging on hand to erect staging in every tank of a large tanker.

The Chief, Office of Marine Inspection, Security and Environmental Protection is sponsoring and Research and Development Program in FY 1992 to identify a more effective and efficient method by which to conduct tank examinations on tankships. The Project will involve the development of a device to be used by inspectors that will be small enough to fit through a manhole, suitable for use in an explosive atmosphere, and the ability to display remotely on a video screen.

D. <u>Personnel Safety and Frequency of Tank Inspections</u>.

Several companies commented that the strict requirements for benzene have significantly increased the time needed to clean and gas-free cargo tanks. Trinidad stated that it normally takes 7 days to clean and gas free an entire vessel, and requires taking the vessel out of service. Ballast tanks are also difficult to clean and gas free as they frequently have mud in the bottom that must either be removed completely or at least stirred up to release any entrapped gases.

2. Tracking Structural Failures/Critical Areas Inspection Plan (CAIP)

Methods used to document and track structural failures range from sophicated computer programs to none. For the most part, critical areas inspection plans consist of the knowledge contained in the heads of the people who regularly conduct internal surveys for the operators. The front line used by several companies is the vessel's crew. Other operators rely heavily upon in-house personnel and professional surveyors under long term contract to inspect the same vessels. The operators justified their "people" methods on the grounds that these individuals are familiar with the vessels and know where the problems are. There appeared to be no effort by some operators to document structural failures for long term evaluation for signs of patterning or repeating. Other operators have taken, or have begun to take, active and agressive approaches to tracking structural cracking and developing written critical areas inspection plans.

Two operators have recently developed sophisticated computer programs. Although the primary intended use for these programs is for budgeting and maintenance purposes, they are capable of storing repair, gauging and modification histories in minute detail for each vessel. They can function as a critical areas inspection plan and capture structural failure profiles. On the other extreme, some companies who did not have a viable program in effect for tracking and resolving structural failures instituted new programs as a result of the Commandant's letters of December 1989, and our subsequent meetings with them. A few companies admitted that they had had to start from scratch to put together historical records and develop profiles for their vessels. These companies complemented the Coast Guard for providing the incentive for them to do this as they all agreed that effective programs for tracking and resolving structural failures is good management and business practice.

Another operator is developing special condition and repair specification survey reports to be used in conjunction with a computer database. Development of the program slowed during recent months due to shifts in corporate needs to address other matters pertaining to tank vessel safety that came about as a result of the EXXON VALDEZ oil spill. This program is still in draft stages; however, they are in the process of contracting out the software development. In conjunction with the special survey reports, this operator is also developing a program that is intended to produce (1) a thorough survey of all ships upon which to generate a "critical area" inspection plan, (2) an in-house manual for inspection and approved repairs, and (3) a computer program that will provide access to their database.

One operator places a great deal of emphasis on its shipboard management program. Masters and chief engineers are company employees, as are the other licensed officers, and are made responsible for the maintenance and repair of their vessels. This extends to shipyard periods where the crew is responsible for the quality control of work performed on their vessels. As an aid to the vessel's crew in carrying out maintenance responsibilities, the operator has provided a shipboard computer system to track preventative maintenance. The system was designed primarily by shipboard personnel. Under this program, every item on the ship is identified as a separate "system". Individual cargo tanks, for example, are items in the "cargo system". Regular maintenance is performed on the elements in each system so that the overall work load is spread out over time. Crew stability is very important to this scheme.

Companies that drydock their vessels overseas, particularly in Korea and Japan, have realized an added benefit not provided by U.S. shipyards. Following a drydocking period in an overseas shipyard, the shipyard facility provides a report that extensively details all repairs that were made to the vessel, including detailed drawings that depict all fractures found, their location, size, and how repaired. These reports are used to establish a database for the structural profiles of the vessels, and to identify repeat problem areas for development of critical areas inspection plans.

3. Preferred Methods For Repair

A. Evaluating Fractures.

Again, philosophies regarding the repair of structural cracks, corrosion and pits varied widely. Generally speaking, a majority of the operators, following discovery of a fracture, look at the surrounding areas, past history (isolated incident or repeat problem), and the next yard availability before deciding upon a course of action. Normally, immediate repair is effected on cracks in critical areas, but cracks in non-critical areas, often referred to as "nuisance cracks", can be left alone with either minimal temporary repair or no repair at all.

B. Corrosion and Pitting.

A few operators felt that nobody has a handle on pitting and the reason(s) why it occurs, while others indicated that a back-up method is needed for tank coatings to prevent corrosion cells from forming when the epoxy chips away. Corrosion control procedures are futher discussed in section IV.7 below.

C. Repair of Cracks.

The method generally used to repair cracks varies by operator. Depending upon the size, location, and potential for propagating, most cracks are repaired by veeing out the crack and rewelding. Some operators have set certain standards or criteria for whether a crack is to be veed out and rewelded, or new steel inserted. For example, if a fracture in a side longitudinal extends more than 1/2-way through the web of the longitudinal, new steel is inserted; otherwise, the crack is veed and rewelded and face plate renewed. The concept of "wounded steel", i.e., steel that has been subjected to fatigue damage of unkown magnitude or has cracked due to fatigue damage, was expressed and that "wounded steel" should always be replaced. Based upon this philosophy, operators remove the "wounded steel" and follow one of two options for fixing cracks resulting from fatigue: new steel is added in kind to "restart the clock" on fatigue life, or the detail is redesigned to reduce stress.

D. Repair of Corrosion Pits.

A general philosophy followed by several operators was to fill pits with epoxy when they reach a depth of 1/4" - 3/8". Pits are clad welded if there are several within an area of 6" x 6" or less. ABS and Lloyds have approved one operator's repair procedure for pits, which specifies plate inserts for deep or close proximity pitting, clad weld for shallow pits, and epoxy coating for shallower pits. Still another operator's policy is to pencil blast bad areas every shipyard, reweld pits that are more than 3/8" deep or otherwise fill with compound, and recoat.

E. Repair of Mild and High Tensile Steel.

The operators made no distinction between high strength and mild steel with regard to repair practices, as long as proper weld procedures are used. A couple of operators noted that they are constantly at battle with shipyards, particularly overseas, to adhere to proper repair procedures. Though not discussed by the operators directly, one concern with the use of high tensile, and other specialized, steels is material availability. Often these materials are not available or, when they are, quantities are frequently insufficient for implementation of the most effective, long term, permanent repair.

F. Minor Fractures.

Some operators consider nuisance fractures as just that - miscellaneous cracks in non-critical areas that do not require immediate repair. These operators referred to studies that show that a crack may occur in an area of high stress, but that once the crack developes, the stress is relieved. Since surrounding stresses are relatively low, the crack will not propagate and only requires monitoring until the next shipyard period. These operators are reluctant to conduct immediate repair of these types of cracks because undue operational delays of the vessel would occur.

Some operators, on other hand, consider certain Class 3-type fractures just as important as a Class 1 or 2 crack and repair them as soon as possible, regardless of size or location. In general, the operators do not attempt to analyze crack propagation rate since, in most cases, the steel has cracked because a detail has reached the end of its fatigue life. Their repairs consist of modifying the local detail that failed such that the fatigue life of the detail is extended.

G. Analysis of Fractures.

The operators are increasing their focus on poorly designed structural details and fatigue. As the cost and acceptability of finite element analysis becomes more inexpensive and routine, more operators are contracting structural engineers to conduct finite element analysis and to engineer modifications to details to relieve stress concentrations in areas where cracks have occurred.

The most detailed statement regarding the analysis of cracks was made by an operator who stated that they make an effort to analyze all cases where patterning is apparent. Depending upon the results of the analysis, location, threat to the integrity of vessel, and pollution potential, particular details are selected for modification. This operator believes that cracks in the side shell near the neutral axis are not critical if the loading on the structure is predominantly hull girder longitudinal bending. Cracks in the CVK, however, may require immediate repair due to main hull girder longitudinal bending. For other types of loading, i.e., torsion, an evaluation of the main hull girder for repair would be dependent upon the location and type of loading on the structure in the vicinity of the crack. Analysis of details can and do produce effective modification or repair solutions. Analysis must not be focused on increasing the strength (scantlings) of the vessel, but on providing a better load path for the stresses. Some analysis shows that material must actually be removed in order to correct a problem.

Generally, fatigue evaluation is an extremely complex analysis incorporating concerns related to loading input, material type, local structural arrangements, and workmanship, all of which have been identified as being problem areas with TAPS vessels. Fatigue evaluations are not yet a common and practicable component in the design process. One significant point noted by several operators, including the one above, is that a fix, if not properly analyzed, will simply shift the problem to another area. When this occurs, a cracking problem may develop that is even more serious than the original problem, and more difficult to fix. The operator discussed above believes that a lot of operators and shipyards conduct finite element analysis to analyze details, but that many of these analyses are often done badly, or are performed on insufficient models. Performing this type of analysis requires a lot of time and expertise. Finding a viable solution is a long and tedious operation, usually requiring 1 year or more to develop a solution. Long term permanent fixes for problems that appear on a vessel today will be 3 to 5 years in the making. Sometimes the cost of analysis exceeds the cost of repair, and the benefits must therefore be weighed. On the other hand, one operator downplayed the effectiveness of finite element analysis, pointing out that finite element analysis is often only based upon static loading conditions which does not take into account the effects of complex dynamic loads that actually occur in a seaway.

In order to be fully effective and correct, a detailed analysis usually requires a determination of the global hull loadings. This is a costly and time consuming problem. An evaluation of the environment in which the vessel operates must include consideration of all dynamic stresses placed on the vessel, including longitudinal, shear, torsion, etc. Finite element analysis is a useful tool for comparative purposes. Despite advances in computer technology in recent years, it is still a time intensive proposition when global loading information is required, taking on the order of 1 year to develop a viable working model for the entire structure of a ship.

H. Resolution of Repairs For Structural Failures.

The bottom line expressed by most operators is that cracks must be evaluated on a case-by-case basis. There is no singular fix for every crack - what might work for one vessel may not work for another, and several repair alternatives may be appropriate for a given situation. The structural failure histories, supported by information provided by the operators, show that some vessels within a class suffer cracks in one area while the other vessels within that class don't. The reasons for this are many and include variations in routes, differences in trading patterns, differences in the way masters ballast their vessels, and modifications made to a vessel's structure either during or after initial construction. For example, in the Atigun Pass class of vessels, two of the vessels had considerably fewer documented structural failures than the other vessels in that class. It was learned during our meetings that the owner of the two "cleaner" vessels had installed a raised forecastle on his two vessels, while the other vessels are flush deck at the bow. Whether or not this difference in structure has been the reason for the differences in cracking is unknown.

4. Instructions To Masters

A recurring theme expressed throughout the Report of the Tanker Safety Study Group is that tanker masters are under intense pressure from their operators and Aleyeska Pipeline Terminal to maintain schedules, including the use of bonuses and fines as an incentive to minimize at sea time. The Tanker Study Group stated

> "Schedules generally dictate operations; the schedule must be adhered to above all else. Some owners and operators force vessel masters to drive ships hard in order to meet the schedules; it is cheaper to repair a crack later than miss the schedule for loading or discharge."

The information provided by every TAPS operator was exactly the opposite of the findings by the Tanker Safety Group. The operators unanimously stated that there is no pressure put on the masters to maintain schedules and that their masters have ultimate discretion to slow a vessel down in heavy seas to prevent damage to the vessel. Several operators stated outright that their masters were never criticized for delays in a vessel's schedule provided a decision to reduce speed was made in the interest of vessel safety. The operators indicated that they repair most cracks as soon after they are found as possible because taking a vessel out of service to repair cracks was too costly in most cases.

The Merchant Vessel Inspection Standards Development Branch [Commandant (G-MVI-2)] is developing a Navigation and Vessel Inspection Circular that will call attention to, and endorse, IMO Resolution A.647(16), "IMO Guidelines on Management for the Safe Operation of Ships and for Pollution Prevention". The intent of the IMO Resolution is to promote and support the concept that operating efficiency and profitability can be increased if the owner or managing operator provides effective supervision and plans a safety strategy which anticipates problems. One of the key points of the Resolution is that, while recognizing that the master is ultimately responsible for the the safety of the crew and safe operation of the vessel, the vessel owner or managing operator is obligated to provide the master with a safe ship and a trained crew, and that he be given the latitude to make decisions without undue pressure.

5. Ballasting Procedures

Nearly all of the operators have instituted procedures, either formally or informally, establishing the use of certain cargo tanks as "swing tanks" in order to carry additional ballast above that required by MARPOL to be carried in segregated ballast tanks. Ballasting requirements and procedures differ between operators. Several operators noted the differences inherent in VLCC operations as compared to smaller ships in that masters can't feel the effects of weather on the hull of a VLCC as is possible on a smaller ship. As a result, they recognize the need for additional ballast to get the hull down into the water and decrease the hull's exposure to pounding from high seas. Few operators require specific amounts of ballast to be loaded. Most set minimum requirements and rely upon the judgement of the master to set ballast conditions, which they have noted to vary between masters and weather conditions.

Whatever dirty ballast is on board at the time a vessel moors at Alyeska Pipeline Terminal in Valdez must be discharged prior to loading cargo. Alyeska recovers the oil from the dirty ballast in compensation for taking it; however, the Terminal has limited storage capacity of 1-1/4 million barrels for dirty ballast water. The maximum rate of discharge that the Terminal can take from a vessel is also limited. The more dirty ballast a vessel carries into Valdez, the longer the turn-around time, thus an incentive to arrive with as little as possible.

6. Corrosion Control Procedures

A. Tank Coatings.

As stated in the Report of the Tanker Safety Study Group, "Classification societies allow a reduction in scantlings of internal structural members and shell plating if a suitable coating system and/or a corrosion control system is installed and maintained....It appears that most operators do a fairly good job on coating maintenance and that cracks in coated tanks are relatively easy to spot due to rust streaks and discoloration". With a few exceptions, the TAPS operators expressed critical concern for the proper maintenance of tank coatings and/or cathodic protection systems, especially on vessels where a reduction in scantlings had been allowed. The long term costs of maintaining tank coatings are much less than the long term repair costs associated with steel renewal as a result of corrosion.

Most operators stated that corrosion is not a problem if coatings are properly applied and maintained. The key to tank coating longevity is proper surface preparation. New vessel tank coatings are usually inorganic zinc, which is good for about 7 years. Inorganic zinc is difficult to replace, however, as it will not fill in pits. Most operators replace the zinc coating with an epoxy coating once breakdown of the zinc coating exceeds 15%. Epoxy coatings, if properly applied, will last up to 15 years. A drawback to epoxy coatings is that they are not as plyable as zinc coatings. This has caused problems on bulkheads between ballast and cargo tanks where flexing of the bulkhead between load and ballast conditions causes the epoxy coating to crack, allowing seawater to come into contact with the steel. Subsequent accelerated corrosion then occurs, leading to a fracture in the bulkhead between the oil and ballast tanks.

Despite the apparent advantages of epoxy coatings, some operators are reluctant to dedicate large sums of money to tank coatings, particularly with the issue of double bottoms and double hulls a very real possibility. Inexpensive (and less effective) lanolin-based "float coats" are sometimes used for a "degree" of short term corrosion protection. Some operators are also reluctant to apply coatings after construction because it is their belief that the coatings may mask corrosion wastage at welds and other indications of problems.

B. Anodes.

Some operators either install anodes in zinc coated tanks to provide adequate tank protection until epoxy coatings can be applied, or install anodes as a back up their epoxy coatings. The philosophy regarding the use of anodes is that deterioration of the anodes will indicate a breakdown of the tank's coating and will provide a relatively large anode compared to the small area of steel exposed by the epoxy breakdown. Anodes in ballast tanks are beneficial only on voyages longer than 5 days, and only when the tanks are ballasted with salt water, in order to give the anodes the time and medium to build up electrolytic action.

C. Double Bottom/Double Hull Vessels.

Corrosion control appears to be particularly critical for double bottom and double hull vessels. The most striking example of this was that of a double hull vessel that was the first of three in a Class. The ballast tanks on the first vessel were not originally coated when the vessel was built, whereas those on the other two vessels were. In addition, the first vessel was built without a particular bracket detail in the inner bottom underdeck support structure for the cargo tanks, whereas the other two vessels had the brackets installed. The missing brackets allowed the inner tank bottoms on the first vessel to undergo considerable flexing, particularly since this boundary was general loaded on one side with either ballast below or cargo above, and with the other side being empty between cargo and ballast voyages. This resulted in accelerated corrosion and deep grooving in the inner bottom tank tops near the longitudinal bulkheads, particularly in tanks 3, 4 and 5. The original operator of the first vessel put minimal maintenance resources into the vessel, which included an inexpensive lanolin-based coating in the ballast tanks. Another operator purchased the vessel in 1983 and, in 1984, recoated tanks 3, 4 and 5, including the double bottoms and wing tanks, with epoxy. As a result of a detailed survey of all tank tops and double bottoms conducted in October, 1987, the coating was found to be breaking down on the double bottom plating in way of the underdeck longitudinals as a result of the working of the inner bottoms, resulting in further concentrated corrosion and cracking of the inner bottom plating. The second operator subsequently renewed all inner tank bottoms in tanks 1 - 6 and installed the brackets originally left out of the vessel. No problems have been noted since the steel renewal and addition of the brackets. Neither of the other two vessels have experienced the same flexing and corrosion problems experienced on the first vessel.

Another operator has also experienced corrosion wastage in the wing tanks of its double hull vessels that carry heated cargo. The heating of the atmosphere in the wing ballast tanks causes a warm, moist atmosphere at the top of the wing tanks. Once the tank coating barrier broke down, accelerated corrosion occured on the steel in localized areas because of the relatively small anodes that were in effect formed where coatings failed. Coatings in general tend to fail at intersections and knife edges, of which double hull vessels have many. He expects to have to completely blast and recoat all ballast tanks on these vessels within the next few years at an approximate cost of $10 million per ship.

V. Summary

1. Responsibility for Inspections.

Most operators indicated that it is their responsibility to find and repair cracks. Several felt that, because they rely more upon their own people or independent surveyors to find cracks rather than upon Coast Guard inspector, the Coast Guard should assume more of a role as an overseer between the operators and ABS for ensuring that cracks are found and properly repaired. Unless the Coast Guard changes its system for rotating personnel, the operators believe that the level of Coast Guard experience and expertise in the area of large tanker inspection will not improve.

2. Vessels Requiring Special Inspection and Reporting Measures

The trend of disproportionately higher incidences of structural failures on the Atigun Pass Class of vessels has continued since the establishment of the new definitions for structural failures. Between 20 December 1989 and 30 April 1990, a total of 11 structural failures were reported to G-MVI, including 7 Class 1, 3 Class 2 and 1 Class 3 failures. The following vessels accounted for these failures:

CLASS/ VESSEL	Class 1	Class 2	Class 3	Notes
America Sun				
AMERICAN TRADER	1			Possibly caused by 2/90 grounding off Huntington Beach, CA
Atigun Pass				
BROOKS RANGE	3		1	
KEYSTONE CANYON	1			
THOMPSON PASS	1			
EXXON BENICIA		1		
EXXON NORTH SLOPE	1			
Arco Anchorage				
ARCO JUNEAU		1		
Sunship TAPS				
KENAI		1		
Chevron GT				
CHEVRON LOUISIANA		1		

Clearly, of the 11 failures reported, the Atigun Pass Class has accounted for 63.6% of the total number, and 85.7% of the Class 1 failures.

3. Guidance to the Coast Guard Inspector.

Following the initial review of vessel files, it was clear that many structural failures, including Class 1 failures, had not been reported to Headquarters. In addition, there were a number of fractures that breached the oiltight integrity of a vessel's hull, resulting in a pollution incident;

however, because these failures were less than 10 feet in length, they were documented only as Class 2 failures and frequently never came to the attention of Headquarters personnel until long after the incidents had occurred. For these reasons, on 20 December 1989, Policy Letter 23-89 was published establishing new definitions for structural failures. A Class 1 failure was redefined to include any fracture in the oil/watertight boundary of a vessel's hull. Repair proposals for Class 1 failures were also required to be submitted by the cognizant OCMI to Headquarters for review and acceptance prior to repairs being made.

As a result of feedback from the field indicating a heightened awareness of the documentation and reporting of structural failures, and the identification by the TAPS study group of vessels requiring special inspection measures, new policy will be published that further refines the documentation and reporting of structural failures, including the following:

a. With the exception of those vessels requiring special inspection measures, the review and acceptance of repair proposals for all classes of structural failures will be made by the OCMI. As always, final approval of the repair remains with the OCMI. Notifications to Commandant (G-MVI) of Class 1 structural failures on vessels other than those requiring special measures will to be made for informational purposes only.

b. Procedures for Class 1 structural failures on foreign flag vessels are established.

c. The definition of a Class 1 failure now includes internal fractures that are 10 feet or longer in length. The definitions of structural failures are also clarified to distinguish them from structural damage.

d. Form CG-2752, Report of Structural Failure, Collision Damage or Fire Damage to Inspected Vessel, is discontinued and will no longer be used to report structural failures. Form CG-2692, Report of Marine Accident, Injury or Death, is to be used in documenting all Class 1, Class 2 and pattern-type Class 3 structural failures. Form CG-2692 will be revised to incorporate the information applicable to structural failures previously required by, and specific to, Form CG-2752.

Another policy letter is in draft which will provide inspection guidance for large tank vessels. This policy letter will include draft revisions to Chapters 5, 6, 7 and 8 of Volume II of the Marine Safety Manual.

Finally, in response to Recommendation No. 33 of the Report of the Tanker Safety Study Group, dated 6 October 1989, a copy of Guidance Manual for the Inspection and Condition Assessment of Tanker Structures has been distributed to those Marine Safety Offices that conduct examinations on large vessels.

VI. CONCLUSIONS

The following conclusions have been developed based primarily upon the meetings with the operating companies, but also upon recommendations contained in the Report of the Tanker Safety Study Group, dated October 6, 1989. To assist the reader, reference information is provided at the end of each conclusion. Where reference is made to the Tanker Safety Study Group, the recommendation number is given; all other cross-references are to the applicable sections of this study.

TAPS Study Findings

1. TAPS tanker hull cracking has been concentrated primarily in the vessels of the following five classes: Atigun Pass, America Sun, ARCO Anchorage, Seatrain, and Sansinena. In addition, the vessel MOBIL ARCTIC, and the vessel COVE LEADER, which entered the TAPS trade in April 1990, have experienced disproportionate numbers of structural failures. (Sect III.4)

2. The vessels of a single class, the Atigun Pass, have experienced a majority of the most frequent cracking occurrences and are experiencing recurring cracking for which fully effective long term retrofits have not been devised. (Sect III.4)

3. Operation in the Gulf of Alaska is not the primary cause of structural failures; however, the harsh environmental conditions encountered within the confines of that body of water have been linked to the higher than usual frequency of structural failures on these vessels. (Sect III.5.E)

4. Structural failures that result in pollution incidents can happen at any time of the year in the TAPS trade. All vessels routinely operating in the TAPS trade, particularly vessels whose hull structure contains high tensile steel, should be closely observed to detect any vulnerability towards structural failures. (Sect. III.5.A & E)

5. All of the TAPS operators understand and agree with the concept of a critical areas inspection plan; however, the methods used by the operators to document and track structural failures and repairs range from sophisticated computer programs to no formal method whatsoever. The degree to which the operators appreciate the associated concerns and have taken steps to develop solutions varies greatly. The lack of a formal, written critical areas inspection plan can have a detrimental effect when there is a change in inspecting personnel, often accompanied by the sale of the vessel. The development and use of formal critical areas inspection plans would allow inspectors to target their inspections and minimize the extent of an examination necessary to determine a vessel's condition. (Sect. IV.1.C & Sect. IV.2)

6. There were a number of responsible operators who have already taken steps to improve their methods of conducting internal surveys of their vessels, documenting structural problem areas, and determining proper repair solutions. Some operators already have programs where they conduct frequent (every 6 months) internal inspections of their ballast and cargo tanks, and either conduct special pre-shipyard exams or allow sufficient time while in the yard to develop their own sophisticated repair specifications. Some operators have even developed sophisticated computer programs that assist personnel with the

maintainence of critical areas inspection plans. In general, the personnel of the company or contractor who performed the inspections have 20 to 30 years of experience in performing structural inspections. (Sect IV.1.A & C; Sect IV.2)

7. Some companies who did not have a viable program in effect for tracking and resolving structural failures instituted new programs as a result of the Commandant's letters of December 1989, and our subsequent meetings with them. A few companies admitted that they had had to start from scratch to put together historical records and develop profiles for their vessels. These companies complemented the Coast Guard for providing the incentive for them to do this as they all agreed that effective programs for tracking and resolving structural failures is good management and business practice. (Sect IV.2)

8. Although numerous companies subscribe to weather routing services, weather routing does not appear to be a feasible method for avoiding severe weather in the Gulf of Alaska due to the restricted trackline vessels must follow in transiting to and from Valdez. (Sect. III.5.E)

9. There is no single cause of structural failures, although poor design of details and poor weld workmanship, particularly on those vessels constructed with high tensile steel, appear to contribute significantly to the occurrence of structural failures. Hull cracking often initiates either in or as a result of: (Sect. III.5.C & 5.D; Sect. IV.3.H)

a. poor or incomplete "wrap welds" around cutouts;

b. poor quality of major field hand-welded hull erection joints;

c. weld scars from improperly removed or pad welded lifting clips;

d. welds with undercut, with incomplete penetration, or made using incorrect amperage;

e. jagged, rough flame cut or trimmed openings, cutouts or snipes;

f. structural members (details) not installed during construction; and

g. improper repair procedures and/or sequences.

10. As a class, tank vessels have been designed using many sophisticated analytical techniques leading to very efficient, optimized structures that comply with classification rules and IACS recommendations. In many ways, these efficiencies brought about great advances in the ship building and operating industries and facilitated the extreme growth in tanker size. However, the general effects of structural optimization is suspected of bringing out many weaknesses in the ways tank vessels are designed and constructed, such as: (Sect III.5.A and III.5.D)

a. A general lightening of scantlings has resulted, which may be in the form of lighter structural members or greater spacing of stiffeners.

b. Many of the details used in vessels have been designed from historical experience and fabrication preferences, and without any specific guidance contained in classification society rules. Some structural details on these larger vessels have proven to be inadequate and subject to failure.

c. As a part of this optimization process, the use of high tensile steel has further intensified the problems with structural design.

11. Reductions in scantlings required by classification society standards, the use of corrosion allowances, and the use of high tensile steels in and of themselves have generally not contributed to structural failures. (Sect III.5.A & B)

12. The occurrence of fatigue damage on TAPS vessels will continue to be a problem due to the inability of structural designers to remove all stress concentrations. Many structural components on ships have, and will continue to have, fatigue lives of only several years. When these components fail in fatigue, appropriate repairs may include either a replacement of steel in kind which may simply "restart the clock" on the same fatigue life, or redesign and creation of a new and longer fatigue life. (Sect III.5.D; Sect IV.3.C)

13. The number of structural failures is more attributed to both the inadequate design and analysis of structural details, workmanship, and either the non-installation during initial construction or lack of continued maintenance of corrosion control systems in ballast and cargo tanks. (Sect. III.5.C & D; Sect IV.6)

14. A significant portion of the structural failures that have occurred on TAPS vessels are the result of fatigue failures that commonly manifest themselves in welds and structural discontinuities in details and transitions. Generally, fatigue evaluation is an extremely complex analysis incorporating concerns related to loading input, material type, local structural arrangements, and workmanship, all of which have been identified in the report as being problem areas with TAPS vessels. Fatigue evaluations are not yet a common and practicable component in the design process. (Sect. III.5.D; Sect. IV.3.G)

Mitigation and Repairs

15. The Coast Guard and ABS cannot substitute for proper judgement and responsibility of the vessel owner in the maintenance and operation of his vessels. The ultimate responsibility for finding and tracking structural problem areas lies with the vessel operator, and it is imperative to keep this safety net in place. The Coast Guard in many instances relies upon the surveys performed by exclusive ABS surveyors, many of whom have similarly long experience as industry in performing structural inspections. (Sect. IV.1.C; Sect V.1)

16. Repair proposals for structural failures must be carefully evaluated on a case-by-case basis. Consideration must be given to a number of factors including, but not limited to, variations in structural details or modifications within a class of vessels, specific trading patterns, and ballasting precedures. A repair can in some instances, if not carefully considered, do more damage than good by causing high stresses in a more critical location. (Sect IV.3.G & H)

17. The design details on a particular vessel are often duplicated throughout the cargo and ballast tanks. For this reason, a thorough inspection of only

two or three representative tanks in conjunction with a critical areas inspection plan will generally provide a good indication of the structural condition of the vessel. This integrated plan for inspections should be considered sufficient to satisfy the requirements of 46 USC 3714 for a detailed inspection of structural strength and hull integrity for tankships over 10 years old. (Tanker Safety Study Recommendation 6; TAPS Study Sect. IV.1.B; Sect IV.2)

18. Operating companies have generally instituted procedures to ensure that large tank vessels are operated in a prudent manner to reduce heavy weather damage. The only reliable method presently available to the master for judging the effects of weather upon the hull is his personal sensory feedback. This feedback may be imperceptible on very large tankers. As a result, the master may not reduce speed or change course sufficiently to mitigate heavy weather damage. Operational hull response monitoring equipment, now completing the development stage, shows promise for assisting the master in the evaluation of loading from heavy weather upon the hull. (Tanker Safety Study Recommendation 10; TAPS Study Sect. IV.4 & IV.5)

19. In general, new construction vessels do not contain lap joints that are seen as problematic. Lap joint construction should be avoided wherever possible. It appears that operators are already repairing fractured lap joints with butt-welded joints when possible. The replacement of existing fractured lap joints with butt-welded joints should be a standard repair procedure whenever possible. (Sect. III.5.D)

20. High tensile and other specialized steels have caused problems with regard to availability. Operating companies whose vessels are constructed with these types of steels need to ensure that stockpiles are maintained so that, when repairs are required, a sufficient amount of the specified steel is available to conduct the repair. (Sect IV.3.E)

21. Tank coatings and/or cathodic protection must be properly installed and maintained to prevent, or mitigate corrosion. The installation and maintenance of corrosion control systems is a company management decision that significantly affects tanker structural performance, particularly as vessels age. (Sect. IV.6)

22. The International Maritime Organization has adopted resolution A.647(16), "IMO Guidelines on Management for the Safe Operation of Ships and for Pollution Prevention", which brings to the attention of all administrations that promoting more uniform methods in ship operation and maintenance is essential. The Coast Guard is preparing a Navigation and Vessel Inspection Circular (NVIC) to disseminate these guidelines. (Sect. IV)

<u>Mitigation - Constraints and Resources</u>

23. Operating companies have experienced similar problems as the Coast Guard with regard to resource allocations and budget cuts. Reorganizations in recent years have frequently resulted in the downsizing of engineering and maintenance support staffs. This has forced many operating companies to use only one individual to conduct surveys on their vessels. These personnel are familiar with the vessels and probably do not overlook problem areas; however, they usually have not kept a formal record of all problems that existed. In some operating companies, because of smaller engineering staffs, it may be

impractical to expect them to be able to cope with the administrative and technical requirements that are needed to effectively implement programs to reduce the incidences of structural failures. Joint industry projects and co-operative efforts among the operators are the most effective means for resolving these problems. (Sect IV)

24. Many fractures can be attributed to poor quality control during vessel construction. Despite the presence of Coast Guard, classification society and shipyard personnel, there is insufficient manpower and time to conduct a thorough inspection of all welds and structural details to ensure that the vessel has been fully constructed to the approved plans. (Sect. III.5.C & D)

25. Rafting is considered by many operators as the best means by which to conduct an internal tank inspection. There are conflicting considerations, however, that must be made with regard to tank entry procedures and the safety of personnel. The rafting of tanks conducted outside of a shipyard are usually done without the benefit of a marine chemist to certify tanks safe for entry. The Coast Guard may be unable to attend close-up surveys due to its policy regarding tank entry. (Sect IV.1.C)

26. There is a need to provide more detailed descriptions of various coating and anticorrosion systems and how they relate to scantling reduction. Revisions to Chapters 5 through 8 of MSM Volume II have been drafted which include the subject information. This information will be incorporated into Change 4 of MSM Volume II. (Tanker Safety Study Recommendation 11)

27. The Coast Guard's findings from the 1988 Casualty Review Council report, using reports of structural failures submitted on Coast Guard Form CG-2752, were not contradicted by any information collected from field offices or from the TAPS operators during our meetings.

VII. RECOMMENDATIONS

A wide variety of maintenance and philosophical views were expressed by the TAPS operators, and similarly a wide variety of vessel structural performance exists. This variety of views and vessel performance, taken in concert with limited Coast Guard resources, necessitates that we target our attention on specific operators and specific vessels that require the most attention. The recommendations that follow have been structured based upon the philosophy that we must limit the impact on available resources and rely on the responsibilities entrusted in the operators and classification societies as we resolve the issues pertaining to the structural problem with TAPS trade vessels.

1. All tank vessels in the TAPS trade should be required to:

   a. have written critical areas inspection plans that include:

      (1) historical information on structural failures, repairs and modifications;

      (2) the frequency of inspection required for particular areas; and

      (3) the mechanisms for tracking trends, i.e., gagings, renewals and coating/anode systems;

   b. undergo structural inspections on more frequent intervals than presently required to satisfy minimum classification and regulatory needs, with at least one internal structural survey performed annually, noting in particular those areas listed on the vessel's critical areas inspection plans; and

   c. perform immediate repair of all fractures located in known critical areas, upon class approval.

2. The vessels in the America Sun Class, in addition to the above, should be required to:

   a. Continue immediate notification procedures, and proceed with repairs only after classification society approval and Commandant acceptance of repair proposals; and

   b. Be closely monitored in active repair areas to ensure the effectiveness of the repairs.

3. The vessels MOBIL ARCTIC and COVE LEADER, and the vessels in both the Seatrain class and Atigun Pass class, in addition to all of the above, should be required to undergo an internal structural survey every 6 months, noting in particular those areas listed on the vessel's critical areas inspection plan, in addition to satisfying the annual structural survey requirements.

4. The Coast Guard should not advocate Coast Guard attendance of close-up surveys when its policy prohibits its inspectors from entering tanks without a marine chemist certificate. On a vessel-by-vessel case, the Coast Guard should evaluate the need to attend each close-up survey along with the classification society, taking into account the location of the vessel and

gas-free condition of the tanks to be surveyed. On the other hand, the Coast Guard also should not support a double standard by advocating frequent internal examinations of tanks by industry personnel when a marine chemist has not certified a tank safe for men.

5. Coast Guard Headquarters should notify all owners and operators of TAPS vessels of the above requirements.

6. The requirements contained in items 2, 3 and 4 above should be applicable to those vessels regardless of service, since structural failures on TAPS trade ships are mostly a function of actual structural characteristics, and not solely due to their operation in the Gulf of Alaska environment.

7. The vessel operators, ABS, and Coast Guard should form joint work groups to address various items applicable to design and maintenance of tank vessel structures. A good example of a successful international group that has already accomplished work in this area is the Tanker Structure Cooperative Forum (TSCF). In the United States, a joint industry project (JIP) being performed by the University of California, at Berkeley, titled "Structural Maintenance for New and Existing Ships", will be an active forum where many of the issues raised in this report will be addressed. The Coast Guard, as part of the Ship Structure Committee, is participating and should encourage participation by all TAPS operators. The University of California project and others should address the following:

a. Once the first generation of critical areas inspection plans has been developed and reviewed by the classification society and the Coast Guard, vessel operators should work with the Coast Guard and ABS in a joint effort to establish "performance requirements" for future critical areas inspection plans.

b. A methodology should be established so that the owner of each vessel within the same class of vessels would share information on repairs conducted by them, and that the effectiveness of the repairs should be compared to ensure that the best performing repair is utilized.

c. With ABS serving as project group leader, a continuing joint working group should be established that would meet on a regular and formalized basis to discuss ongoing structural concerns of TAPS vessel operators and to establish a feedback loop for follow-up information in much the same way as the TSCF or the OCIMF operates.

d. Standard procedures should be established for the safe entry of tanks when internal tank surveys, particularly by rafting, are conducted outside of a shipyard. These standards should address respiratory protection, visibility, and lighting.

8. The Coast Guard and ABS should schedule a meeting within 30 day of the date of this report so that the Coast Guard can formally present the report to ABS and discuss its contents. In preparing for this meeting, we recommend that the TAPS study group members review the "long-term issues" set out in the Work Plan for Investigation of Structural Failures of Vessels in the TAPS Trade, dated March 1989, and reprioritize the issues. At the meeting, the Coast Guard and ABS should set an agenda to accomplish the following:

a. Ensure that, for vessels built to reduced scantlings, the initial installation and continued maintenance of corrosion control systems is a critical classification verification function.

b. Enhance classification society rules and policies pertaining to vessel structure so that they focus more attention on assurance that adequate design analysis is performed so as to ensure that vessels have properly designed structural details, particularly in the areas of brackets and structural transitions.

c. Explore the concept of enhancing classification society rules and policies pertaining to vessel structure to increase the margin of safety to allow for "system uncertainties" over which designers have no control, e.g., welder performance and quality control during construction and subsequent vessel operation and maintenance.

d. Consolidate and develop new policy and inspection guidance that addresses the issues of structural design, fabrication/repair procedures, workmanship, and quality control requirements, using as a basis all existing guidance published by ABS, the Coast Guard, and IACS, as well as reports of the Ship Structure Committee and the International Ship Structures Congress (ISSC).

e. Develop specific guidance on construction procedures, repair procedures, and the design of structural details such as lapped joints, etc. This guidance should address lessons learned and inspection requirements should be publicized for field inspectors by means of timely bulletins, class notes, NVICs, etc. The mechanisms to assure timely as well as thorough guidance resulting from the above should be considered.

9. <u>Coast Guard Headquarters</u> should carry out the following:

a. Formalize the structural failure classification, reporting and analysis procedures in Volume II of the Marine Safety Manual, including:

(1) Consolidation of Coast Guard Forms CG-2752 and CG-2692 to provide one mechanism for the documentation and reporting of structural failures to Coast Guard Headquarters; and

(2) Entry of all reported structural failures into CASMAIN for better future statistical tracking and analysis.

b. Where joint guidance is not developed, evaluate the need for to either develop new, or expand upon existing, guidance contained in the Marine Safety Manual regarding the inspection of tank vessels, in particular for ballast tanks and corrosion control systems.

c. Reemphasise the importance of the Casualty Review Council. The Casualty Review Council should place emphasis on overseeing the follow-up action to the Recommendations by this study, and upon human factors issues.

10. The TAPS Study has concentrated on U.S. flag tank vessels operating in the TAPS trade. We recommend that consideration be given to requiring a critical areas inspection plan be considered for all U.S. Flag tankships, regardless of service. We further recommend that any U.S. flag vessel with special design features be required to develop and submit a critical areas inspection plan along with the other plans submitted for review and approval in order to alert all parties to the need for special attention at subsequent inspections.

11. The findings of this study should be provided to IACS.

12. The International Maritime Organization's Marine Safety Committee (MSC), at its 58th session in April 1990, instructed the subcommittees on Ship Design and Equipment (DE), and on Stability and Load Lines and on Fishing Vessel Safety (SLF), to investigate the occurrence of hull cracking in tankers. This report should be submitted to MSC for distribution to the DE and SLF subcommittees.

13. The operators of foreign flag tank vessels that suffer a Class 1 structural failure while in U.S. waters should be required to:

a. perform temporary or permanent repair, approved by the appropriate classification society, prior to conducting cargo operations; and,

b. where a vessel is authorized to depart from a U.S. port with a temporary repair, written notification shall be provided to the Coast Guard from the vessel's classification society prior to that vessel's return to U.S. waters stating that permanent repairs, approved by that classification society, have been completed on the vessel.

14. All TAPS operators should be informed of the technological and human factors advances that have been achieved through the international efforts to develop hull response monitoring. In particular, the operators of the vessels in the Atigun Pass class, American Sun class, and Seatrain class, and of the vessels MOBIL ARCTIC and COVE LEADER should be encouraged to participate in the SSC/SNAME project on response monitoring, as this technology has been demonstrated to be more advantageous than weather routing, and would be most effective on restricted routes such as that in the Gulf of Alaska.