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CLASSIFICATION	SYSTEM NUMBER 510367
UNCLASSIFIED	

TITLE

DDH 205 CLASS STRUCTURAL INTEGRITY HISTORY 1951-1994

System Number:

Patron Number:

Requester:

Notes: Paper #24 contained in Parent Sysnum #510343

DSIS Use only:

Deliver to: DK

#510367 (24)

DDH 205 CLASS
STRUCTURAL INTEGRITY HISTORY
1951-1994

by D.J. Hussey[1], C.D. Roushorn[1], D.G. Smith[2], LCDR K.B. Holt[3], Lt(N) K. Kirkov[3]

[1] Donelad Hydronautics Limited
Suite 720, 1550 Bedford Highway, Bedford, Nova Scotia
Canada B4A 1E6

[2] Command Paint and Preservation Officer (retired)
Naval Engineering Unit Atlantic
FMO Halifax, Nova Scotia B3K 2X0

[3] Surface Ship Structures, Naval Architectural Services
Directorate of Ship Engineering
National Defence Headquarters
Ottawa, Ontario, Canada K1A 0K2

Presented at the Canadian Forces/Chief Research and Development Meeting on "Naval Applications of Materials Technology", Halifax, May 1995.

ABSTRACT

The keel for the first Canadian designed destroyer escort (DDE), HMCS ST. LAURENT was laid down 22 November 1950, launched November 1951 and completed 1955 followed in quick succession by six more ships of the DDE 205 Class. The 2900 ton DDEs were converted to DDHs commencing in 1962 with the fitment of a large hangar/flight deck complex for an operational 22,000 lb. Sea King helicopter. The last ship, HMCS FRASER, ended over four decades of reliable service by the 205 Class ships in 1994.

This paper addresses the structural integrity of the DDH 205 Class over forty-three years in five distinct periods:

a) Eight years as a DDE, 1955-1963;
b) First thirteen years as a DDH, 1963-1976;
c) Two years prior to Destroyer Life Extension (DELEX), 1976-1978;
d) DELEX at twenty-seven years average age post launch, 1979-1982; and
e) Twelve year life after DELEX, 1982-1994.

It is believed this is the first factual public record of the corrosion and structural problems experienced by a naval ship class over an entire ship class lifetime and life extension. Techniques developed to eliminate or at least retard such problems are presented.

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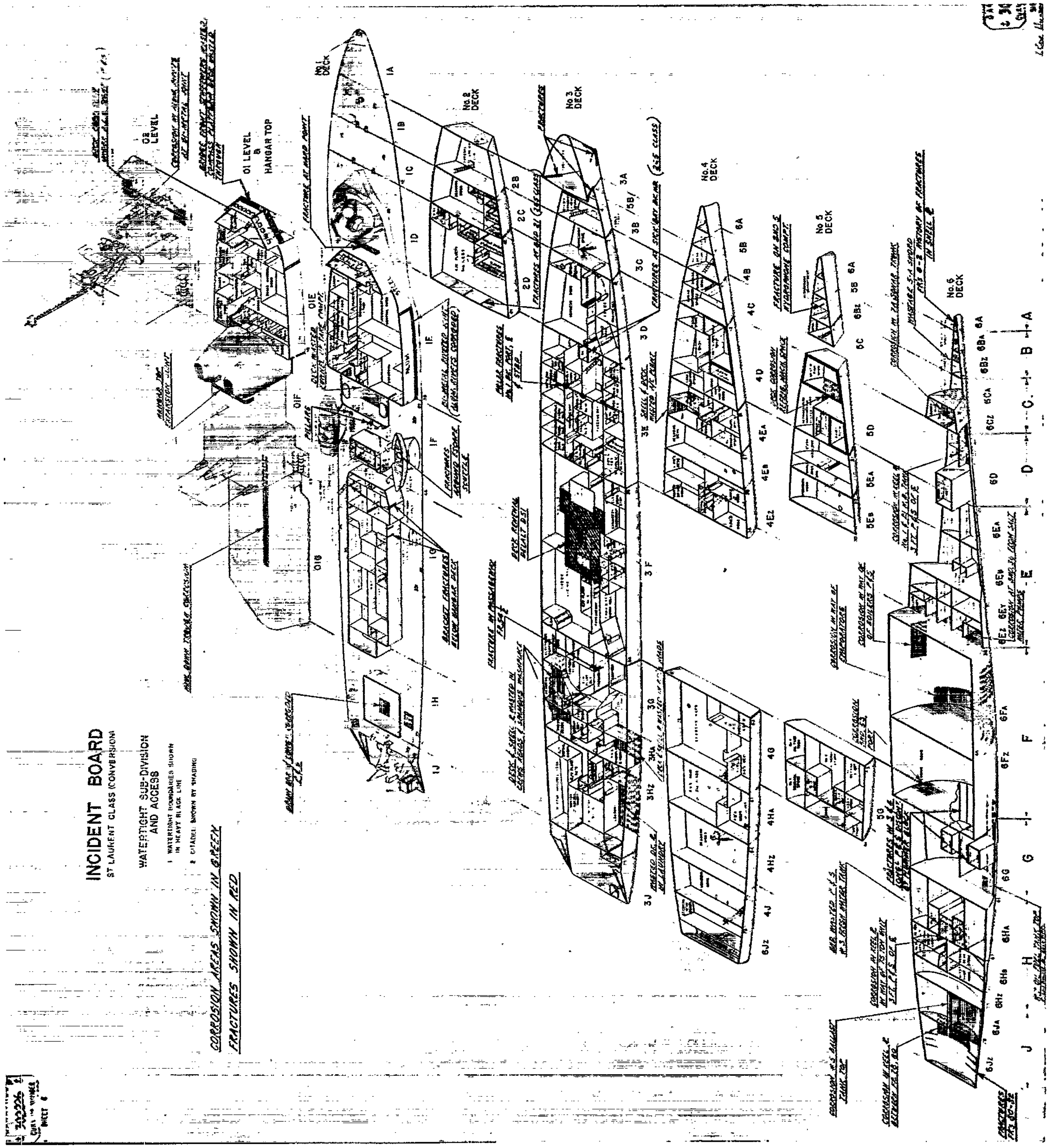


Illustration i-1 DDH 205 Incident Board Showing Corrosion Areas in Green and Fractures in Red for the Period 1951-1981

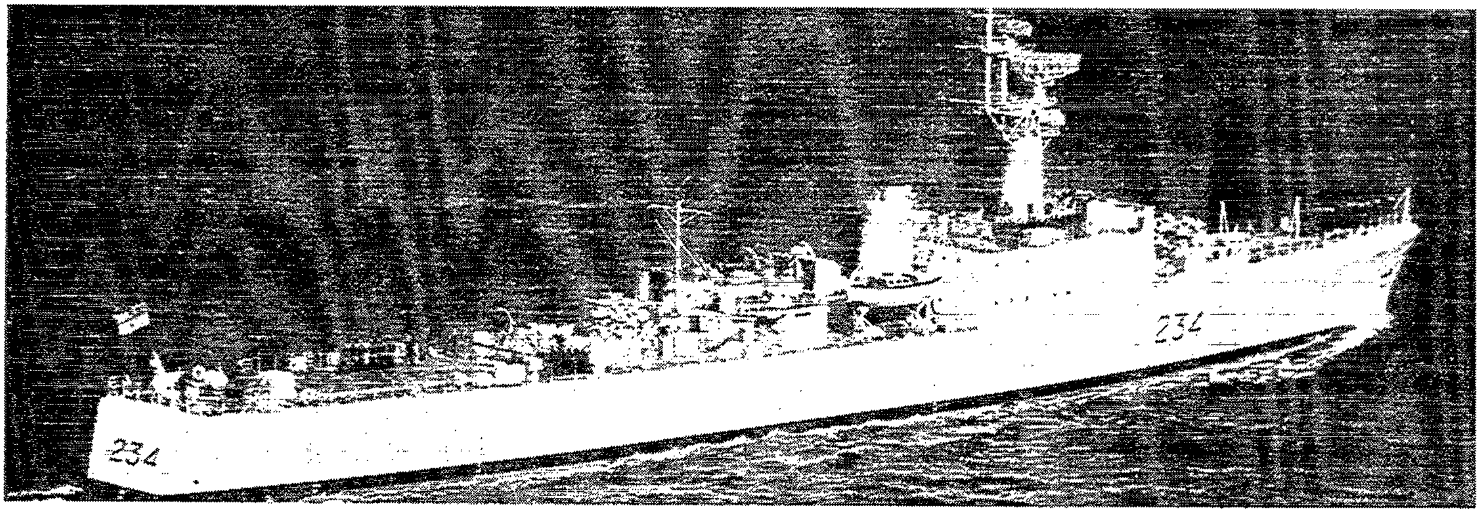


Illustration i-2 HMCS ASSINIBOINE Before Conversion

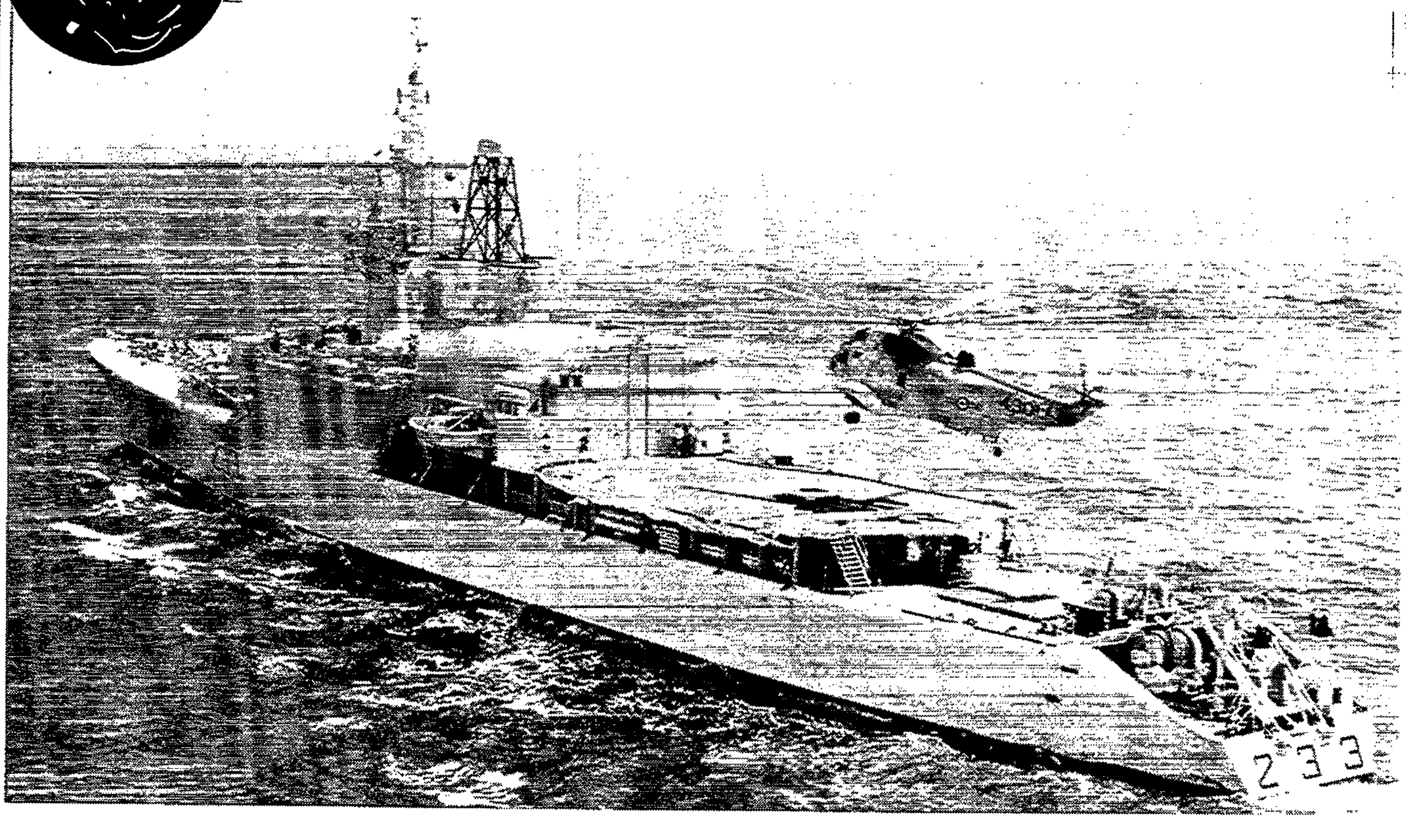


Illustration i-3 HMCS FRASER After Conversion with its Sea King Helicopter

1.0 INTRODUCTION

DDE/DDH 205 Class ships have stood the test of time providing quite satisfactory service with an excellent utilization rate. As these ships aged, failures occurred. Most structural failures may be attributed to deficiencies in detail design and/or a less than optimum fabrication quality in specific areas. The large Flight and Hangar complex fitted during the conversion from a DDE to a DDH had an impact on the structural integrity of these ships. This paper describes the structural failures, giving:

a. location and description of failure;
b. probable cause of failure; and
c. proposed or adopted method of repair.

By 1981 the DDH 205 Class steam driven destroyers, 25 years of age since initial commissioning, had extensive localized corrosion over various parts of the hulls. This paper describes most areas of corrosion, giving:

a. location and description of corrosion;
b. probable cause of corrosion;
c. proposed or adopted repair method; and
d. action taken to prevent or retard further corrosion.

The loss of operational capability because of structural integrity reduction due to cracking and/or corrosive attack is illustrated. A comparison is made of the structural history of the DDH 205 with the newer DDH 265 and DDH 280 Classes. Conclusions are drawn from the structural integrity history of these magnificent ships with the hope that lessons learned will be considered for integration into future ship design specifications, drawings and in-service maintenance policies.

2.0 BACKGROUND TO THE NOVEL ST. LAURENT HULL FORM

Reference Illustrations i-1 to i-3

During World War II the Royal Canadian Navy (RCN) became the third largest allied force at sea, after the Royal Navy and United States Navy, by building over 300 ships of British design. Although the RCN anti-submarine warfare (ASW) capability was standardized with the British during the war, there was no British (or American) destroyer designs available which met Canadian requirements for a renewed post war navy. An all Canadian design was commenced in 1948 with the intention that the ship should be of the size of the Wartime Destroyers, but modified so as to make the ASW weapons the main armament, intentionally sacrificing the anti-air role to that of anti-submarine.

Despite the fact that Canada had very little previous warship design experience, the RCN established a new concept of stability, a new hull construction (including a NBC pre-wet and contaminant wash down system, an enclosed citadel, within an air conditioned hull, isolated from the external atmosphere and a ship which eventually sailed for 43 years), a new shipbuilding engineering and electrical industry, a new propulsion plant manufacturing industry, new RCN standards of furniture, valves and piping (CuNi), etc., commonality of equipments, and a new concept of habitability as an integral part of the development of a new class of ship. This was a fair achievement for a nation of only 12 million people at the time.

The Canadian DDE 205 hull form had unique stability and structural hull features. The hull form, rise of floor and midship section, and the watertight subdivision of the DDE 205 St. Laurent is such that the ship would not sink by capsizing but by remaining upright as flooding progressed to the Upper Deck. The escape scuttle was located in the deckhead rather than the ship's side, a proportion of the life rafts on the middle line on the Pilotage Deck (Bridge top), etc. The hull structure erection sequence and structural design was organized to allow the ships to be prefabricated in units, which in an emergency could be put together far from water, and shipped to assembly berths. These units weighed about 20 tons each and were fitted together in such a manner to ensure accurate adjustment of the ship and alignment of the plating. Adopting British practice, framing in way of amidships generally consisted of deep main transverse frames at 4 feet 6 inches or 5 feet frame spacing with smaller half frames placed between the main frame stations for extra support in critical panting and berthing regions. Lighter longitudinals provided the longitudinal strength required for a large length/beam ratio, characteristic of a modern monohull warship. The longitudinals were "eggboxed" with the transverse frames to form a rigid grid to which the plating was moulded to form the unit. See Figure 2-1.

Unique features of the DDE 205 hull construction were the rounded deck edge and the "turtle back" Forecastle which extended to Fr. 27. Although aesthetically pleasing, naval architects incorporated these features for improved strength, less foc'sle deck wetness, and to facilitate washdown of nuclear, biological and/or chemical (NBC) contaminants in a hostile environment. The break of the Foc'sle had long been a serious stress concentration in a rivetted ship needing careful attention in a welded ship. The St. Laurent form achieves an extra deck height forward (2 Deck which ends at the Bridge Front Fr. 21 or about 1/3 of length of the ship) while at the same time ensuring continuity of strength in the highly stressed region. During the early life of this class, the Naval Constructor-in-Chief (NCC) emphasized the serious nature of any welding or cutting on the hull without, it was hoped, frightening anyone.

The fine fore end shape with V-shape hull sections and high freeboard over the forward one-third of the ship's length greatly reduced panting and slamming loads and was responsible for the outstanding seakeeping performance in the rough waters of the North Atlantic. The ability to maintain high speeds in a rough seaway before the onset of slamming required greater attention to detailed structural design and the need for increased scantling in the panting region of the hull forward.

Improved high speed manoeuvrability, to combat the modern high speed submarine, was achieved by incorporating a longer "cut-up", greater rudder area by fitting twin rudders in the race of twin screws and improved rudder design.

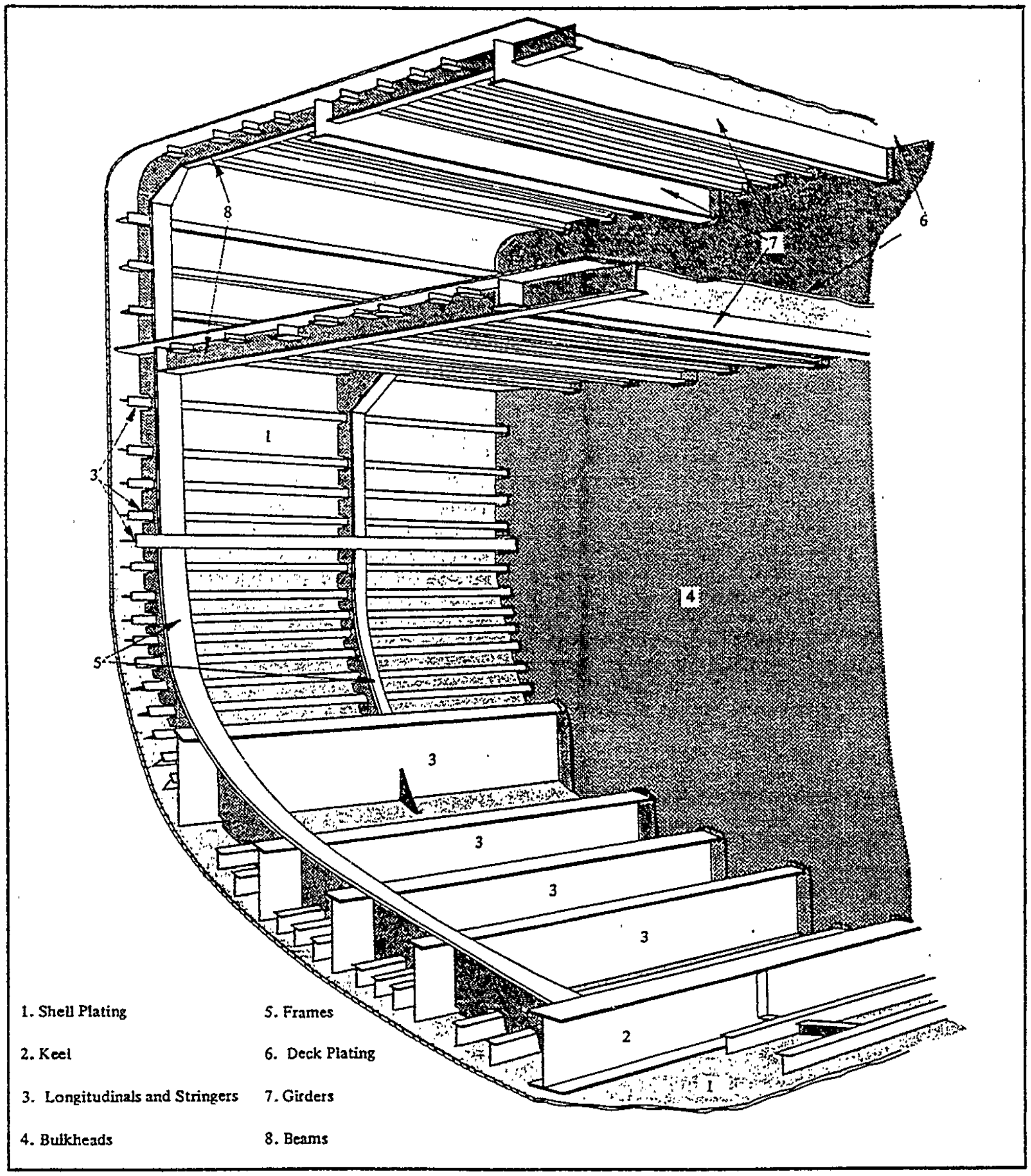


Figure 2-1

Framing Section - Midship

The Weather and Pilotage Decks, at one time astonishingly free of obstruction in preparation for the nuclear age, continued to be comparatively clean with the Anchor Windlass and the ASW Mortar below decks. The enclosed Bridge/Command Position was an inevitable step which the RCN took at the same time as the RN but ahead of the USN. Most Weather Deck fittings were of aluminum to reduce the chipping and painting workload caused by corrosion of steel fittings.

The RCN was in the forefront of state-of-the-art developments in Cathodic Protection. The St. Laurent Class was fitted with a steel anode impressed current system commencing about 1960 developed from experimental installations on the original WWII Tribals. Similarly, the RCN under water paint systems attracted considerable attention in the RN and USN.

The beam of the DDE 205 Class at 42 feet was one foot wider than the original 1948 RN Type 12 design of similar hull size otherwise. This feature and the fitment of an aluminum superstructure, with a steel Bridge Front to counteract sea slap and gun blast overpressure, allowed the Canadian Navy to eventually convert the DDE 205 to a DDH without having to fit a salt water displacement fuel system. These design features permitted the operation in Sea State 5 conditions of a large 22,000 lb. Sea King ASW helicopter from a relatively small 2900 ton destroyer revolutionizing ASW warfare in the mid 1960s.

The following lists the four classes, 20 ships, of the St. Laurent hull form and its derivatives with displacement 2900 tons, length overall 366-373 feet, beam 42 feet and draft 14.5 feet.

CLASS	PENNANT NUMBER	NO. OF SHIPS	LAUNCHED
St. Laurent	205	7	1951-54
Restigouche	257	7	1954-57
Mackenzie	261	4	1961-62
Annapolis	265	2	1961-63

3.0 STRUCTURAL PROBLEMS

3.1 Failure Mechanism

Two general methods of structural failure which are significant in the case of the DDE/DDH 205 Class ships are:

a. **Fracture** is an unstable, rapid propagation of a crack in the presence of an applied stress; and

b. **Fatigue failure** is the stable propagation of a crack in the presence of a cyclic stress.

Ships in a seaway are continually experience cyclic stress due to hogging and sagging, and on occasions, racking. With few exceptions the characteristics of fatigue failure eventually become evident. However, because initiation of cracks frequently occurs at so few cycles it becomes a moot point as to whether the initial crack resulted from true fatigue or from a very high stress during a few cycles. In most cases it is better in a dockyard environment, where time is of the essence, to look for the source cause in terms of stress concentrations, such as: inadequate use of materials; inappropriate fabrication techniques such as faulty welding, rough plate edges, misalignment of structure, incorrect selection and use of welding rods; and generally poor detail design in high stress areas causing abrupt structural changes or hard points.

Before describing examples of structural failure in some detail, it is pointed out that there is a materials engineering factor which affects the susceptibility of the steel structure to fail. As the temperature of the sea water and air drops, the probability of a brittle fracture initiation increases. Canadian ships regularly operate in such an environment as, for example, the Fishery Patrols in the cold eastern North Atlantic off the Newfoundland coast. Since 1965, commencing with the AOR 509 and DDH 280 Classes, the Canadian Navy has specified the hull structure be constructed of a notch tough steel incorporating good weldability characteristics with a steel manufacturer's guaranteed impact test.

To combat in-service brittle fracture in new construction ships, conversion/modernization or after a large repair job, all heavily loaded structural members should be periodically inspected for early warning signs of fatigue failure. This is a health monitoring type of inspection which is part of the conditional maintenance performed over the years by experienced Canadian Naval Hull Inspectors. Hussey wrote in 1982, Reference 1, that ship designers should be cognizant of the importance of providing accessibility for hull surveys and hull maintenance/ship husbandry, especially in machinery and/or damp spaces. A ship design which is "too tight" may be prohibitably expensive to life extend and/or convert at normal mid-life -- it has happened to other navies! Ship detail designers are prone to neglect such mundane things as access for ease of inspection, maintenance and repair.

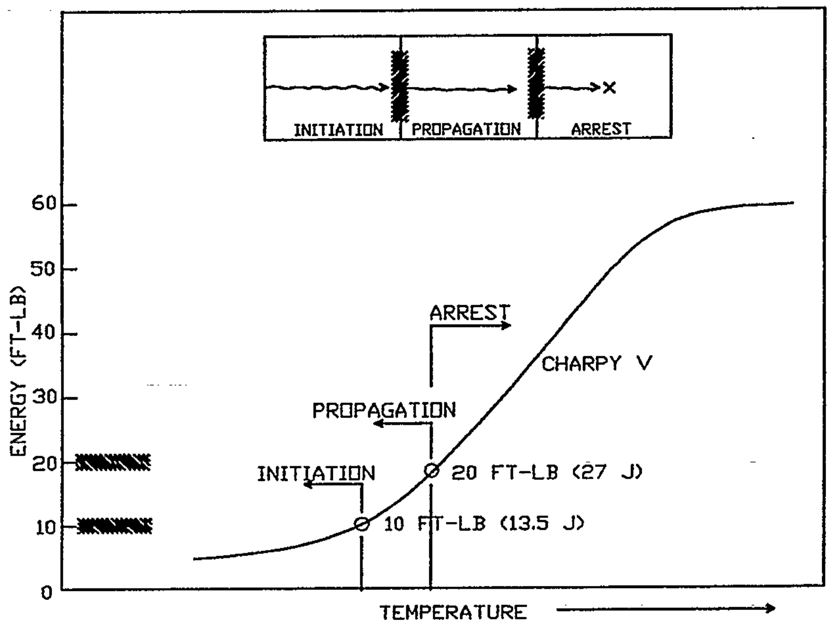


Figure 3-1

Summary of Charpy V (C_v) Energy Values for Ship-Fracture Initiation, Propagation, and Arrest Plates (Ref. 11)

Having said all of the above, there is one particular condition which repeatedly occurs in ship construction and has been the cause of several failures in our ships and that is the hard point "knife-edge intersection". In this case as the ship "works" in a seaway and the structure moves relative to other structure except at the point where they meet or cross. This crossing forms an unyielding "hard" point and one or the other of the deck or bulkhead will crack. The cure is to spread out the attachment point by brackets in one or both structures or to slot one of the unyielding structures to eliminate the hard point. One thing is for certain, hard spots are easy to design in, and pure hell to design out. Examples will be shown to illustrate this failure.

3.2 **DDE 205 Class Structural Defects, 1955-1963** Reference Illustration i-1

The DDE 205 Class was constructed during the period 1951 to 1957, all being commissioned during the period 1955 to 1957. Seven ships of the class were built, HMCS ST. LAURENT was the lead ship, and as a result, it has features which are slightly different than the follow-on ships. Several refinements to the design were made as a result of the lessons learned during the early construction of the ST. LAURENT.

DDE 205 Class were constructed in several different shipyards with different overseeing staffs involved. Even though the ships were constructed to the same set of drawings with the exception of ST. LAURENT, perhaps because of the lead ship aspects, it is clear that each builder did not fabricate the ships in precisely the same way, and as a result, there are differences in the details of how they are constructed.

In the early life of these ships there were a number of structural defects identified and repaired. The structural cracks may fall into one of three basic categories:

a. fundamental design;
b. detail design, drawings, or specifications; and
c. fabrication deficiencies in the form of:

    (1) not meeting the intent of the design;
    (2) undercut weldments;
    (3) incomplete penetration of weldments; and
    (4) plate forming "thins".

Fundamental design deficiencies would normally require a re-examination of the design with a probable modification to rectify the deficiency. Load concentrations beyond those anticipated during the design, or the inadequate assumption of the load configuration associated with the particular design configuration, may be the source cause of some design deficiencies.

Most common is the matter of structural discontinuities and hard points, both causing stress risers locally in the structural configuration. These may be a result of detail design or drawing development showing these features in the structural configuration. More than 40% of the structural cracks may be attributed to detail design and/or drawing detail inadequacies. Fabrication deficiencies will also cause stress risers in the form of misalignment of adjoining structure, undercut or incomplete penetration weldment deficiencies or plate "thins" from forming. Often these are stress risers in the proximity of the weldments.

At Table 3-1, is a listing of a number of known structural defects that occurred in the first eight years of the DDE 205 Class ships. These defects all occurred prior to the conversion to the DDH Class, commencing with the ASSINIBOINE and ST. LAURENT in 1963.

A fundamental design deficiency is apparent in the after end of the Engine Room in way of oiltight bulkhead 53 in the 4th longitudinal, see Table 3-1. All ships of the class cracked in the web plate in way of the rider plate to the longitudinal frames below the shaft bearings. A design modification was implemented early in the life of these ships. This was the only known fundamental design deficiency in the DDE 205 Class during the first eight years of operational life that could have had a consequence leading to safety of the ship.

The intersection of the forward superstructure bulkhead with the No. 1 Deck in way of Frame 21 1/2 may be taken as a fundamental design fault or a detail design fault. All ships of the class were constructed with the forward edge of the forward superstructure at Frame 21 1/2 at the centreline. Four ships were fitted with angled brackets on the centreline and at No. 1 longitudinal, port and starboard. HMCS ST. LAURENT was fitted with a bracket at centreline initially and subsequently fitted with brackets at No. 2 longitudinal, port and starboard. Two ships, HMCS SKEENA and ASSINIBOINE, had no brackets at all. There were differences between the respective ships in regards to this particular area.

It is interesting to note that of all the ships that were differently fitted, only the two ships with no brackets at all had no history of cracking at the intersection of the superstructure bulkhead and the No. 1 Deck. All other ships experienced cracking at the intersection in the vicinity of the No. 1 Deck and forward superstructure bulkhead and/or in the bulkhead No. 21 in way of the lower periphery of the brackets. On each occasion of a crack occurring in No. 1 Deck, clearly it was a major inconvenience with water coming into the Sick Bay, and of course, quite unacceptable for an operational ship. At no time was the safety of the ship of concern.

Each of these ships, with the exception of ST. LAURENT, was fitted with structural modifications in the way of the Frame 21 1/2 to 21 in the form of a structural cruciform following the curvature of the forward superstructure and running downwards from No. 2 longitudinals, port and starboard side, to No. 3 Deck. With this structural modification the forward superstructure load was distributed downward through Nos. 1, 2 and 3 Decks. ST. LAURENT did not have this alteration fitted throughout its entire life. It is also noted that the ST. LAURENT was the only ship of the Class that had the brackets fitted at No. 2 longitudinal. After the modifications to the fitment of the bracket at bulkhead No. 21, by the installation of insert plates in the bulkhead, there were no further cracks, hence there seemed to be no reason to fit the cruciform configuration as in the other ships.

All other structural defects that occurred in the early life of the DDE 205 Class may be attributed directly to detail design or to fabrication inadequacies. Examples of the detail design deficiencies may be attributed to the Boiler Room Intake cracking at Frame 43 1/2 which was a problem with all ships of the class and directly related to a detail structural corner as the source of the cause of the cracking. Elimination of this structural discontinuity rectified the problem.

An example that may be attributed to either detail design or a combination of detail design and fabrication detail is related to the breast plate cracking and forepeak shell plate cracking below No. 5 Deck, between the stem and watertight bulkhead No. 2 in the forepeak. Clearly ASSINIBOINE, ST. LAURENT and MARGAREE had breast plates fitted without face plates. The resultant was a series of cracks located in the vicinity of Frames 0, 1 and 2, propagating through the breast plates and ultimately into the shell of the forepeak causing flooding of the forepeak of course. These breast plates were repaired or replaced in part with the additions of 3/8" x 3" face plate fitted around the periphery of the inner edge of the breast plates in these three ships. SAGUENAY had the face plates already fitted, however, there was a fault in the weldment in such a way that cracks were initiated and propagated similar to the other ships in way of Frame No. 1. The remaining ships of the class had the face plates already fitted and no known cracking occurred.

Examples of fabrication deficiencies could be related to the foremast at No. 2 Platform inadequate welding, the cofferdam at oiltight bulkhead No. 64 to watertight bulkhead No. 65, the steering gear compartment watertight bulkhead 78 to the stern in MARGAREE, all of which were related to welding deficiencies and fabrication.

The cracking in the keel approximately 1 foot aft of the forefoot in HMCS MARGAREE was a direct result of the forming of the plate that caused a "thin" or weak spot in the plate. Also of interest, the MARGAREE was fabricated with a known misalignment of the forefoot from stem to Fr. 1.

Summary 1955-1963

In the first eight years of operational life of the DDE 205 Class there were several nuisance structural failures in the form of cracking in some form or another. Not all ships were built identically and the quality of the fabrication differed between the shipyards. It is not surprising that at that time in the history of the shipbuilding industry in Canada in regards to warship construction, differences would occur and detailed problems would arise. It is noted, in particular, that the largest portion of the structural defects were clearly related to detail design or fabrication matters of one form or another.

With the exception of the crack in the 4th longitudinal in way of OTB 53, none of these structural defects could be taken as being a threat to the safety of the ship or the persons therein at any point in time during the early eight years of the ships life. Of course, the matter of bulkhead 21 where the water was being taken on in the Sick Bay area was quite unacceptable in any sense of the word, however it was not a cause of concern to the safety of the ship, per say. Where the crack propagation was relatively slow and could be observed easily because of the specific location, a drill hole at the ends of the crack effectively stalled progress of the crack for an extended period of time.

TABLE 3-1

DDE 205 CLASS - STRUCTURAL DEFECTS
1955-1963

LOCATION Area	Frame Space, etc.	NAMES OF SHIPS AFFECTED	DEFECT	ACTION TAKEN
Forepeak below #5 deck	Stem - WTB 2	ASSINIBOINE ST. LAURENT MARGAREE SAGUENAY	(a) Cracks in shell plating adjacent to Frame #1. (b) Breast plates cracked.	(a) Cracks veed and welded. (b) Welded or renewed according to severity of fractures. 3/8" x 3" faceplate fitted (negative SAGUENAY).
Forepeak below #5 deck	Stem - WTB 2	MARGAREE	Crack in keel at 1 foot aft of forefoot (crack occurred twice).	Crack veed and welded.
Steering Gear Compartment	WTB 7 - Stern	ST. LAURENT SAGUENAY	Cracking and weld failure at junction of rider plates and steering bridge table, Frames 80, 81, 81 1/2 and 82 port and starboard.	Veed and welded in ST. LAURENT. SAGUENAY to be taken in hand at refit.
Sick Bay	WTB 21	ST. LAURENT FRASER SAGUENAY OTTAWA	Cracks at deckhead on C/L and on port and starboard C/L bracket stiffeners.	To be repaired during conversion in accordance with CANAVHED instructions.
Fore end of Superstructure at weather deck.	Frame 21 1/2	SAGUENAY FRASER MARGAREE	Crack in weld joining deck and front of superstructure at centre line.	Veed and welded. Exterior doubler fitted to deck about 12" x 6".
Boiler Room Intakes	Frame 43 1/2	ST. LAURENT FRASER SAGUENAY SKEENA OTTAWA ASSINIBOINE	Hairline cracking of welds at #3 deck level in passage and Crew's Dining Hall.	To be repaired during conversion in accordance with CANAVHED instructions
Foremast	#2 platform	SAGUENAY FRASER SKEENA	Weld failure at tripping brackets of AN/SPS 12 pedestal.	Veed and welded.

TABLE 3-1

DDE 205 CLASS - STRUCTURAL DEFECTS
1955-1963

LOCATION		NAMES OF SHIPS AFFECTED	DEFECT	ACTION TAKEN
Area	Frame Space, etc.			
Cofferdam	OTB 64 - WTB 65	MARGAREE ST. LAURENT SAGUENAY	Welding cracked at WTB 65 from #3 F.W. tank.	Veed and welded.
3"/50 Gun Support	Frame 16 - Frame 19	SKEENA SAGUENAY MARGAREE FRASER	Crack in weld at #2 deck, Frame 18 on port and starboard sides at deckhead.	Crack veed and welded. 3" x 12" x 10 lb. doubler fitted on face of standing flange.
Fog Oil Tank	OTB 73 - OTB 75	MARGAREE SAGUENAY	Weld crack at OTB 75 at corner (port or starboard).	Veed and welded.
Engine Room	OTB 53, 4th longitudinal	All Ships	Cracks in plating in way of rider plate to longitudinal frames below shaft bearings.	Modified and repaired in accordance with Esquimalt drawing #8535.
Steering Gear Compartment	WTB 78 - Stern	MARGAREE	Cracks in shell plating and at welds of internal framing in vicinity at WTB 78. Cracks were both longitudinal and athwartships and were 3 in number.	Veed and welded.

3.3 **DDH 205 Class Structural Defects, 1963-1976** Reference Illustrations i-1 to i-3

The original designers of the DDE 205 Class assumed the ships would have a life of about 20 years after commissioning. It was no surprise that the seven ships of this class would complete midlife conversion/modernization to DDHs during the period 1963-65. During conversion the ships underwent a major reconfiguration which changed the appearance of the ships and the structural arrangements to accommodate an operational helicopter and facilities and the Variable Depth Sonar (VDS) system.

At the conversion of the DDE 205 Class to the DDH 205 Class, the after superstructure was removed and the uptakes from the Boiler Room were split Port and Starboard sufficiently to allow the nose of the helicopter to be located between the uptakes in the new hangar. The new hangar and flight deck after superstructure was installed with the flight deck material of Lukens T1 steel (100,000 psi yield stress) to keep weight as low as possible and with the hangar and supporting superstructure of marine grade aluminum. The hangar has an expansion joint aft of the funnel uptakes which allowed for the flexing of the ship in seaway. Three inch longitudinal movement of the expansion joint at the top of the hangar was witnessed on occasions in sea states greater than five. Very little change was made to the main weather deck structural configuration during this conversion other than the modifications to accommodate the twin uptakes and the cut away stern for the VDS. In other words, the scantlings at #1 deck prior to the DDH conversion were essentially the same as they were afterwards. The aft portion of the ship was reconfigured substantially to accommodate the installation of the variable depth sonar and the reconfiguration of the tankage for a change in the fuel tank capacities including the additions of the JP5 Tank and Pump Room.

The stability margin of the DDE 205 ships was such that the Flight Deck could be placed one deck height above the uppermost continuous hull deck (No. 1 or Weather Deck). The Flight Deck had to be robust enough to handle the landing loads and the inertial parking loads of a 22,000 lb. helicopter in Sea States 5 to 7! The "Beartrap", a Canadian innovation, is a constant tension device for recovery of the helicopter from its hovering position, securing the helicopter in the trap and transversing the helicopter into the hangar. The hangar deck was constructed of steel.

There were two main factors which affected the location of the Flight Deck on the DDH 205 Class:

a. It must be high enough in the ship to prevent the take-off and landing pattern being obstructed by the ship's superstructure and environmental conditions;

b. It should be as low as possible in the ship to minimize the effects of pitch and roll, and to minimize the impact on ship stability.

In the face of these conflicting requirements, life's usual compromise was reached. An obstruction-free area approximately 78 feet long and 40 feet wide was provided (at the expense of the after gun turret and one set of mortars) one deck above the forecastle deck and abaft the main superstructure and hangar. For the record, the Flight Deck is only 6 feet longer than the aircraft! The after part of the fuselage can overhang the after end of the Flight Deck, effectively increasing the length of the deck by some 10 feet.

No major changes were made to #1 Deck midships region of the steel hull, Fr. 39-45 except that necessary to accommodate the twin funnel openings, port and starboard of the ship's centreline (as opposed to the single C.L. funnel of the DDE) to permit the nose of the helicopter to fit between the uptakes in the hangar. The outboard strake of plate at 1 Deck Fr. 39-45 was 17 lbs. (7/16 inch, 11mm, 17.85 lbs.) while the inboard plate was 12 lb. and the centreline strake was 10 lbs. (1/4 inch or over 6mm). It appears there was no appreciation of the large vertical loads which would be transmitted to the 1 Deck midships area from the large hangar (and parked helicopter) cantilevered from the flight deck, supported only by the structure surrounding the Boiler air intake(s), see Figure 3-2.

The conversion designers thought this was unnecessary because their calculations, using the 1954 Muckle Method of balancing the ship on a standard trochoidal wave height equivalent to L/20, revealed the following (after conversion):

Sagging	Maximum B.M.	=	31,130 tons ft., 8 feet aft amidships			
Hogging	Maximum B.M.	=	43,581 tons ft., 7 feet off amidships			
	I	=	111, 613 in^{2}ft^2			
	y (1 Deck)	=	14.07 ft.;	I/y	=	7940 in^{2}ft.
	y (Keel)	=	14.43 ft.;	I/y	=	7720 in^{2}ft

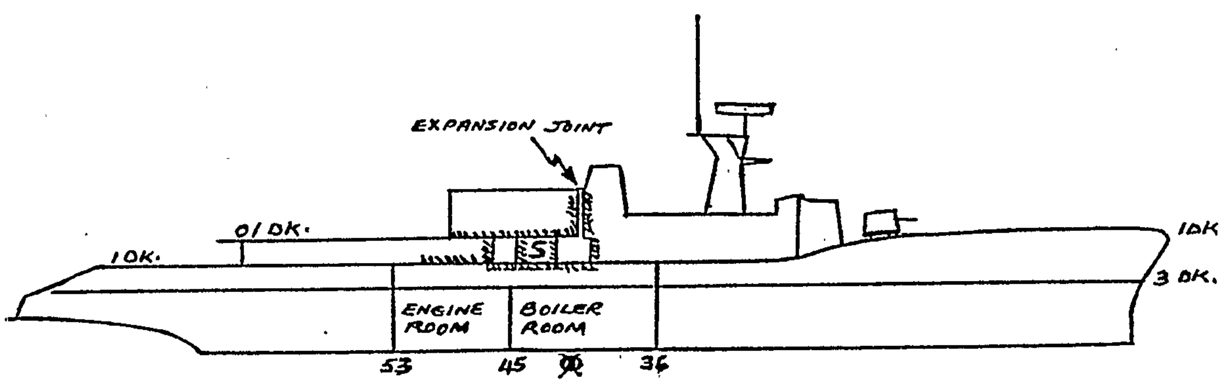


Figure 3-2

Rough Profile of a DDH 205/265 Class Destroyer

Hence, the following stresses (B.M. divided by I/y):

TABLE 3-2

DDE/DDH 205 KEEL AND DECK STRESSES BEFORE AND AFTER CONVERSION

	AFTER CONVERSION			BEFORE CONVERSION		
	tons/in²	PSI	MPa	tons/in²	PSI	MPa
Sagging						
Deck (compression)	3.92	8780	61	4.03	9030	63
Keel (tension)	4.03	9030	63	4.14	9270	64
Hogging						
Deck (tension)	5.49	12300	85	4.99	11180	78
Keel (compression)	5.65	12660	88	5.12	11470	80

Assuming a nominal yield strength, σ_y, of 32,000 psi, these hogging and sagging primary stresses were comfortably less than 0.5 σ_y. For comparison purposes the primary deck stress for HMCS NIPIGON, DDH 266, was calculated to be 14,240 psi (98.2 MPa) after her mid-life modernization in 1987-89.

During the period 1963 to 1976, the DDH 205 Class the ships experienced the following structural failures:

3.3.1 OTB Fr. 36 Discontinuity + Hard Point

The cracking occurred at the junction of the transverse watertight bulkhead Frame Station 36, forward Boiler Room bulkhead and the longitudinal bulkheads forming the boundaries of No. 3, 4 and 5 fuel oil tanks. The cracking typifies the knife edge intersection problem and was compounded by the fact that several ships showed misalignment between the longitudinal bulkhead and the web of the longitudinal. Repairs were affected by carrying the longitudinal rider plate through the main transverse bulkhead 36 to the first vertical stiffener of the longitudinal FFO tank bulkhead, lining up the web of the longitudinal with the plate of the longitudinal FFO tank bulkhead, installing insert plates in both bulkheads (where the cracks had occurred) and fitting a beam end type bracket shown at Figure 3-3.

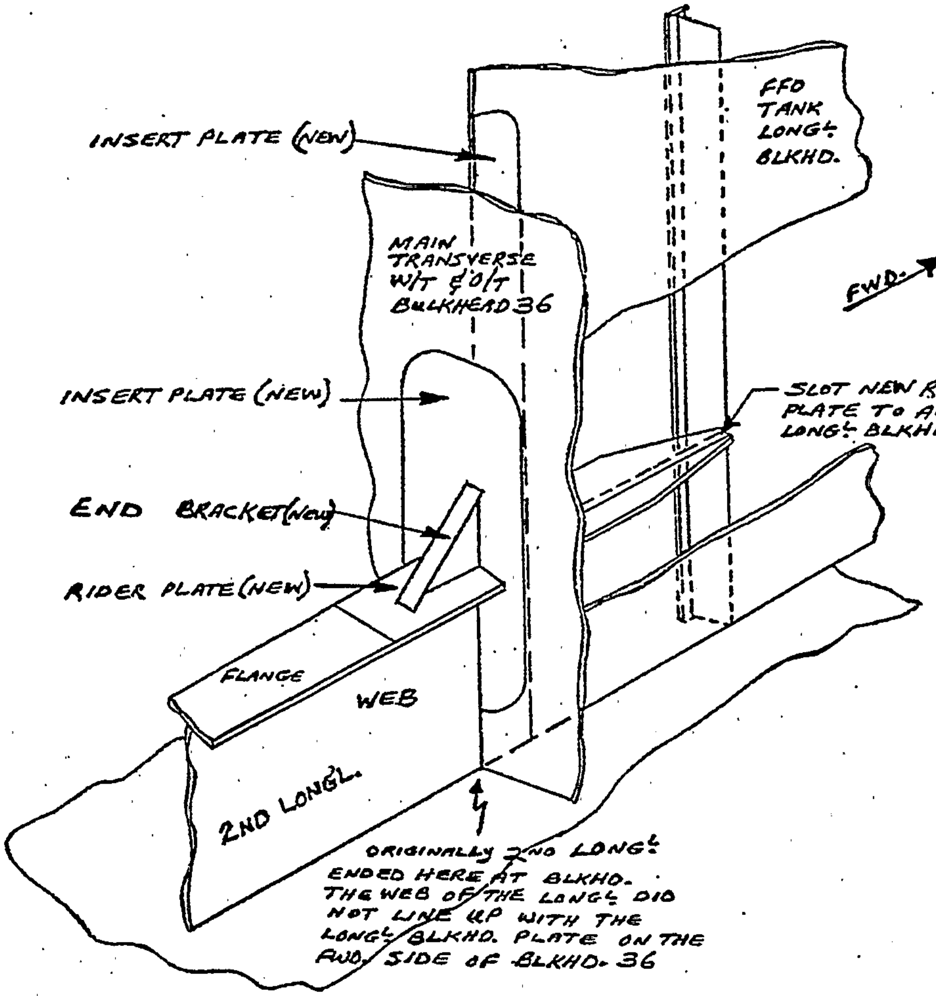


Figure 3-3

Junction of the Transverse Watertight Bulkhead Frame 36
Forward Boiler Room Bulkhead and the Longitudinal Bulkheads
Forming the Boundaries of No. 3, 4 and 5 Fuel Tanks

3.3.2 Superstructure Fr. 36 Hard Point

This crack occurs at the connection between the aluminum funnel casing port and starboard and the aluminum bridge structure at approximately 01 Deck level. DDH's which have rivetted superstructures have not exhibited this failure.

In welded construction a hard point exists at the location of funnel casing/01 Dk which again typifies the "knife edge intersection". Two repairs have been tried to relieve the hard spot, adding insert plates and addition of a gusset plate inside the funnel casing in line with 01 Deck.

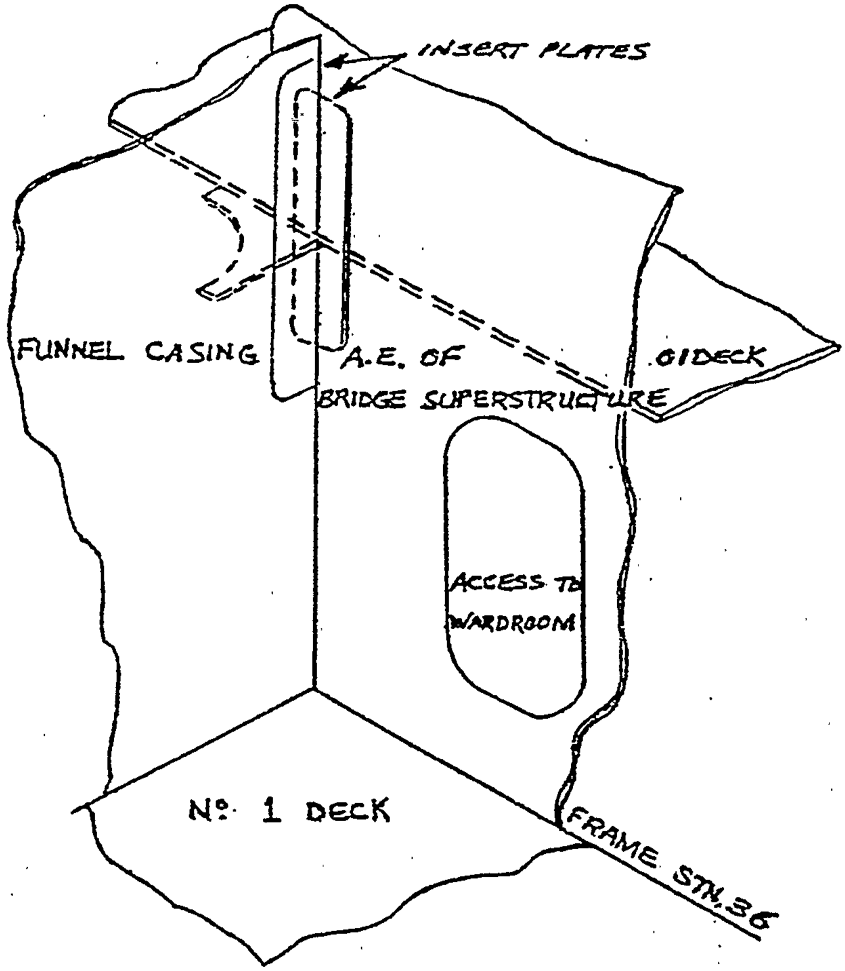


Figure 3-4

View of Starboard After End of Bridge Superstructure
Looking Forward and Toward the Centreline

3.3.3 Pillars (No. 1 Deck Midships Frame 41 and No. 3 Deck Frame 27)

There are basically two pillar head connection methods: floating free such as pillars located on 1 Deck midships supporting the hangar deck and fixed such as pillars located at Frame 27 between 1 and 3 Decks.

(1) No. 1 Deck Midships Frame 41. The failure occurs at head of pillars, No. 1 Deck, which supports hangar structure. The crack results from the relative movement of the hangar deck with No. 1 Deck. In effect, the pillar is being subjected to tensile forces for which it was never designed. Two alternatives exist: strengthen the connection with the use of gusset plates or allow the hangar to move relative to the pillar. The latter has been adopted for this area because of the relatively large movement in the area. See Figure 3-5 and 3-6.

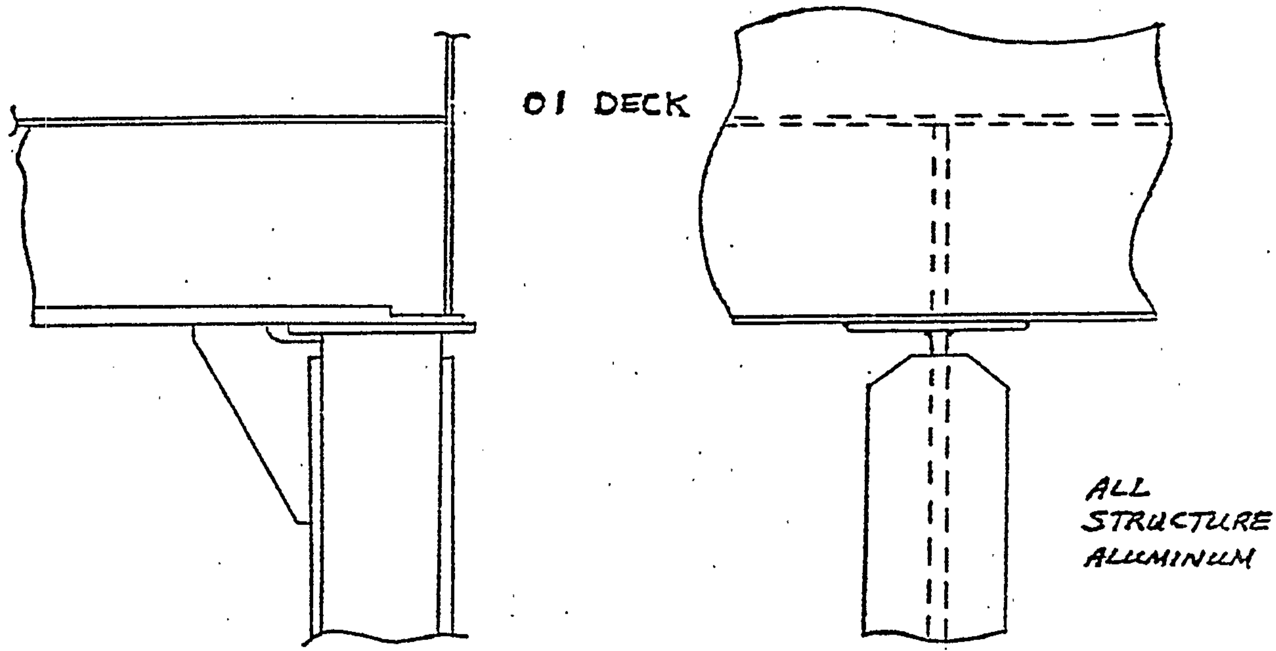


Figure 3-5

"Original" Pillar Head Arrangement
Port and Starboard Midships Frame 41

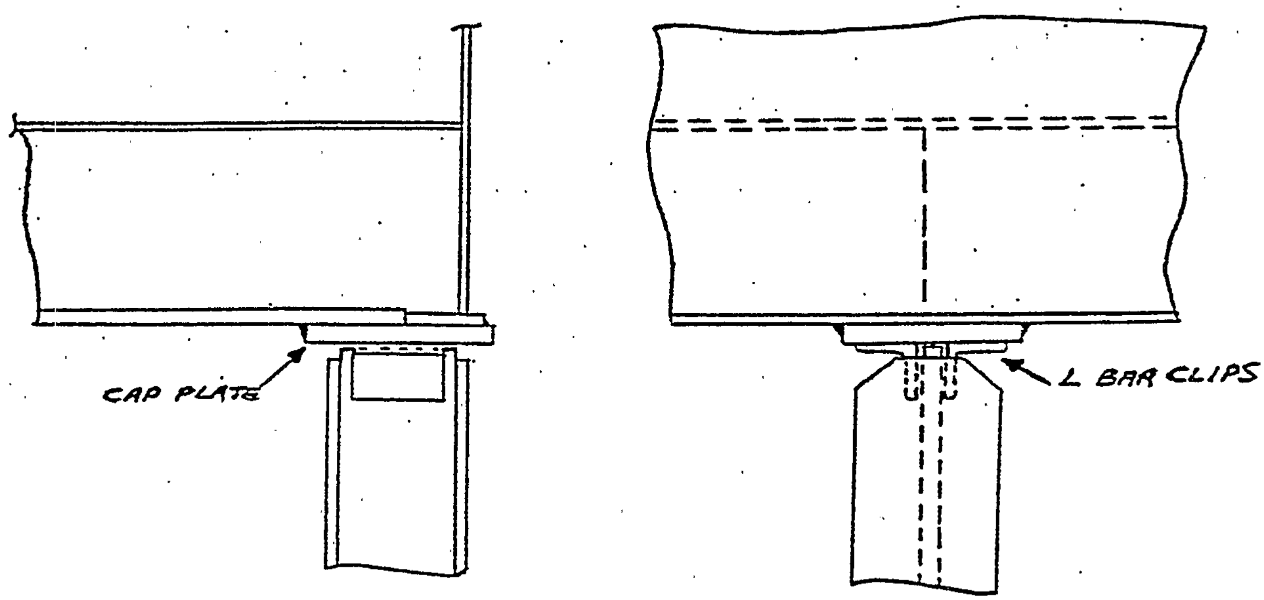


Figure 3-6

"Redesigned" Pillar Head Arrangement
Port and Starboard Midships Frame 41

(2) <u>No. 3 Deck Frame 27</u>. Three (3) in number pillars exist at Frame 27 to resist compressure loading forces between 1 Deck and 3 Deck. As stated previously, pillars are not normally designed to withstand tensile loadings of any great magnitude. In this case it was decided to restrain vertical movement between the pillar head and the 1 Deck supporting longitudinal structure to alleviate stresses from minor bulkheads which would hopefully prevent cracking and noises caused by the relative movement of minor bulkheads, boundary bars, etc. This problem was not considered so much as a structural one as it was psychological in that the cracks and noises were readily visible and audible to the ship's company. It also kept the officers awake in their cabins and created an abundance of volunteers for the morning watch!

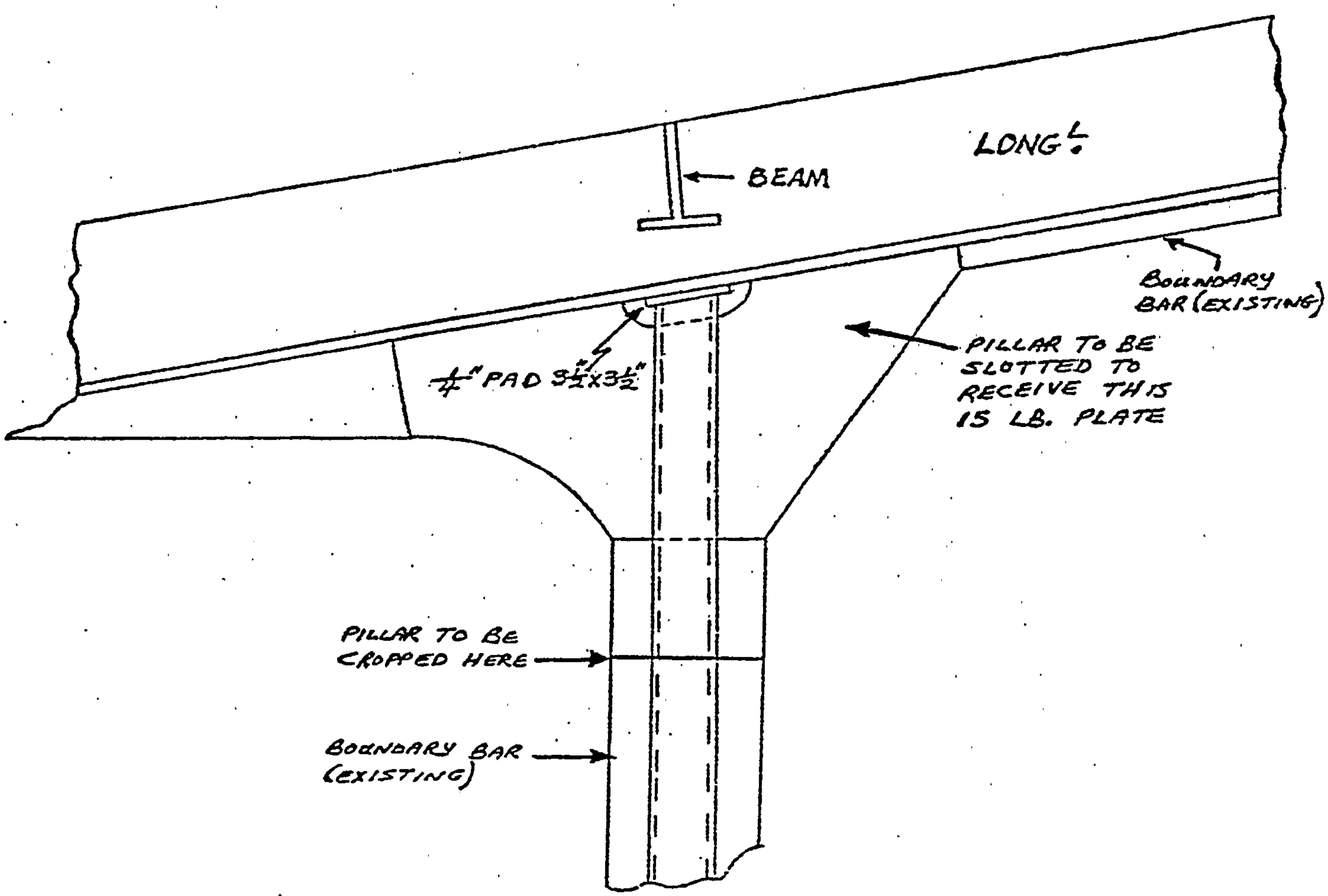


Figure 3-7

Typical Pillar Head Connection 3 Deck Frame 27
(Modification to each Pillar is Custom Designed)

3.3.4 Cracks at Knuckle, Frame Station 27 1/2

Almost all ships have experienced cracks on 1 Deck at the knuckle. The problem appears to result from the panting of the panel in a seaway with the stiffeners being too rigid because of the knuckle bend and not being able to follow the motion in a seaway. Longitudinal cracks develop along the welds of the stiffeners and by 1979 on SAGUENAY, OTTAWA, SKEENA, and MARGAREE cracks have also developed in the deck plate in way of the longitudinals. The repair is to either relieve the hard points at the knuckle by cutting slots in the longitudinals or stiffening the panels by running a flat bar across between the longitudinals. The latter to restrict panel panting has proved to be more economical. Section 5.0 uses this fracture to demonstrate the high cost of stripout, inspection, repair and replacement.

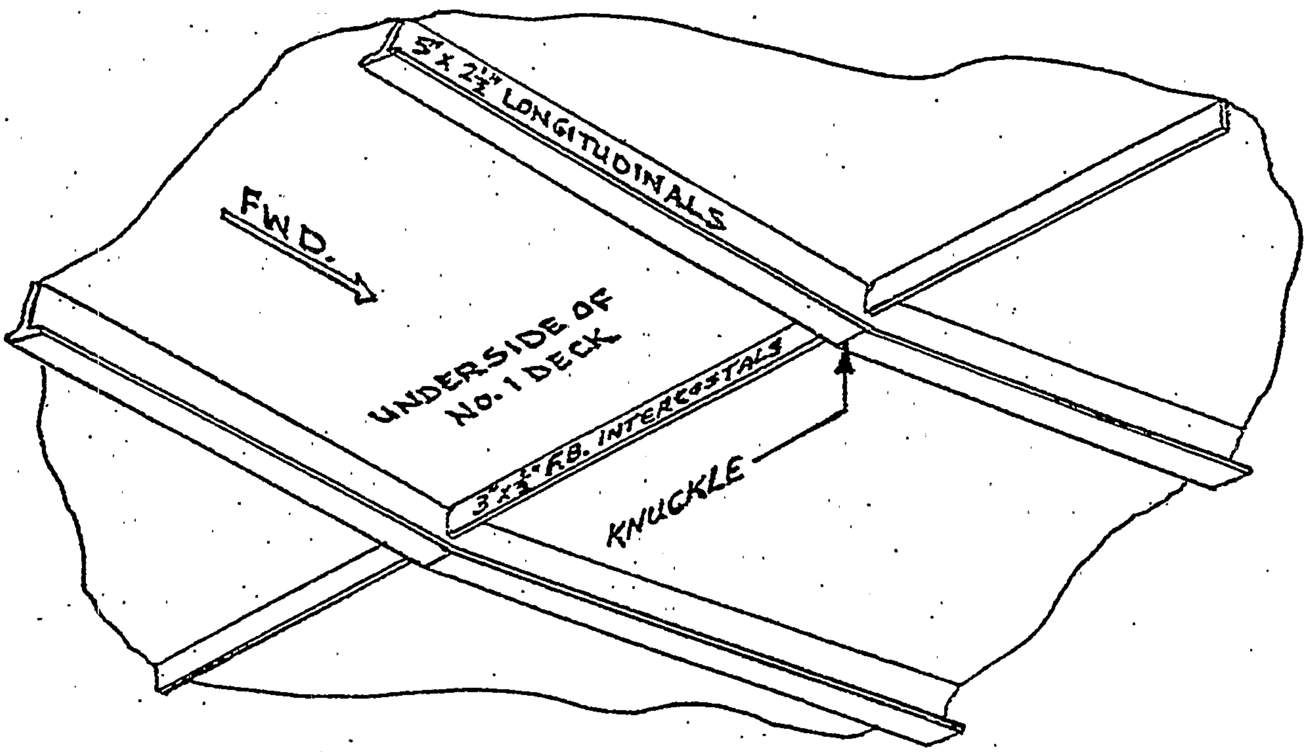


Figure 3-8

Knuckle
Frame 27 1/2

3.4 Midship Defects, 1976-1978 Reference Illustration i-1

3.4.1 Background History

The seven DDE/DDH 205 Class ships spanned a lifetime between 1951 (HMCS ST. LAURENT) 1st launching to 1994 (HMCS FRASER) last decommissioning. Table 3-3 provides "Principal Events in the Life of DDE/DDH 205 Class 1951 to 1994 Related to the Midships Structural Failures". The conversion to DDH was completed between 1963 and 1966.

The first occurrences of fatigue like failures in the midships area of the ships of the DDH 205 Class were detected in 1976. All structural defects in whatever form could be encompassed in an envelope between Frame 38 and 46 longitudinally, and just outboard of longitudinal #3 Port, to and including, longitudinal #3 Starboard. The failure pattern in each ship tended to be unique, the details of which are illustrated in the associated figures, Figures 3-9 to 3-13 inclusive.

Commencing in 1976, with HMCS SKEENA, through 1979 several occurrences of midships structural cracking occurred. In 1978 three ships of the Class had debilitating structural failures in the midships area between Frames 38 1/2 to 45 1/2 which were cause to remove the ships from the scheduled operational programs until such times as they could be repaired to make them safe for future operations. Clearly there was a midships structural class problem of fatigue and/or fracture failures notwithstanding that each of the ships were uniquely different from each other in the pattern of the failures. Interim repairs or emergency repairs were undertaken to put the ships back into operational programs simultaneously with the development of Destroyer Life Extension Alteration, DELALT D51 for the replacement of all plating and longitudinals between Frame 38 1/2 and 45 1/2 and just outboard of longitudinals # 3 Port and Starboard. Figure 3-14 illustrates the renewals and reconfiguration in the area of concern implemented by DELALT D51.

The specifics of the structural failures and the emergency repairs or interim repairs are discussed and illustrated by ship in the following sections.

3.4.2 Midships Structural Cracking DDH 205 Class

Prior to 1976 there is no known structural cracking in the midships area of #1 deck except for the 1960 occurrence of HMCS ST. LAURENT centreline longitudinal cracking immediately forward of Frame 45. This particular defect appears to have been a fabrication inadequacy in the form of incomplete penetration or undercutting of the weldments.

3.4.3 HMCS SKEENA and FRASER Reference Figure 3-9 Interim Repair

In 1976 HMCS SKEENA had some structural cracking in the vicinity of Frame 43, Starboard side under the after superstructure. Similar structural cracking occurred in HMCS FRASER in late 1976 or early 77 (Figure 3-9 refers). Both of these ships were repaired during their respective refits in 1976/77 by cropping out the defective area and replacing with a 17 lb. insert plate. These two ships were the first to show a significant structural failure in the midships area which could be interpreted as being a fatigue failure.

3.4.4a HMCS SAGUENAY Reference Figure 3-10 Temporary Emergency Repair

HMCS SAGUENAY was given a check survey in early autumn of 1977 and was found to be free of any cracking in the midships portion of the ship. It is known the ship was called to an emergency rescue mission in the North Sea approximately November of 1977 in which the environmental conditions were Sea State 6 and the ship had full power on to execute the emergency. In the January to March time frame HMCS SAGUENAY served in the Fishery Patrol off the Grand Banks area in some rather significant sea conditions and very cold temperatures. In March 1978 HMCS SAGUENAY reported unusual structural noises and entered St. John's, Newfoundland harbour for an on-site inspection. Several longitudinals were fractured or in the progress of cracking. These included failure of longitudinal #2 Port and Starboard side in way of Frame 40; a crack had initiated in longitudinal #3 Starboard; partial cracking of longitudinal # 1 Port and Starboard; and centreline longitudinal crack in way of Frame 43 1/2. It is interesting to note that the line of the failures was approximately a "V" with the apex at the forward end of the Boiler Room air intakes branching outwards approximately 30° to the centreline to Frame 39 1/2 in way of longitudinal #3. An operational restriction was placed on the ship to sail from St. John's to Halifax in Sea State 4 or less.

Temporary emergency repairs were undertaken to ensure the safety of the ship for its deployment through the remaining operational commitments until August of 1978. Clearly, the emergency repairs were essential to ensure the ship's safety. Also it was clear that the proper interim repairs would take several weeks cutting into an operational commitment for Fisheries Patrols. The emergency repairs implemented in March 1978 included the installation of inverted "T"s above the line of #2 longitudinal Port and Starboard side spanning two frames either side of the #2 structural failures. The centreline longitudinal was repaired temporarily by "veeing out" and re-welding the area of the crack in the longitudinal member. The remaining known cracks were not touched at this time. Each time the ship returned to port between its Fisheries Patrols, the opportunity was taken to inspect the ship to ensure no progress in the area of structural failures.

3.4.4b HMCS SAGUENAY - Reference Figure 3-10 Interim Repair

In August 1978 the interim structural repairs were implemented by replacing a length of #2 longitudinal and modifying it to remove the structural discontinuity in the proximity of Frame 39. A section of the centreline longitudinal was also replaced just forward of the Boiler Intakes. All other repairs consisted of "veeing out" the defected area and rewelding the #3 and #1 longitudinals. No plate replacement was undertaken at this time. A minor crack was "veed out" and welded.

3.4.5 HMCS ASSINIBOINE Reference Figure 3-11 Interim Repair

In the spring of 1978 HMCS ASSINIBOINE reported taking on water in the proximity of the Galley ventilation trunk, Port side, Frame 42. Upon inspection it was discovered that there was a continuous crack through the #1 Deck plating and the longitudinals from #3 longitudinal Port, across the Galley exhaust, #1 longitudinal Port, up the Boiler Intakes coaming, shearing all rivets in the bimetallic connection, down the coaming into the deck, across #1 and #2 longitudinals and was progressing towards #3 longitudinal. The centreline longitudinal was fractured in three locations in the proximity of Frame 43 1/2 just forward of the Boiler Intake in way of Frame 42 and just forward of Frame 45. It is significant that this ship had a continuous crack in #1 Deck midships from outboard of #3 longitudinal Port to just inboard of #3 Starboard. This is over half the width of the ship. The ship was removed from operational programs until such time as full interim repairs could be implemented. Extensive examinations of the area immediately forward and aft of the identified crack in No. 1 Deck area was undertaken to ensure there were no further failures occurring. It was this inspection procedure that discovered the centreline longitudinal failure near Frame 42. Interim repairs undertaken included a replacement of the centreline longitudinal from Frame 41, to and including, 45 1/2. A short section of #1 longitudinal Port and Starboard side was also replaced and an insert plate was installed in the proximity of the cracked area.

3.4.6 HMCS MARGAREE Reference Figure 3-12 Interim Repair

In the late summer of 1978 HMCS MARGAREE had structural failures of the centreline longitudinal in two locations, forward of Frame 45 and in the proximity of Frame 43. Cracking of the numbers 1 and 2 longitudinals was in progress and deck plate cracking had initiated between Frame 42 and 45. None of the cracks seemed to be in a specific pattern nor were they indicating that they were about to progress as a continuous crack across the ship. Of particular interest is the details of the centreline longitudinal passing through the Boiler Room inlets. The centreline longitudinal on all other ships of the Class was fitted with a "T" and rider plate configuration with flange top and bottom. In the case of MARGAREE it was a "T" with no rider plate on top.

The interim repair for this ship included replacement of the centreline longitudinal from approximately Frame 42 to Frame 45 1/2, with the section 43 1/2 to 45 being now an "H" section. A short section of #2 longitudinal Starboard was replaced in the proximity of Frames 42 to 43 and a small insert plate was installed in this general area. All other detected cracks were "veed out" and welded without replacement of the section or the plating involved.

3.4.7 **HMCS FRASER Midships Fracture** Reference Figure 3-13 Emergency Interim Repair

Subsequent to the interim repairs identified above at 3.4.3, an instantaneous fracture occurred forward of the Boiler Room emergency escape hatch on the boundary of the new insert plate and old plate weldment. The point of initiation of this fracture was at the weldment of the insert where 3 beads of weldment were positioned diagonally across the insert weldment. The reasons for these three beads of weldment are unknown but could be related to a holding bracket for the insert plate positioning. The fracture occurred off the coast of Halifax in a Sea State 4 stern quartering sea. The ship reported an "odd" wave hitting them at the time of fracture. The fracture had radiated out in two directions in a random, irregular pattern, one inboard and one outboard from the point of inception. The total length of the crack was about 20 feet. The noise created was heard throughout the ship and because of the weather conditions at the time, water immediately started to enter the ship through the fracture crack. The ship returned to Halifax Harbour as soon as possible thereafterwards for an evaluation and appropriate repairs.

The inspection of the area indicated that a fracture had occurred and the inception was, as indicated above, at the very point of the intersection of the short beads across the insert weldment. A beautiful chevron pattern on the plate edge was quite obvious. The plate had some distortion (buckling) characteristics and the fracture crack had opened up a fraction of an inch. The total length of the fracture occurred in both directions through the existing old plate. By inspection it appeared that the locale of the fracture initiation was a source of high stress concentration, probably in the form of residual stresses which, when combined with longitudinal stresses and the stresses due to the racking of the ship in the stern quartering sea, was sufficient to cause the stress levels to be beyond the ultimate strength of the structural members. The interim repair in this case was to replace a substantial panel of plating with slightly heavier plate from just inboard the centreline to outboard of #3 longitudinal, between Frame 43 and Frame 41. The longitudinals affected by the fracture were "veed out" and rewelded except #2. A section of the #2 longitudinal was replaced between Frame 41 1/2 to aft of 43.

3.4.8 HMCS ST. LAURENT and HMCS OTTAWA

No known midships structural cracking or failures occurred with the exception of that mentioned in 3.4.2 above pertaining to the ST. LAURENT. HMCS ST. LAURENT was decommissioned in 1974 and had not quite reached 20 years since the commissioning of the ship. So far as is known by anyone knowledgable of the subject, HMCS OTTAWA had no midships failures or cracking of any form through its life prior to the implementation of DELALT D51.

3.5 **Destroyer Life Extension (DELEX), 1979-1982** Reference Figure 3-14 DELALT D51 and Illustration i-1

1978 saw the removal of three DDH 205 Class ships from operational status pending completion of structural repairs in order to ensure the safety of the ship and personnel therein. Prior to this time, two ships had structural failures of lesser nature in a similar area of the ship. It was quite apparent there was a Class problem in the midships structure of #1 deck between Frames 39 and 45, and longitudinal #3 Port to longitudinal #3 Starboard. Peacemeal repairs and/or replacements of the plate and/or longitudinals would not ensure the tenure of life for these ships other than of relatively short duration, simply because the replacement of either plate or longitudinal members would move the failure site further along the structural configuration. The whole of the area affected in all ships was examined and it was concluded that the replacement of the #1 deck plating and the replacement of all longitudinals between Frames 39 and 45 was essential as a minimum to ensure an extended further life of the ships beyond the next refit cycle. DELALT D51 was initiated in conjunction with the DELEX Project and appropriately funded through the DELEX Project. Figure 3-14 shows the extent of those structural replacements. In the development of the D51 some areas of plating were increased in thickness and some longitudinals in specific locations were increased in size. The inception of DELALT D51 took place in October of 1978 and the first off installation was specified in HMCS ASSINIBOINE and integrated into the refit specifications closing 7 January 1979. Each ship of the Class going to refit thereafter included the DELALT D51 structural replacement. There is no known occurrence of structural failures in the No. 1 Deck midships areas of these ships subsequent to the implementation of the DELALT D51.

3.6 Life After DELEX, 1982-1994

3.6.1 Background History

During the period 1980-1982 each of the ships had completed their Destroyer Life Extension Refits. Each ship was operational for an additional eight to as many as twelve years in the case of HMCS FRASER after 1982. With the exception of

HMCS ST. LAURENT all ships saw a life of 36 to 43 years from launch. At Table 3-4 is a summary of the defects occurring from 1982 to the decommissioning of the respective ships. Specific observations and comments will be made on the more important defects during this period of the life of the ships.

3.6.2 Centreline Vertical Keel Distortions

Between 1982 and 1985 HMCS FRASER, OTTAWA and MARGAREE showed signs of the inception of centreline vertical keel buckling. In all three of these ships the locations were at Frame 67-68 and at Frame 33-36. In each case the centreline vertical keel was fitted with diagonal stiffeners, Port and Starboard side of centreline vertical keel web. These ships completed their life without further progress of the buckling phenomena.

In addition to the three ships mentioned, HMCS ASSINIBOINE had centreline vertical keel distortion at Frames 71-73. A similar stiffening was adopted for this particular case. It should be noted however, that ASSINIBOINE was subjected to a grounding situation prior to this occurring in which substantial deformations of the centreline vertical keel occurred in way of Frame 45 and the adjoining bulkhead between the machinery spaces. The principal part of the grounding was repaired during a refit in 1984/85.

3.6.3 Longitudinal Bulkheads and Associated Shell Plate and Tank Top Cracking

All ships of the Class experienced longitudinal bulkhead failures at Port and Starboard No. 1 Diesel Oil Tank, No. 5 Fuel Oil, bulkheads between Nos. 1 and 2 Fresh Water Tanks and Nos. 6 and 7 FFO Tanks. These failures occurred as cracks in the structural members and plating or as distortions to the bulkhead panel. Many of the stiffeners on the bulkheads were cracked near the top or bottom. In the case of the lower boundary cracking, some cracks propagated into the shell plating causing a significant leakage and a pollution problem. In the case of the failures near the top of the bulkhead stiffeners some cracks propagated into the tank tops causing fumes and oil leakage to the interior of the ship. Most longitudinal bulkheads that were subjected to this failure were fitted with additional horizontal stiffening in addition to the appropriate detail repairs made in the vicinity of the damaged plating or stiffeners.

HMCS FRASER, and one other ship, which cannot be confirmed at this writing, showed signs of shell buckling in the vicinity of Frame 67 and moving upwards diagonally towards the stern and also in the vicinity of Frame 36 and moving upwards diagonally towards the bow. No attempt to repair this was undertaken and the two ships involved concluded their operational life without incident.

3.6.4 Bulkhead 53 Cracks

All ships of the Class experienced cracking in bulkhead 53 in way of the shell longitudinals within the Fuel Tank area. No. 2 longitudinal had failures in each ship. Some ships had additional cracking in way of further outboard longitudinals. The machinery seating and longitudinal configuration as it approached and passed through bulkhead 53 was modified to reduce the structural discontinuity which appeared to be the source of the problem.

3.6.5 Pillars Distorted

Various pillars were found distorted in FRASER, MARGAREE and OTTAWA with little commonality of the failure in the Class. Nothing more needs to be mentioned about the pillars overall, with one exception. HMCS ASSINIBOINE had several pillar distortions and failure problems in way of the Galley Frame 41 and 43; Diesel Compartment Frame 14; Gunner Room Frame 18; No. 10 Mess Frame 64; No. 3 Mess Frame 16 and 19. It is important to note that all of these pillar distortions in HMCS ASSINIBOINE occurred in the time frame after the grounding. There was no similarities in the pattern or specific failures in other ships of the class.

TABLE 3-3

PRINCIPAL EVENTS IN LIFE OF DDE/DDH 205 CLASS
RELATED TO MIDSHIPS STRUCTURAL FAILURES

Ship	Pennant Number	Launch Year	Commiss. Year	Conversion Completion DDE to DDH Year	1st Documented Midship Defect Year	Interim Midship Repairs Year	Related Figures	DELALT D51 Year	Decommis. Year	Life from Comm. Years	Life from Launch Years	Life from DELALT D51 Years
ST. LAURENT	205	1951	1955	1963	1960[1]	--	--	--	1974[3]	19	23	--
SAGUENAY	206	1953	1956	1965	1978	1978	Fig. 3-10	1979	1990	34	37	11
SKEENA	207	1952	1957	1965	1976	1976/77	Fig. 3-9	1981	1993	36	41	12
OTTAWA	229	1953	1956	1964	--	--	--	1982	1992	36	39	10
MARGAREE	230	1956	1957	1965	1978	1978	Fig. 3-12	1980	1992	35	36	12
FRASER	233	1953	1956	1966	1977[2]	1977 1979	Fig. 3-9[2] Fig. 3-13[2]	1981	1994	38	41	13
ASSINIBOINE	234	1954	1956	1963	1978	1978	Fig. 3-11	1979	1988[4]	32	34	9

1 HMCS ST. LAURENT centreline longitudinal cracked immediately forward of bulkhead # 45. The longitudinal was not continuous through bulkhead 45 but welded to bulkhead forward and aft respectively. Ship decommissioned prior to implementation of DELALT D51.

2 HMCS FRASER initial centreline area cracking occurred in 1977 starboard, forward of BR inlets. See Figure 3-9. Instantaneous fracture initiated at boundary of repairs in 1977 and original plating propagating through old plating and longitudinals. See Figure 3-13.

3 The lead ship, HMCS ST. LAURENT, was paid off into reserve in 1974 and subsequently cannibalized for parts until the decision to scrap her in 1979.

4 HMCS ASSINIBOINE, the first DDE to be converted to DDH, effectively broke her back during a 1983 grounding. Repairs were effected during a 1984-5 refit prior to the decision to pay her off in 1988.

TABLE 3-4

DDH 205 CLASS - STRUCTURAL DEFECTS
POST DELEX REFIT 1982-1994

LOCATION: Area	LOCATION: Frame Space, etc.	NAMES OF SHIPS AFFECTED	DEFECT	ACTION TAKEN
Centreline Vertical Keel (CVK)	Fr. 33-36	FRASER, OTTAWA MARGAREE	Centreline vertical keel distortion Fr. 33-36 and Fr. 67-68 - inception of buckling 1982-85	Added a diagonal stiffener Port & Stbd. side of Centreline Vertical Keel (CVK) web. Arrested buckling for remainder of operational life.
	Fr. 67-68	FRASER, OTTAWA MARGAREE (+ANNAPOLIS)		
	Fr. 71-73	ASSINIBOINE	Inception of buckling 1984	Added a diagonal stiffener Port & Stbd. side CVK
Centreline Girder between Boiler Uptakes	Fr. 37-41, 3 Dk.	MARGAREE, FRASER & OTTAWA (+ ANNAPOLIS)	Centreline long'l distorted and fractured 1984-85	Centreline long'l replaced Fr. 36 1/2 - 42 1/2
Fuel Tanks in way of (IWO) shell long'ls	Fr. 53-54	ALL SHIPS	Blkd. cracked IWO shell long'ls at #2 long'ls Port and Stbd, all ships, #3 long'ls some ships 1983-85	Modified the transition from machinery seat to long'l and intersection of blkd. 53 to eliminate structural discontinuities.
Longitudinal Bulkheads	- No. 1 Diesel Oil Tank Port & Starboard -No. 5 FFO Tank Port & Starboard - Blk. between No. 1 & 2 FW Tanks - Blk. between No. 6 & 7 FFO Tanks	ALL SHIPS OF DDH 205 CLASS (+ ANNAPOLIS NO. 5 FFO TANK)	- Blkd plate distortions and stiffener cracking near top and bottom of long'l blkds - Shell plate cracking in some ships (see below) - Tank top cracking in some ships 1982-85	Added horizontal stiffening on long'l bulkheads, repaired or replaced defective plate and stiffeners.
Boiler Room Escape Hatch Dk. Insert	No. 1 Dk. Fr. 43-44	MARGAREE ASSINIBOINE SAGUENAY	Cracked IWO hatch hinge recess	Veed out and welded.
No. 1 Dk. IWO Knuckle	No. 1 Dk. Fr. 27-28	ASSINIBOINE OTTAWA	Cracked IWO Knuckle 27-28	Veed out and rewelded plus addition of intercostal stiffener between long'ls

TABLE 3-4

DDH 205 CLASS - STRUCTURAL DEFECTS
POST DELEX REFIT 1982-1994

LOCATION Area	Frame Space, etc.	NAMES OF SHIPS AFFECTED	DEFECT	ACTION TAKEN
Pillars Distorted or Cracked	Boiler Room Capstan Compt.	MARGAREE	Pillar head cracked	Veed out and rewelded plus minor modifications.
	Capstan Compt.	FRASER	Pillar head cracked	Replaced some pillars that buckled.
	Fr. 26 under No. 1 Dk.	OTTAWA	Pillar head cracked	
	Galley Fr. 41 & 43 Diesel Compt. Fr. 14 Gunner Room Fr. 18 No. 10 Mess Fr. 64 No. 3 Mess Fr. 16 & 19	ASSINIBOINE	Various failures in ASSINIBOINE pillars including buckling and/or crack top or bottom	
Bilge Keels		MARGAREE OTTAWA SAGUENAY	Bilge keel plate cracked	Veed out and rewelded some small insert plates.
Forepeak Tank Shell Plate	Fr. 0-2	OTTAWA ASSINIBOINE MARGAREE	Shell plate in forepeak tank cracked	Veed and rewelded.
Shell Plate Various	No. 8 FFO Tank Fr. 61-62	MARGAREE	Shell plate cracked IWO No. 11 long'l	Veed out and rewelded minor modifications in detail.
	No. 1 Diesel Oil and No. 5 FFO	FRASER (+ ANNAPOLIS)	Shell plate cracked IWO vertical blkd. stiffeners and propagated to shell	
	Bilge Keel IWO shell	OTTAWA	Shell plate cracked in way of bilge keel crack propagation	
No. 6 Longitudinal Stbd. Side	Fr. 36 No. 1 Deck Stbd. Side	SKEENA FRASER	No. 6 longitudinal cracked less than two feet forward Fr. 36	Replaced a three foot section of #6 long'l vicinity of construction unit boundary - a fabrication defect.

FIGURE 3-9

H.M.C.S. FRASER & SKEENA - 1976-77

PLAN VIEW BENEATH NO.1 DECK - FRAMES 37 TO 47

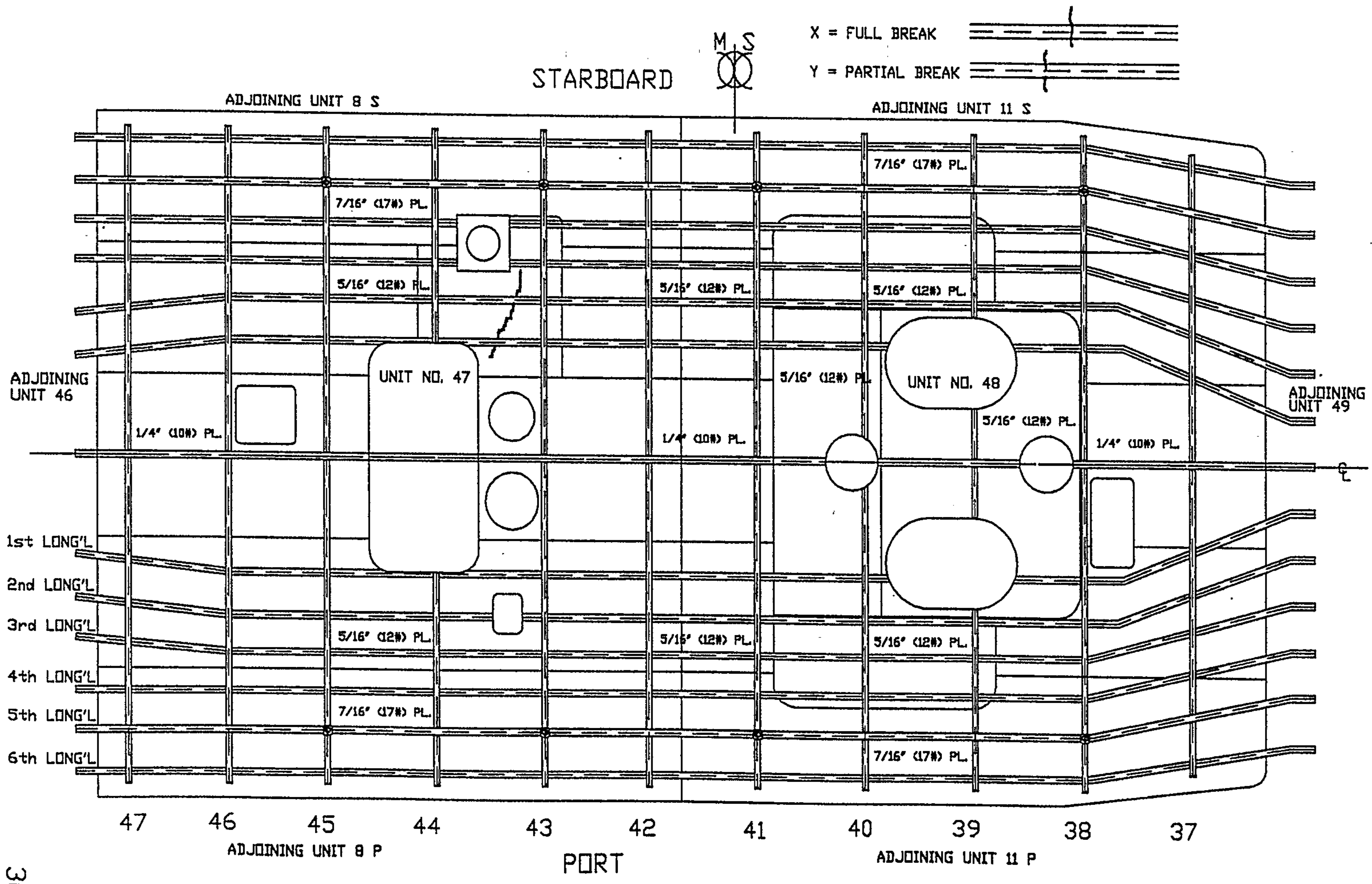


FIGURE 3-10
H.M.C.S. SAGUENAY - 1978
PLAN VIEW BENEATH NO.1 DECK - FRAMES 37 TO 47

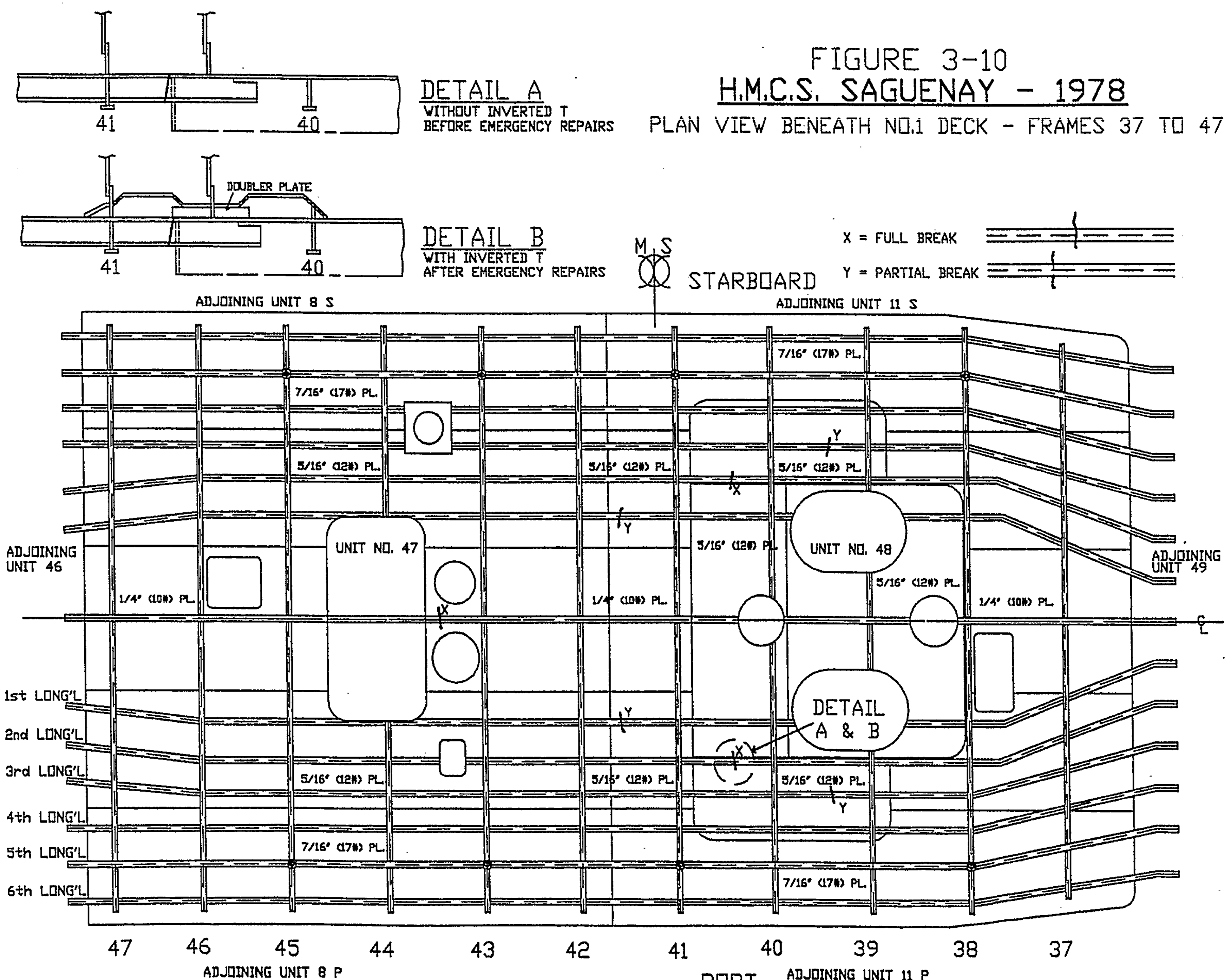
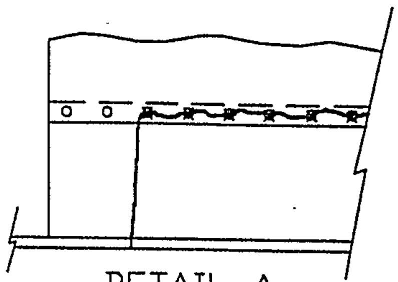


FIGURE 3-11

H.M.C.S. ASSINIBOINE - 1978

PLAN VIEW BENEATH NO.1 DECK - FRAMES 37 TO 47



DETAIL A

⊠ SHEARED SECURING BOLTS

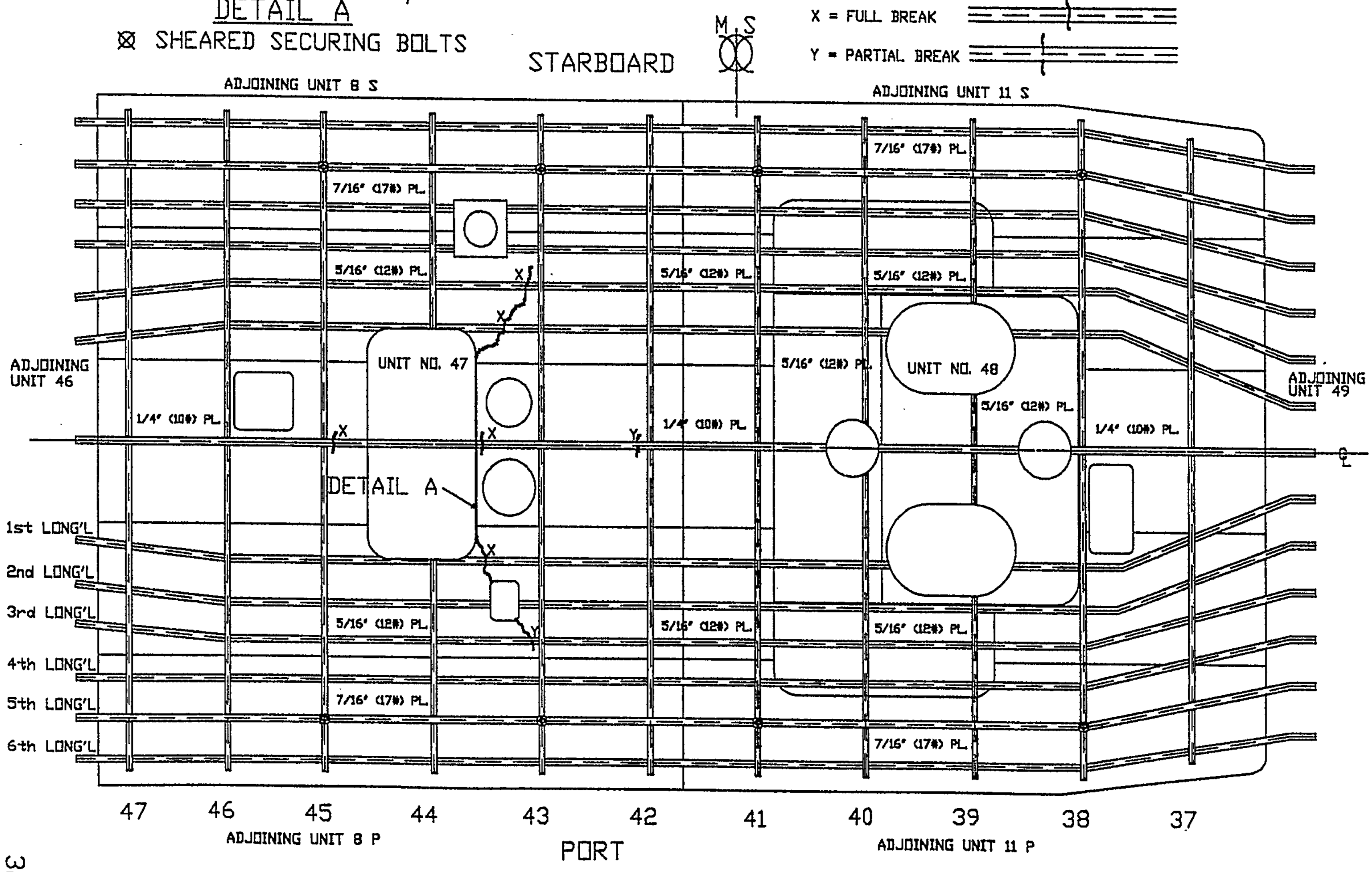
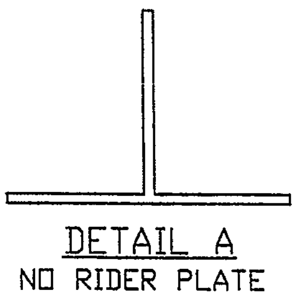
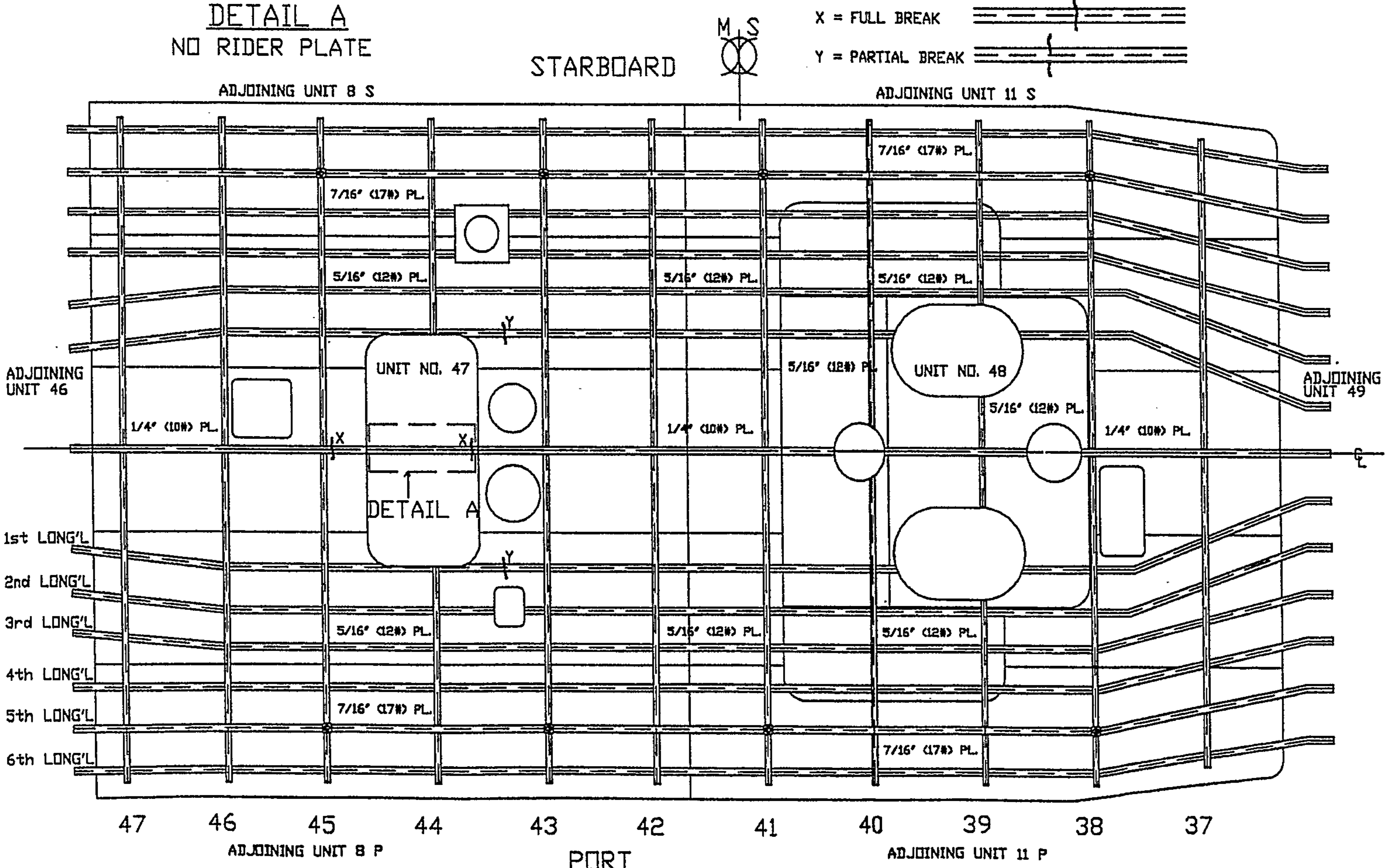


FIGURE 3-12
H.M.C.S. MARGAREE - 1978
PLAN VIEW BENEATH NO.1 DECK - FRAMES 37 TO 47





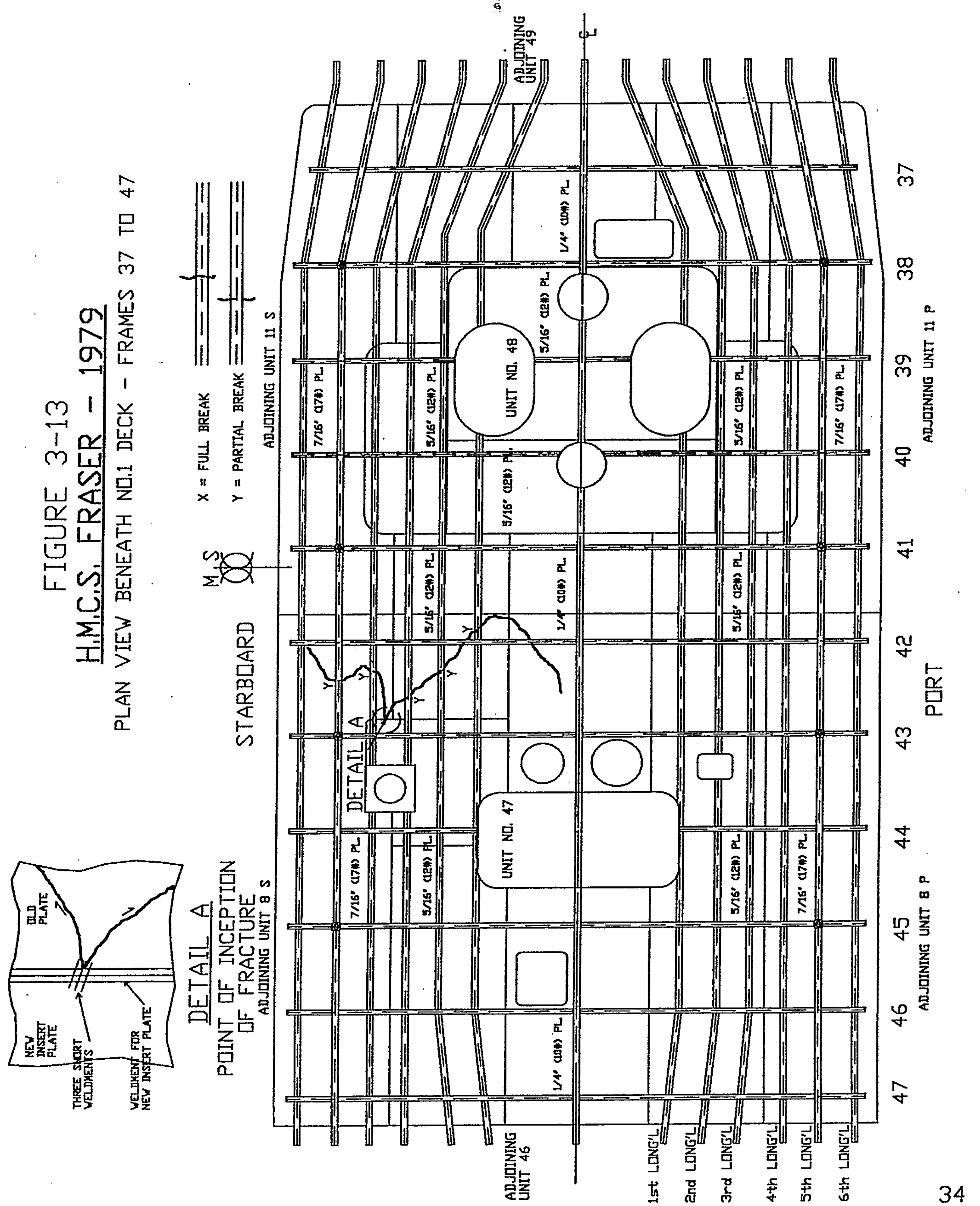


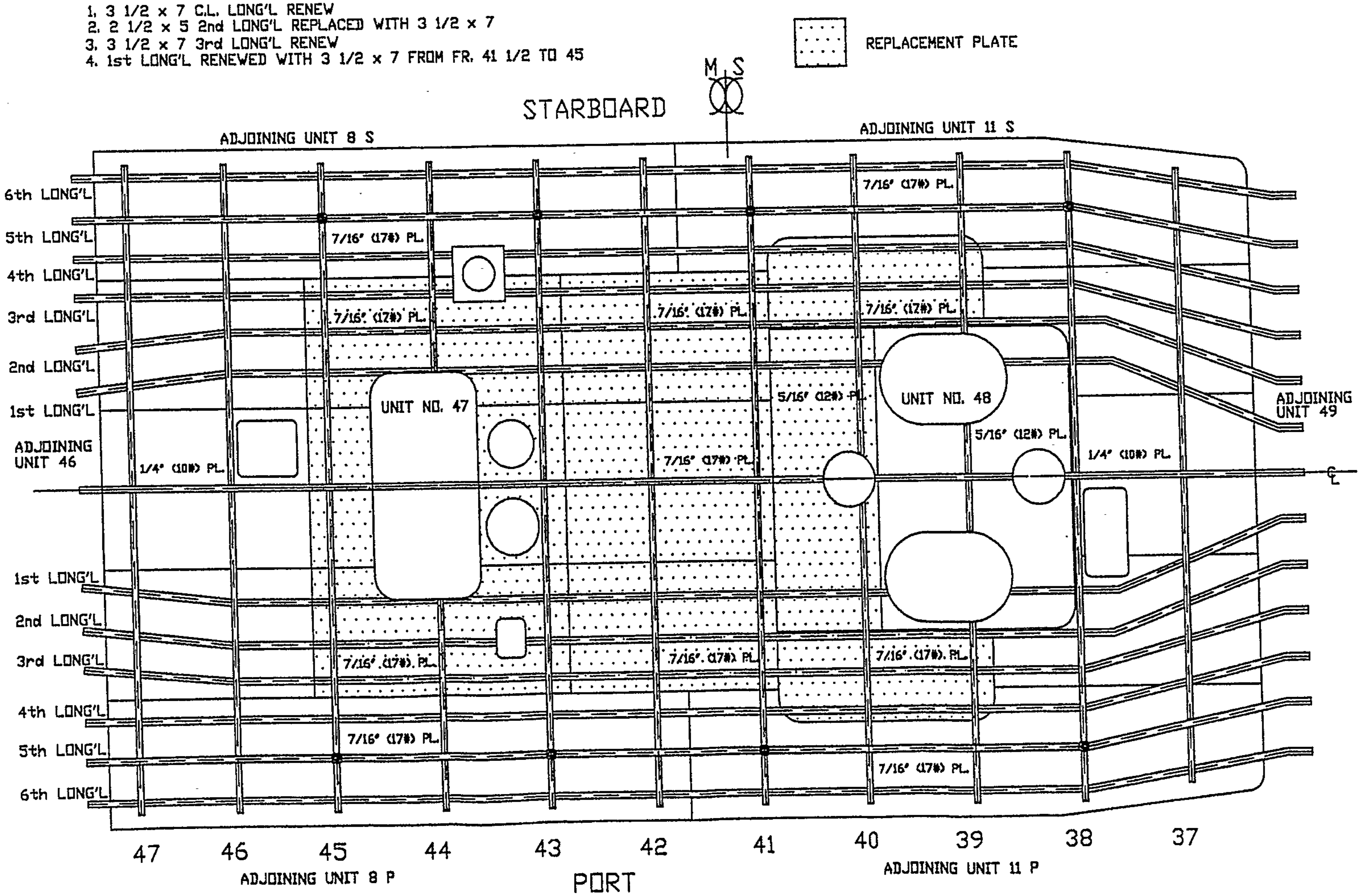
FIGURE 3-13
H.M.C.S. FRASER - 1979
PLAN VIEW BENEATH NO.1 DECK - FRAMES 37 TO 47

FIGURE 3-14

DELALT 51 - NO.1 DECK, MIDSHIPS AND AREA "AFTER MODIFICATION"

PLAN VIEW BENEATH NO.1 DECK - FRAMES 37 TO 47

1. 3 1/2 x 7 C.L. LONG'L RENEW
2. 2 1/2 x 5 2nd LONG'L REPLACED WITH 3 1/2 x 7
3. 3 1/2 x 7 3rd LONG'L RENEW
4. 1st LONG'L RENEWED WITH 3 1/2 x 7 FROM FR. 41 1/2 TO 45



4.0 CORROSION PROBLEMS Reference Illustration i-1

4.1 State-of-the-Art circa 1948-1958

During 1948 Constructor Captain A.N. Harrison, O.B.E., R.C.N., Director of Naval Construction, formulated the Royal Canadian Naval Committee on Corrosion and Fouling and served as its first Chairman. It was at this time that the R.C.N. began its post-war new design and construction program. Although much has been learned about corrosion during W.W. II, the experiences had to be properly recorded and consolidated for future use and reference.

In 1950 Constructor Commodore R. Baker, O.B.E., R.C.N. (R) arrived in Canada to commence the design and construction of the St. Laurent Class of destroyer escorts and the Bay Class of coastal minesweepers. He succeeded Captain Harrison as Chairman of the Corrosion Committee and with considerable flair and dynamic leadership brought considerable recognition to the Committee and its members.

Coincident with these first ventures by Canada into advanced naval ship design and construction was the formation of the Defence Research Board. The Naval Research Establishment Dockyard Laboratory (now Defence Research Establishment), developed advanced techniques for the painting, preservation, dehumidification, cathodic protection and selection of materials for marine vehicles. Much of the research found its way into R.C.N. Specifications and Books of Reference.

Under the leadership of Mr. T. Howard Rogers the Dockyard Lab contributed much to the British Non-Ferrous Metals Research Association by putting its research on copper-nickel-iron alloys into practical use on the new class of Canadian destroyers. He also conducted much of the investigations into "The Uses and Abuses of Aluminum in "Bay" Class Minesweepers". He is best known, however, for his book, The Marine Corrosion Handbook, which is a collection of all the marine corrosion knowledge available up to 1959, Reference 4. He wrote a second updated version in 1968, Reference 6.

By 1958 the research effort on cathodic protection and paint systems had reached such a high level of success that D.R.E. Dartmouth terminated research in these fields. It was now time for HMC Dockyards to hone the practical implementation of this research. One of the D.R.E. Dartmouth scientists, Donald G. Smith, joined the R.C.N. as a Sub-lieutenant and became the Command Paint and Preservation Officer. For over thirty years LCDR Smith, O.M.M., C.D., C.F., helped the Canadian Navy save hundreds of millions of dollars and greatly enhanced the operational capability of our ships and submarines by continuously pioneering the practical development and operational use of advanced cathodic protection and paint systems. The result has been progressive increase of intervals between refits from 18 months to two years to four years, and now, to even greater intervals of time. The structural repair/replacement necessary because of corrosion related wastage to sustain operations at sea is somewhat less than would have been the case without these developments and practical applications. Several of LCDR Smith's papers have been published internationally and he, like others before him, has helped to keep the Canadian Navy in the forefront as world leaders in cathodic protection and ship preservation coating systems.

4.2 Corrosion Mechanism

Marine corrosion engineering like ship structural engineering is a very complex subject to master and apply. Classic reference texts are References 4 and 6. Successful ship structural engineers have a good grasp of corrosion mechanisms, corrosion defense and wastage allowances. The reader is encouraged to study an excellent 49 page summary of the subject by Professor J. Harvey Evans written in 1972. See Reference 9, Chapter 16, pages 382-431. There is little doubt that successful warship structural design is highly dependent on a thorough understanding of corrosion mechanisms, especially where relatively thin skinned warships are expected to be operationally effective beyond 20-25 years of service and at a reasonable cost.

4.3 Corrosion On DDE/DDH 205 Class 1951-1981 (and DDH 265 Class 1961-1981)

There was evidence of corrosion on the **internal** DDE 205 Class hulls after four years of operational experience (1959-60). The problem continued into the early sixties as the conventional paint systems used in the bilges continued to break down exposing the plate and welds. The resultant pitting was randomly dispersed over the more anodic exposed plates and welds. The R.C.N. which had been experimenting with many anode types during the fifties decided to fit MK 5 magnesium anodes in the bilges. Zinc anodes worked well in oil-free environments such as ballast and fresh water tanks but would become coated in oily bilges and not function properly. Magnesium anodes worked satisfactorily in machinery space bilges.

During 1967-68 the keel plates in the Engine and Boiler Rooms of the 10 year old DDE 257 Restigouche Class were replaced and anodes fitted in the wet bilges. During survey it was discovered that these ships had suffered extensive pitting 450 thousands of an inch deep. The original plate thickness was one-half inch.

Probably the single most contributing factor to the early corrosion problems on these ships was the use of 1-GP-48 oil based iron oxide primer which was used to cover the complete interior hull including water ballast tanks, machinery bilges and so on. The 1-GP-48 iron oxide primer was applied before and during construction as a standard anti-corrosion coating in most, if not all, shipyards. Because 1-GP-48 broke down easily, research was carried out to find an overcoat barrier coat which could be applied over the iron oxide to give better protection. During 1959-60 an attempt was made to reinforce the GP-48 with another oil based coating, 1-GP-93 which did not work very well. The structure was coated with 2 more coats of GP-48 primer followed by 2 barrier top coats of the aluminum 93. The sad result was this did not work well either. Inorganic zinc, first applied in controlled test areas in 1960-61, was used on new construction commencing in 1968. The inorganic zinc provided much better corrosion control service. During the late 1970s much more persistent coatings such as coal tar epoxies for use on the S.W. ballast tanks and non-toxic epoxy enamels in potable F.W. tanks were applied at the first available opportunity. The Command Paint and Preservation Officer was initially restricted from using these wonderful epoxy coatings in tanks because they required clean, bare metal only achieved with sandblasting steel. This was rectified in 1978-79 by permitting holes to be cut in the tank bottom allowing other spaces in the ship to be sealed off from sand dust. Men and hoses simply entered the ship from the dock floor rather than from inside the ship. Although the coal tar epoxy based coatings provided excellent corrosion control due to their permeability properties, their use was later disallowed because of potential carcinogenic problems to applicators.

Anodes can only work well as a cathodic protector when immersed in a good electrolyte such as salt water. This means that anodes are basically ineffective above the sloshing line in machinery space bilges. Since there is no sloshing up the turn of the bilge when the ship is alongside a jetty, the anodes are basically ineffective above the normal still bilge water level. So a good paint system is needed over the entire machinery space including wet bilges because there are many areas under or behind machinery and structural seatings, etc., where it is difficult to survey and maintain a paint system. Bilge areas should be given a proper application of protective coatings before the machinery and piping is installed making the area difficult to access. It should be mandatory that properly qualified and experienced Naval Overseers, knowledgeable in protective coatings and structure, be present in the machinery spaces during paint and preservation operations. This is discussed briefly in Section 4.3.1 on DDH 280 corrosion.

There is no requirement to fit anodes in FFO, W.B. (except AORs) or F.W. tanks. Anodes do not work well in F.W. tanks because F.W. is such a poor electrolyte, unless a lot of anodes are installed. In addition, F.W. tanks do not suffer from very much corrosion activity since they are coated with a thick, specially designed and specially approved Fresh Water Tank Coating (usually epoxy based); are easily accessible and are usually of such a size that men can work in them without any problems. The Canadian Navy does not normally fit anodes in salt water W.B. tanks because again, they are readily accessible and easily maintained. An exception to this practice is the 22,000 ton AOR ships. During the late 1970s anodes were fitted in the very large AOR S.W. tanks because they are difficult to maintain as well as costly to paint due to their size. Ballasting for trim and stability is a common occurrence on these ships. The anodes are to be renewed as they are consumed. For completeness, it should be noted that a new approach was also being used on the AOR 509 Class forepeak. These forepeaks have corroded and are very difficult to sandblast and properly clean out preparatory to painting because of inaccessibility. The forepeak tank sides and bulkheads are not now painted but are fitted with a zinc anode cathodic protection system to the point of over protection to be sure to retard or eliminate further corrosion. The only area of the forepeak tank painted is the tank top.

With the exception of the machinery space bilge problem there were really no other major problems on the 20 steam-driven destroyers until the decision was made in 1976 to life extend these ships beyond twenty-five years of service. When HMCS ST. LAURENT was decommissioned in 1974, 23 years after launching of 19 years after commissioning, her hull was considered to be in good shape.

Using the colour-coded incident board located at the beginning of this paper, major areas of corrosion discovered by survey just prior to and during the destroyer life extension (DELEX) refits of HMCS ASSINIBOINE, SAGUENAY and MARGAREE during 1979-80 are now described by deck level.

4.3.1 No. 6 Deck

Sonar 5A sword shipbuilder's tube was very inaccessible making the hanging of anodes and the coating of the structure with a protective coating virtually impossible during normal refits. The original shipbuilder's tube was galvanized and with the deterioration of coating over time and dissimilar metals at the Sonar 5A housing, active pitting occurred.

Sonar 7A trunk is also inaccessible and difficult to maintain. During normal refits the structure was hand-cleaned as well as possible. Even if this space were reasonably accessible, the equipment was too delicate to allow sandblasting.

The keel plates of No. 1 and 2 W.B. tanks had to be renewed indicating anodes probably should have been placed in the bilges of these tanks years ago. In the future anodes may not be necessary because the W.B. tanks are coated with multi-coats of polyamide cured epoxy finish which have provided excellent adhesion and curing properties.

Boiler Room corrosion was quite extensive which is not surprising when all the factors are considered. These ships were all coated during construction with oil based iron oxide primer, 1-GP-48, without the benefit of anodes. Many of the areas around boilers, under and around machinery and blind bilges were inaccessible to survey and maintain. The normal atmosphere in a B.R. was very conducive to the acceleration of corrosive attack. Also over the years, rust was painted over repeatedly in difficult to access areas of structure.

The main areas of corrosion on the first two DELEX ships, ASSINIBOINE and SAGUENAY, were the forward end of the B.R. under and around the S.W. pumps in way of the boilers and aft end of the B.R. in way of the evaporators. The MARGAREE survey found the ship to be badly wasted in so many large areas (approximately 90%) of the B.R. that the only practical solution was to replace the entire B.R. structure from longitudinal 8 to 17, i.e., from turn of the bilge to 3 Deck and from forward of Bulkhead 36 to aft of Bulkhead 45 in order to pick up sound structure - a two month job. The main lesson learned from this is **accessibility** for survey and maintenance is a must if a ship is expected to be operationally effective after 20 years. It should be specified that all ships (in service 18-22 years) due for a life extension should have all machinery fitted against the ship side or covering blind bilges stripped out for survey of adjoining structure. In MARGAREE's case, it was noted that the undersides of the webs of the longitudinals were corroded as well. There were no anodes fitted in the blind bilges, but the remaining accessible bays had MK5 magnesium anodes fitted. There was much evidence of successive painting over corrosion products which just absorbed more condensation to make matters worse.

There is a striking difference between the corrosive attack in the machinery bilges of the old DDH 205 Class ships and the newer gas turbine driven DDH 280 Class, launched almost two decades later in 1972. On the 205 ships the pitting and corrosion was not localized to the weld but spread, more or less, randomly over the entire plate and weld surfaces. It appears that the electrodes used with the post W.W. II relatively low notch tough plate on the 205 Class were fairly compatible. During 1980 it was discovered that the potential difference between the low hydrogen E7018 electrodes and the notch tough G40.21 "T" quality steel used on the 280 Class was more pronounced causing the attack on weld material in the machinery bilges. This leads one to conclude it would be a good idea prior to new construction to take a couple of pieces of the steel chosen for that design, weld them together with the correct welding rods and measure the potential difference in order to determine the cathodic protection properties.

Engine Room Bulkhead 53 port is inaccessible for maintenance. The E.R., which is much dryer than the highly humid atmosphere of the B.R., was in very good condition overall. Over the years the main condenser inlet tubes had deep pitting over an area one foot from the valve. This deep pitting of the inlet tube was caused by the bimetal coupling of the bronze alloy valve and the adjacent mild steel inlet tubes in an area very difficult to maintain due to its inaccessibility. A SHIPALT for a top hat and anode was implemented. During SAGUENAY's 1979 DELEX refit, however, both tubes had to be remanufactured at great expense. It is understood one other ship, (ST. CROIX), had this problem some years previously.

No. 7 FFO tank top and margin plate is the only oil fuel tank to have a major problem. The tank top margin plate is inclined downwards, at approximately 45 degrees in this case, to be perpendicular to the ship's side. All such margin plates corrode because they are such natural catch basins for water. The answer to this problem is to use a different detail design in future ships to eliminate the catch basin and to pay more attention to the maintenance of this area on existing ships.

The nonstructural bulkheads, port and starboard, of No. 3 F.W. tank - a black non-toxic and not very effective bituminous coating was used on F.W. tanks until the late 1970s. The Canadian and American navies then changed to epoxy enamels suitable for potable water. Since 1978, sandblasting has been allowed in F.W. tanks. Men and equipment enter tanks through holes cut in the ship's bottom.

The relatively inaccessible area under the 75 ton A/C Refrigeration Machinery plant aft of Fr. 67 was surveyed in HMCS SKEENA in 1976. The hull inspector lost his hammer in the skeg. A similar experience occurred a few months later in HMCS FRASER when the hull inspector's hammer went through the bottom aft of Fr. 67 ending up on the dock floor. These two ships had the affected bottom plating, structrual members and skeg reconstructed to as-built condition in their respective refits, probably as arisings. All ships of the class had some structural reconstruction in way of Fr. 67-69 and skeg included in the refits immediately following 1976.

Tank top of No. 5 W.B. tank - it is not possible to cathodically protect a tank top, so the replaced tank top was coated with epoxy based materials which is a much better material than the old oil based iron oxide primer.

Keel plate in the forward end of the Tiller Flats in way of the bilge suction found the paint coating around the bilge suction would deteriorate allowing the first two bays to corrode freely. Over the years the corrosion spread outward from the bilge section. Fitment of an anode in the vicinity arrested this active corrosion.

4.3.2 No. 5 Deck

Refrigeration machinery space deck corroded. It was not anticipated during design that auxiliary machinery spaces would be continuously damp because of leaky gaskets. It is particularly bad when a S.W. pump is also located in the space. The use of better coatings, such as inorganic zinc or zinc rich epoxies, provided much more long-time service than oil based iron oxide used originally.

4.3.3 No. 4 Deck

Shell and deck wasted in A/C plant - see comments in Section 4.3.2 and Section 4.3.1 with respect to the 75 ton A//C Refrigeration Machinery Plant aft of Frame 67.

4.3.4 No. 3 Deck

Crews Heads Aft, After Seaman's Washplace, P.O.'s Heads, and Laundry Deck had "nice looking". boxes fitted to house the brass fittings. The boxes would fill up creating a bimetallic couple with the deck plate. The boxes were never cleaned properly because they were so small. These spaces were usually kept warm and were continuously damp aiding the corrosion mechanism.

Mortar well sumps were inaccessible and continuously exposed to the corrosive S.W. environment.

4.3.5 No. 1 Deck

The funnel uptake compartment deck was originally coated with iron oxide GP 48 primer. This very hot (when steaming) relatively inaccessible compartment was usually filled with air which is quite acidic. It is possible that this deck would have to be replaced after 20 years no matter what deck coating was used, but it is thought that a modern epoxy coating would stand up well. Inorganic zinc is not recommended because of the acidic content of the atmosphere in this space and the residue would dissolve the zinc based finishes.

4.3.6 Superstructure

The steel bridge front and part of the bridge deck has had to be replaced on several ships including NIPIGON (16 years after commissioning). The original drains from the bridge window wells were only one-half inch diameter making them prone to blockage from cigarette and other debris. The water would back up and find its way under the bridge front insulation and under the deck tile. This repair is quite expensive because there are quite a variety of "black boxes" attached to the bridge front bulkhead. Although a SHIPALT was engineered a number of years previously to replace these small drains by one and one-half diameter lines, it was implemented on only a couple of ships.

There is a bimetal riveted joint just forward of Fr. 29 superstructure girth where the steel superstructure front and the aluminum superstructure meet and at one deck level where the 1 Deck steel boundary bar and the aluminum superstructure are joined. The boundary between the aluminum and steel was originally coated with zinc chromate and carton flannel to prevent bimetallic corrosion. After a long period of time this becomes brittle and leaks setting up a bimetal couple which causes the aluminum rivet to waste and shear off. When the rivets were replaced a more flexible polysulphide epoxy alumilastic embedding compound was used.

Deck under the A.L.O. sights on top of the superstructure had an accessibility problem as well as heat from the unit's heating coils. This same problem occurred under the boat winch amidships which also has a heating coil fitted.

4.3.7 Aluminum Hangar

Naval Architects and ship structural engineers interested in expansion joint design are encouraged to seek out the solution developed by C1HT J. Osborne, MMM. A SHIPALT was raised, to be implemented on an as-required basis when the expansion joint was corroded or worn sufficiently to justify replacement. Osborne's solution is simple in design using neoprene type rubber, much quicker to implement than repairing the old design and is extremely easy to maintain.

4.3.8 Flight Deck

The original hauldown troughs fitted on the DDH 205 Class were inaccessible and subject to the extremely harsh S.W. environment. These troughs are very difficult to re-align when tampered with so maintenance was minimal over the years. The troughs were covered with zinc rich coatings as they are cleaned out and repaired. The newer troughs fitted on the DDH 280 and 265 Classes are much easier to maintain and align.

4.3.9 External Hulls and Appendages

The Canadian Navy has had outstanding success keeping **external** hulls in a very high state of preservation. Unlike hull internals, access is very easy for survey and sandblasting, permitting the proper application of preservation materials. The problem is to develop and apply a good material in the first instance.

A vinyl paint system for the underwater hull was introduced by S/LT D.G. Smith (later LCDR, Command Paint and Preservation Officer) during 1958 and 59. At first there were teething problems because it was found that if the appropriate thickness of paint film was not used during application, the paint would strip. Painters were used to applying 1 1/2 mils of conventional coatings in one application. Vinyl has a low solid content and at least two coats are required to give a 1 1/2 mil thickness. A minimum of 6-8 mils is required to withstand current density when impressed current cathodic protection was installed.

During 1968 the Jungle Deck and hull above the water line, on AOR 508, were a mass of corrosion. PROVIDER was treated to a new above-water inorganic zinc paint system which lasted until 1978 when it had to be redone. NIPIGON followed later in 1968 when her complete above-water hull was sandblasted to the bare hull and treated during a refit at Sorel, P.Q.

The internal structure of the skeg in way of the after cut up, bilge keels and rudders are filled up with a bituminous coating and drained. No problems have been experienced to date.

The permanently fitted impressed current external hull cathodic protection system has been secured to bilge keels since the early sixties. This steel anode system would be more effective if it were fitted alongside the ship but this is not practical. Later, several ships were fitted with a small lead silver anode system which is still giving good results. The newer 280 Class use dinner plate-size platinum anodes. They basically consist of a little tungsten wire covered with inert platinum. These anodes give very good noise and drag signatures compared to the sacrificial zinc anodes fitted on the much larger Operational Support Ships. The zinc anodes have also given excellent results but do need replacement periodically.

The results of the vinyl paint system for underwater hulls used in conjunction with the impressed current system plus the above-water inorganic zinc system have meant that Canadian destroyer hulls are in excellent shape externally. It is not necessary to send sailors over the side to chip paint any more. Experience has now demonstrated that after 9 or 10 years the hulls have to be sandblasted to bare metal and recoated because the paint tends to delaminate from the weight of the many cosmetic coats applied over the years and perhaps from the difference of thermal expansion rates of multi-coats of alkyds and the base steel plate.

External hull corrosion has been kept to a minimum as pointed out above except for a localized area where there was cavitation erosion and pitting on the DDH 205/265 rudders and "A" brackets. A jury rig fix using DEVCON and spot welding was quickly thrown off from the parent metal re-exposing the deep pits which simply continued to grow. During the early 1980s, the Command Paint and Preservation Officer trialed two very promising but expensive materials - INERTA 160 on ASSINIBOINE and ZEBRON on MARGAREE. Both are excellent high build solventless materials. INERTA 160 is a black epoxy and ZEBRON is a polyurethane. Exotic equipment is required for application. A complete underwater hull of a 590 class tug was also coated for trial purposes. These materials are used by the Canadian and U.S. Coastguards on icebreakers because they are highly abrasive resistant and should be excellent in the slush ice water our navy and auxiliary vessels often work in. If the trials went well, it was planned to cover complete underwater hulls, including the boot topping, with these materials. In the interim, boot tops were coated with high build vinyl black which are only partially satisfactory because they are not particulary abrasion resistant to rubbing of ships side by fenders, etc. Unfortunately, all of the above coatings did not solve the cavitation/erosion problems on the rudders despite the potential coating abrasion resistance, flexibility properties and so on.

Rudder cavitation erosion was a problem on the twin screw/twin rudder DDH 205 and its derivatives where the rudder was placed in the race of the propeller. The DDH 280 which had twin screws and a single centreline rudder did not appear to have rudder problems prior to the TRUMP modernization commenced in 1987.

4.4 Corrosion on DDE/DDH 205 Class, 1981-1994

After the DDH 205 Class ships completed their destroyer life extension refits, there were no startling or eventful corrosion problems for the remaining thirteen years, 1981-1994. The proper application and maintenance of the preservation materials developed, trialed and perfected during the previous thirty years, as discussed in Section 3.4, have provided very positive results.

5.0 HIGH COST OF STRIPOUT, INSPECTION, REPAIR AND REPLACEMENT

Stripout, repair and replacement takes much more time than most people realize. An example of the involvement to implement a relatively minor structural repair should illustrate the point.

The repair described in Section 3.3d. and by Figure 3-8, "Fractures at Knuckle, Frame Station 27", covers the original deck plating fractured in way of eleven in number longitudinals. The Ship Repair Unit Atlantic took 1000 manhours or 16 working days to supply, fit and weld in place a new 3/8" x 18" x 26' steel insert plate, plus thirty linear feet of 1/2 inch by 3 inch flat bar intercostals installed between the longitudinals to stiffen the plate panels.

The lead shop was the Plate and Boiler Shop with 13 other shops assisting plus hire/fire brush hands. To facilitate repairs, the following items were removed or released, and replaced (or renewed) on completion of repairs:

Space	Description	Shop(s) Involved
Captain's Pay Office	10 sq. ft. deckhead insulation.	Shipwright
	14 ft. D.O. transfer line.	Pipe Shop & Laggers & Riggers
	14 ft. firemain & lagging.	Pipe Shop & Laggers & Riggers
	6 ft. electrical cable.	Electrical
Passageway - No. 1 Dk.	All electrical cable incl. trays and hangars, FS 26-29.	Electrical & Riggers & & Shipwrights
	16 ft. F.W. pipe.	Pipe Shop

Space	Description	Shop(s) Involved
No. 10 Cabin - No. 3 Dk.	Stowage rack & 2 lockers.	Riggers & Boilermakers (unbolt it)
	5 ft. pipe.	Pipe Shop & Laggers & Riggers
Lobby 3 Dk.	All electrical cables incl. hangars FS 27-29. 14 ft. vent trunking.	Electrical & Pipe Shop (hangars) Sheet Metal Ship & Laggers
Quad Cabin 3 Deck	3 ft. curtain plate incl. rivets coated with alumilastic. 8 ft. electrical cable .	Platters & Boilermakers & Shipwright U/W Repair Electrical (only remove screws not bolts & clamps (Boiler Shop)
	4 pipes 10 ft. long incl. lagging.	Pipe Shop & Laggers & Riggers
	Inboard bunks incl. lights.	Electrical & Shipwrights (unbolt) & Riggers
Communications Control Room 1 Deck	2 desks incl. 4 deck pads; 1 cabinet; Safe & seat.	Boilermakers & Platters & Riggers & Burners
	Seat for stateboard. 1 pedestal chair.	Platters Boilermakers & Platters & Welders & Chippers
	84 deck tiles and underlay; 1 ft. of tile boundary flat bar.	Paint Shop & Shipwright U/W Repair (tile) & Burner Shop & Welders & Burners & Chippers
Passageway 1 Deck	4 ft. ground bar plus 15 all rivets and aluminastic.	Boiler Shop & Shipwrights U/W Shop & Burners & Chippers & Welders
	4 sq. ft. tile underlay and 5 ft. ground bar. 1 non-skid thread. Tile fairing plate.	Shipwrights U/W Repair & Paint Shop Shipwright U/W Repair Boiler Shop

Space	Description	Shop(s) Involved
Radar 3, 1 Deck	12 deck tile plus underlay.	Shipwrights U/W Repair & Paint Shop
	5 ft. tile boundary bar.	Boiler Shop
	39 inches steel angle for radar set base.	Boiler Shop & Welders & Burners & Chippers
Miscellaneous	Protect electrical cables during hot work.	Laggers
	Reposition cables where they interfere with new flat bar stiffeners.	Electrical & Riggers
	Disturbed pipe joints - new gaskets plus function test.	Pipe Shop
	Staging.	Shipwrights
	Cleaning, etc.	Brush hands
	Misc. removals.	Determined by lead shop who discusses the matter with the NEUA Hull Inspectors

1000 manhours to remove the cracked plate, replace it with a new 39 square foot insert plate(s) and 30 linear feet of new 1/2 by 3 inch flat bar! 600 pounds of steel! Clearly the removals, replacements and renewals of non-steel materials was by far the largest percentage of manhours and of cost. In this case the actual structural repairs were about 20 to 25% of the total manhours and less than 20% of the material costs. It is not unusual to find that the removals, renewals and replacements necessary to effect a structural repair is three times to as much as ten times of the actual structural repair. Prevention of the need for structural repairs is the best cure and most economic solution. The trick is to be clever enough with structural detail during the design and building stages to eliminate the necessity for such repairs years later. A continuum of knowledge and experience, passed downwards through the organizational hierarchy, is necessary to gain the advantages of improved detail design, minimize structural defects and hence, minimize the cost of structural maintenance. Without building on practical knowledge and experiences the same mistakes and same problems will be repeated every 15 to 20 years and, unfortunately, new and more difficult problems may also be introduced.

6.0 COMPARISON OF DDE/DDH 205 WITH DDH 265 AND DDH 280 CLASSES

Although there is eight years difference between the DDH 265 and DDH 205 Classes (31 years of service versus 39 years by 1994), they exhibited similar structural and corrosion problems. Both classes had the same amount of sea time as DDHs which explains some of the structural similarities. This leads one to hypothesize that it generally takes 10 or 15 years for major structural (and corrosion) problems to surface. When one considers the fact that these designs are well over 40 years of age; and it was the first major warship designed in Canada for operations off the East coast of Canada in the harsh environment of the North Atlantic, these ships have performed beyond reasonable expectation. As these ships grew older, the amount of time they spent at sea appeared to increase.

Many of the structural defect problems encountered by the steam-driven destroyers were apparently designed out of the DDH 280 Class. The drawing and specification configuration control program used during the DDH 280 design has paid great dividends and is justification for implementing such a program for follow-on programs. In the first nine years of service, 1972-1981, these ships only had four detail design problems rectified with no loss of operational time. The one major corrosion problem in the machinery space bilges was discovered before any great embarrassment but it did mean the unscheduled docking of three ships and disrupting their operational schedules for a couple of weeks. Overall, the 280 Class has performed magnificently well during the first half life prior to the recent TRUMP update and modernization.

The attachment of the large hangar and stiff flight deck on the DDH 205 and 265 Classes has had a significant effect upon the midship hull structure in way of the Boiler Room Air Intake and the Funnel Exhaust No. 1 Deck openings. The resulting large vertical loadings did not exist in the same manner on the DDH 280 Class because the Flight Deck is integral with No. 1 Deck. On the other hand, the DDH 280 suffers from a "deckhouse end problem" at the after quarter point.

A recent analysis of the DDH 265 and DDH 280 structural integrity databases, Reference 12, showed that the:

a. DDH 265 had about 2.5 times more defects than the DDH 280;

b. Number of corrosion defects was almost the same for both Classes; and

c. Ratio of crack/corrosion defects was 1:1 for DDH 265 compared to 1:3 for DDH 280.

The above numbers were compiled for a 26 year period (1964-89) for DDH 265 and 21 year period (1972-92) for DDH 280. It is reasonable to assume the DDH 265 record is similar to the older DDH 205 Class.

These statistically based structural databases are interesting, however, conclusions or actions can very easily be misdirected. It is the impact of each structural defect as it affects the safety of the ship or the crew therein, and the operational program of the ship that is important. However, it does point out that the DDH 280 has had a smaller number of structural defects than the DDH 205/265 Classes because of superior detail design and welding sequences, better quality assurance, and the use of much better notch tough steel. The DDH 280 design had the benefit of mature research and development, design, overseeing and in-service support teams. Corrosion, despite better paint systems, is still a major problem, except ships are now paid off well after 20 years of service and refit intervals have increased from 18 months to 48 months with the potential for longer intervals. As determined by experience during a 1980 study, the practical effective life of Inorganic Zinc Silicates and Zinc Rich Epoxies is about seven years after commissioning (or nine years from the construction application).

A major contribution to structural integrity health is the notch toughness (sensitivity of the material to brittle fracture) and yield strength characteristics of the steel used in construction. The hull of the DDE 205 and DDE 257 Classes, launched between 1951 and 1957, were constructed of a commercially available mild steel with the added requirements of 0.21% carbon content maximum and silicon killed; ASTM designation is unknown. The DDE 261 and DDH 265 Classes, launched 1961 to 1963, used steel to ASTM A-131 Grade C with maximum carbon content of 0.21%, fully killed and made to fine grain practice. The nominal yield stress is believed to be 32,000 psi (220 MPa). During 1992 the Defence Research Establishment Atlantic/Dockyard Laboratory determined the steel mechanical properties of HMCS GATINEAU, a DDE 257 Class ship launched in 1957, Table 6-1. This steel was not very notch tough; 3 ft. lb. (4J) at -40°F but it was the best available at the time.

TABLE 6-1
CHARPY V-NOTCH STEEL IMPACT TEST RESULTS
HMCS GATINEAU, DDE 236

TEST TEMPERATURE °C	ENERGY, J	
	T-L	L-T
-40	4	8
-20	11	34
0	20	52
20	27	N/A

TL = CRACK RUNNING **with** ROLLING DIRECTION of PLATE
TL = CRACK RUNNING **against** ROLLING DIRECTION of PLATE (i.e. ORTHOGONAL)

Mr. Marc LeMarsh, the Canadian Naval Material Design Authority, specified steel for complete hull structure in 1960 to be a notch tough steel incorporating good weldability characteristics with a steel manufacturer's guaranteed impact test of 40 ft. lb. (54J) at -40°F (-40°C). Due to metric conversion factor confusion this value became 25 ft. lb. (34J) at -40°F! In 1965 Mr. LeMarsh finally convinced Canadian steel mills to roll notch tough steel to Canadian Standards Association specification CSA G40.8 Grade B normalized (later changed to CSA G40.21 38T) for the construction of the 22,000 ton operational support ships, AOR 509 Class.

In 1969 a similar steel was used in the construction of the DDH 280 Class but with the slightly higher yield stress of 40,000 psi. This higher nominal yield strength was 25% or 8,000 psi higher than that of the mild steel used in the DDE/DDH 205 Class permitting lighter scantlings. For comparison, CPF steel was over 56% or 18,000 psi higher than the 205 Class.

Table 6-2 gives the minimum average energy impact test values and the nominal yield strength of the steel used for construction of Canadian frigates/destroyers since 1951 including that for the Canadian Patrol Frigate contract announced in June 1983.

TABLE 6-2

STEEL MECHANICAL PROPERTIES
CANADIAN NAVAL SHIPS
1950-1995

LAUNCH	CLASS	CHARPY V-NOTCH IMPACT TEST (LONG'L)				
		TEST TEMP.	AVERAGE ENERGY MINIMUM		YIELD STRESS	
		°C °F	J	FT. LB.	PSI	MPa
1951-63	DDH 205/265	-40	4	3	32,000	220
1969	AOR 509	-40	34	25	38,000	260
1970-71	DDH 280	-40	34	25	40,000	275
1989-	CPF	-40	40	29.5	50,000	350

A minimum impact test value for the DDH 205 is only 3 ft. lb. compared to 25 ft. lb. for the DDH 280. It is worth noting that the Boiler Room air intakes, located just aft of midships, is the primary location of the major midship fractures during the 1976-78 time frame and the atmosphere can be very cold off Canada's east coast during winter. Further, there has been a tendency to use steels with increasing yield strength values to save weight by using thin plate and/or small stiffeners. This could spell trouble for newer ship classes when this is combined with unrealistic corrosion allowance in machinery space bilge areas and at the lower area of thin bulkheads.

Although the case of higher yield notch tough steels is encouraged for obvious reasons, considerations should be given in future design calculations to limit the "design" yield strength to about 30,000 psi maximum for 3000 ton frigates and 40,000 psi for 4000 to 5000 ton frigates to ensure the hull is robust enough to withstand unforeseen corrosive attack and structural failures.

The DDH 205 and 265 Class hulls were not coated with inorganic zinc when constructed because this marvellous material was not available until the late 1960s when it was specified for the DDH 280 Class. The best time to coat a machinery space is before the machinery is first fitted on its seats. Everything is down hill from that time. On the other hand, the re-coating of the 205/265 external hull with inorganic zinc, commencing in 1968-9 was a much easier proposition. In any event, a rigorous hull survey of the main machinery spaces should take place every 12 to 15 years and any unacceptable structure replaced. An examination of the refit interval period for the newer ships by experienced naval architects, paint and preservation officers, and hull surveyors would reveal if a refit or extended work period should be planned for 6, 7 or 8 years from commissioning (new ships) or recommissioning (modernized ships). The effective life of machinery space anode systems in combination with an inorganic zinc preservation system will be a major factor in the determination of a practical refit interval from a structural integrity point of view. Certainly a corrosion protection effectiveness curve drops off very quickly after six or seven years from initial coating application.

7.0 CONCLUSIONS

7.1 A Tolerant Structural Design

Canadian Naval Engineers can be very proud of their achievements in advanced warship design since the commencement of the St. Laurent design in 1948-49. The St. Laurent design was innovative since conception and tolerant of structural defects. The design was flexible enough to allow a major midlife conversion without reverting to a compensated fuel system. This midlife conversion transformed surface ship ASW warfare into a new dimension. The life of these ships was increased during an extended refit of only 7 to 8 months at a very reasonable cost. The original designers of the St. Laurent Class would be surprised and pleased to know these hulls would still be operational over two decades beyond their expected life of 20 years.

7.2 Milestone Years 1976 to 1979

As the life of the DDH 205 Class approached and exceeded 20 years since commissioning, serious structural and corrosion failures needed immediate attention. Structural restoration was essential to extend the operational life of these ships. Through the foresight of the initiation of the DELCA project, the DELEX program became the vehicle by which most of these ships had a nine to twelve year life extension. Some highlights are summarized:

7.2.1 Structural failures amidships in No. 1 Deck included both longitudinal members and deck plating - the worst case being HMCS ASSINIBOINE (1978) with a continuous crack through all structural members, extending 60% of the width of the upper deck. Any one of these amidships failures could have resulted in catastrophic consequences if not discovered early enough. Immediate interim repairs followed by the implementation of DELALT D51, commencing in 1979 refits to replace all deck plating Frames 39 to 45 and longitudinals #3 port to #3 starboard, restored these ships amidships to equal or better condition than at the time of conversion to a DDH.

7.2.2 Corrosion failures aft of Fr. 67 in way of the skeg and under the 75 ton A/C plant were first discovered in 1976 and 1977 in HMCS SKEENA and FRASER. These areas of corrosion were very close to a penetration of the underwater hull with the potential resultant flooding of the watertight compartment and damage to machinery. Prompt reconstruction of the affected area of plating, structural members and skeg restored the ships to as-built condition. All ships of the class had this repair implemented in refits immedately following 1976.

7.2.3 The financial approval and decision to implement the DELEX (Destroyer Life Extension) program in 1976 and 1978, respectively, provided a sound basis for extending the life of the DDH 205 Class ships in terms of both: a. safe to navigate;

and b. operational capability restored. The Destroyer Life Cost Analysis (DELCA) project was initiated in late 1974 on the full realization that the DDH 205 Class could not be replaced in a timely manner and something had to be done to maintain at least a safe to navigate capability and an operational capability. The DELCA project results were the basis for the DELEX approval.

7.3 The Post DELEX "Golden" Years 1982 to 1994

Late in the operational life of the DDH 205 Class after the DELEX life extension, the DDH 205 ships showed signs of getting "tired". All ships had buckling or shear failures in the longitudinal bulkheads between No. 4, 5 and 6 fuel tanks forward of Frame 36. All of these required repairs. At least three ships, HMCS FRASER, MARGAREE and OTTAWA showed the initiation of centreline vertical keel (CVK) buckling forward of Frame 36 and aft of Frame 67. In each case the CVK was fitted with diagonal stiffening both port and starboard without incident for the remainder of operational life.

7.4 Factors Affecting Amidships Structure

There are four contributing factors affecting the No. 1 Deck amidships structure. These include:

a. stress due to the vertical loads on No. 1 Deck from the hangar and helicopter;

b. stresses due to longitudinal loading;

c. stresses due to secondary and tertiary loads; and

d. stresses due to inappropriate detail design and fabrication, i.e. hard points.

The combination of these stresses were sufficient to cause serious structural failures in No. 1 Deck plating and longitudinals amidships. These failures occurred approximately 12-14 years after conversion to DDH.

7.5 Detail Design and Fabrication Techniques

The DDE/DDH 205 Class ships had a number of structural failures over the years. The vast majority of these structural failures can be traced to inadequate detail design resulting in structural "hard points" and localized high stress concentrations; or, inappropriate fabrication techniques such as faulty welding practices, rough plate edges and misaligned structure in the more highly stresses areas. None of these structural failures, except as may have been contributing in the amidships of No. 1 Deck resulting from detail design or fabrication technique deficiencies, were catastrophic in character or greatly affected the operational capability of the ships for any significant period of time.

7.6 Machinery Bilges and Other Wet Spaces

Accessibility, preparation of surfaces, application of preservation materials and installation of anodes are factors directly related to how well machinery bilges and wet spaces stand up in an operational ship. Brief amplification of these points follow.

7.6.1 Accessibility to locations under and behind machinery and confined structural configurations is essential to facilitate structural surveys and proper maintenance. Those locations that are difficult to access frequently are the most corrosive prone because of the difficulty of surface preparation and preservation application. Experienced hull inspectors and naval architects are in the best position to identify these areas of the ship.

7.6.2 Preparation of surfaces in difficult to access locations can be dealt with in new construction more readily as part of the unit construction and the fact the machinery is not yet fitted. The surface preparation in an operational ship is much more difficult and often far more troublesome and often not inspected adequately prior to preservation application.

7.6.3 Preservation application in difficult to access locations can be accomplished during new construction with reasonable assurance the specification can be met. In an operational ship some six to nine years after commissioning the adequacy of the preservation will be directly related to the quality of the surface preparation and the degree of difficulty to access the locations. Far too often corrosion products and dirt are overpainted in these difficult to access locations.

7.6.4 Anodes should be installed in machinery bilges and other wet spaces in way of the CVK and "A" strake up to the slosh line no matter what paint system is used.

7.6.5 Design for accessibility is an essential key to shipboard flexibility, lower life cycle costs and enhanced operational availability of the ships.

7.7 Corrosion Allowances

A ship is a collection of corrodible items sitting in salt water. The combination of the barrier coatings of preservation and the cathodic protection system(s), under ideal circumstances, prevent the corrosion of these items. Preservation coatings deteriorate with time, 4 to 8 years depending upon the system, and do have surface breaks from abrasion and other causes. Cathodic protection systems do not cover all areas equally. Will a 6mm plate corrode any less than a 15mm plate under the same environmental conditions? Probably not. A corrosion of 1mm in a 6mm plate is 16.7%, whereas a corrosion of 1mm in a 15mm plate is 6.7%. Furthermore, the higher strength steels are more susceptible to stress corrosion cracking which in turn has an impact on the fatigue strength of the plate.

In some of the more difficult to access locations that are continually damp, corrosion allowances of the order of 20% are reasonable. Clearly, an in-depth examination of corrosion prone areas with the objective to identify appropriate corrosion allowances is a study that should be undertaken by experienced hull inspectors and naval architects for specific ship classes.

7.8 Ship Structural Maintenance and Repair Cycle

The structure must be protected and maintained to ensure the operational availability of the ship. Structural hull surveys will be required regardless of the preservation coatings and cathodic protection systems. The frequency of, and scope of, these hull surveys needs to be addressed with the objective to establish a practical plan for the maintenance of the newer ships, in short, extended work periods and refits.

7.9 Materials Selection

The proper selection of structural materials in the first instance will eliminate many future problems and substantially reduce costs associated with the ship's structure. The present structural design Canadian Forces Technical Orders and associated welding, painting, etc. CFTOs do not present the "judgement" knowledge required to make the proper material selections. The preparation and addition of a material selection standard to the available CFTOs would be of appreciable technical benefit and probable cost savings.

7.10 Structural Data Base

This paper has essentially assembled the structural record of the DDE/DDH 205 Class ships from the first launch in 1951 to the last decommissioning in 1994. Insofar as is known, this is the only ship class with the structural defects history documented with the repairs and the rationale for the repair method discussed, and with the probably cause of the defect offered.

7.11 Moving from In Service Support by Inspections, Maintenance, Repairs (IMR) to Reliability, Availability, Maintainability (RAM)

Throughout the life of the DDE/DDH 205 Class ships the structure was inspected in a planned way, maintained primarily at refits subject to the inspection findings and repaired when there was evidence of a need for repair, again primarily at refits. A team of experienced hull inspectors, a paint and preservation specialist and naval architects provided continuity of knowledge about, and familiarity with, the ship class structure. The structural history was recorded in hull survey reports, special hull structure reports of unusual occurrences and in the familiarity and memory of the knowledgeable and experienced individuals involved.

With the current restructuring of both National Defence Headquarters and the Maritime Command there will be a direct impact on the human resource concerned with ship structure. Some changes may be necessary to ensure quick response action to structural problems and predict potential problem areas before they become a problem. Will the RAM methodology achieve the intended objective? It is beyond the scope of this report to answer this question.

Perhaps the structural history of the DDE/DDH 205 Class can be used in some constructive way to test any RAM techniques or other techniques against a known data base. Clearly there is no merit in adopting new techniques and methodologies at considerable expense in terms of time and dollars unless there is a meaningful benefit derived.

8.0 RECOMMENDATIONS

8.1 Recommended Success Criteria

The following success criteria are recommended to minimize structural failure in monohull frigates and destroyers:

8.1.1 Avoid long deckhouses/superstructures and discontinuous (shortened) uppermost main hull deck ship configurations which increase the probability of major structure failure;

8.1.2 Construct the complete hull structure using notch tough steel incorporating good weldability with the manufacturer's guaranteed minimum impact test results. Suggest CSA WT Steel with minimum impact results of 40 Joules at -40°C (29.5 ft. lb. at -40°F). Notch tough steels should be specified for repairs on older ships;

8.1.3 Select steels with a yield strength consistent with the design of minimum acceptable plate thicknesses and stiffener sizes to avoid fatigue failures in the form of "oil can" effect and from corrosion problems;

8.1.4 Provide accessibility for structural survey and maintenance with particular attention to machinery spaces and above and below 1 Deck Amidships;

8.1.5 Use realistic corrosion allowances especially for difficult to access locations and in damp spaces. Corrosion allowances as high as 20 to 35 per cent may be appropriate for higher strength steels;

8.1.6 Use superior preservation coatings and anodes in wet spaces. Completely coat the interior and exterior hull with approved inorganic zinc silicates or better at new construction; and

8.1.7 Use superior detail design practices to ensure structural continuity and avoidance of structural hard points; and, fabrication techniques to ensure quality weldments without undercutting or incomplete penetrations. Construction should not commence until the Owner is satisfied with the Contract Design or ideally the Detail Design of the ship structure.

8.2 Recommended for Development or Further Study

The following subjects are recommended to enhance the present knowledge and quantify the theoretical and practical facts to the benefit of ship structural design and maintenance.

8.2.1 Develop a "Materials Selection Standard for New Construction and Maintenance" for use by commercial shipyards and naval ship repair units;

8.2.2 Conduct a study and analysis of ship structural maintenance and repair cycle by ship class to establish the most cost effective ownership; and

8.2.3 Conduct a study by ship class to determine the practical corrosion allowances by zones of the ship (i.e. machinery bilges and damp spaces, difficult to access locations hidden behind equipment or panelling, etc.). In the case of new construction these would be corrosion allowance additions to structural members additional to design requirements. In the case of existing ships the margin for corrosion on an existing design can be established.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the following who were very generous with their expertise, advice and "corporate memory" during the preparation of this Paper:

Mr. Gerry LeBlanc, Chief Hull Inspector (retired)

Mr. Ed McSweeney, Senior Hull Inspector (retired)

Mr. Ron Chisholm, Senior Hull Inspector,
Naval Engineering Unit Atlantic,
Halifax, Nova Scotia

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