AD-A118 771 ARINC RESEARCH CORP ANNAPOLIS MD F/G 13/10
SYSTEM ENGINEERING ANALYSIS OF AIR CONDITIONING, HEATING, AND V--ETC(U)
JUL 82 J M O'CONNOR N00189-81-D-0126
UNCLASSIFIED 2657-01-4-2755 NL

END
DATE
FILMED
9 82
DTIC

AD A118771

[illegible]
[illegible]
INSTALLED ON LHA-1 AND LPD-[illegible]
CLASS SHIPS

[illegible]

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
AMPHIBIOUS SHIPS AND CRAFT
PORTSMOUTH, VIRGINIA
under Contract [illegible]

ARINC RESEARCH CORPORATION

This document has been approved for public release and sale; its distribution is unlimited.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 2657-01-4-2755	2. GOVT ACCESSION NO. AD-A118 771	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) System engineering analysis of air conditioning, heating, and ventilation systems installed on LHA-1 and LPH-2 class ships.		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER 2657-01-4-2755
7. AUTHOR(s) J. M. O'Connor		8. CONTRACT OR GRANT NUMBER(s) N00189-81-D-0126-GJ07
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARINC Research Corp. 2551 Riva Road Annapolis, Md. 21401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Planning & Engineering for Repairs and Alterations Amphibious Ships & Craft Portsmouth, Va.		12. REPORT DATE July 1982 13. NUMBER OF PAGES 79
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

[Unlimited]

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

System Engineering Analysis
LHA-1 Class Ships
LPH-2 Class Ships
Air Conditioning-Shipboard
Heating-Shipboard
Ventilation Systems-Shipboard

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The analysis documented herein is specifically applicable to the Air Conditioning, Heating, and Ventilation Systems--ship's work authorization boundary (SWAB) groups 511-1, 512-1, 513-1, 514-1, 514-2, and 514-3-- installed on LHA-1 and LPH-2 Class ships. The analysis considers only the systems and equipments installed and the documentation effective as of 22 Aprol 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SYSTEM ENGINEERING ANALYSIS OF
AIR CONDITIONING, HEATING, AND VENTILATION SYSTEMS
INSTALLED ON LHA-1 AND LPH-2
CLASS SHIPS

July 1982

Prepared for

Planning and Engineering for Repairs and Alterations
Amphibious Ships and Craft
Portsmouth, Virginia

under Contract N00189-81-D-0126-FJ07

by

J. M. O'Connor

ARINC Research Corporation
a Subsidiary of Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

Publication 2657-01-4-2755

SUMMARY

The goal of an engineered operating cycle (EOC) program is to effect an early improvement in the material condition of ships at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, system engineering analyses (SEAs) are being conducted for various ship classes on selected mission-critical systems and subsystems that have historically exhibited relatively high maintenance burdens. This report documents the SEA for the Air Conditioning, Heating, and Ventilation Systems installed on LHA-1 and LPH-2 Class ships.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system and the significance of these requirements to an EOC program. The report documents a recommended system maintenance policy and specific maintenance actions best suited to meeting EOC goals.

This report was developed for PERA (ASC) under Delivery Order FJ-07 of Navy Contract N00189-81-D-0126.

The major findings and conclusions of the SEA for LHA-1 and LPH-2 Class Air Conditioning, Heating, and Ventilation Systems are summarized as follows:

- On the basis of a review of part-replacement rates, historical man-hour burdens, and CASREPs, the air conditioning system equipments, including compressors and pumps and their associated drivers, are considered reliable equipments.
- Given adequate time and replacement parts, ship's force is capable of most air conditioning system repairs, including major overhaul.
- Wearout of system components, including compressors and pumps and their associated drivers, is primarily a function of ship operations and the care with which the system is maintained. Consequently, equipment wearout varies from ship to ship and even between installations within the same ship and therefore cannot be accurately predicted.

- Catastrophic failure of an air conditioning plant does not normally result in degraded air conditioning output, since in most operating environments not all of the air conditioning plants are required to be on line to meet all cooling requirements.

- The most frequent failure modes associated with the motors of the compressors and chilled water and salt water circulating pumps were bearing failure and stator winding failure. Bearing replacement is within ship's force capability, while repair of failed stator windings for motors larger than about 25 horsepower frequently requires IMA assistance to rewind, dip, and bake the motors. Both failure modes can usually be prevented prior to failure by monitoring noise and vibration levels and by performing PMS checks.

- Routine overhaul of properly operating equipment is not recommended, since it has been demonstrated that overhaul is no guarantee against subsequent failure.

- The current maintenance strategy for the air conditioning system equipments is to perform PMS and routinely overhaul at the time of ship ROH.

- Most depot-level repair work associated with the heating and ventilation systems is similar to the work normally performed by ship's force and IMAs. It consists of general system repairs to many different equipments throughout the system: repairs to heaters, preheaters, and reheaters; replacement of corroded or broken vent screens; repairs to various ventilation motors; and repair or replacement of ducting and lagging.

- Current maintenance strategy for the heating and ventilation system equipment is one of on-condition maintenance. Repairs needed during the operating cycle are made by ship's force with occasional IMA assistance. CSMP and POT&I deficiencies are corrected during ROH by ship's force with IMA and shipyard assistance as necessary.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Amphibious Force in support of an engineered operating cycle (EOC) program. The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system. It serves as a vehicle for assessing the significance of these maintenance requirements to an EOC program. The objective of a SEA is to define and document a maintenance program that will prevent or minimize the need for unscheduled maintenance, while improving material condition and maintaining or increasing system availability throughout an engineered operating cycle.

1.2 SCOPE

The analysis documented herein is specifically applicable to the Air Conditioning, Heating, and Ventilation Systems -- ship's work authorization boundary (SWAB) groups 511-1, 512-1, 513-1, 514-1, 514-2, and 514-3 -- installed on LHA-1 and LPH-2 Class ships. The analysis considers only the systems and equipments installed and the documentation effective as of 22 April 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

The analysis used all available documented data sources from which system maintenance requirements could be identified and studied. These included the maintenance data system (MDS), casualty reports (CASREPs), planned maintenance system (PMS) requirements, ship alteration and repair packages (SARPs), system alteration information, system technical manuals, ship corrosion-control manuals, and Engineered Operating Cycle (EOC) system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on EOC program ships. Sources of undocumented data used in this analysis included discussions with ships' operating personnel and cognizant Navy technical personnel.

1.3 REPORT FORMAT

The following chapters describe the analysis approach (Chapter Two), present the significant system maintenance experience and essential maintenance requirements (Chapter Three), and summarize the conclusions and recommendations derived from the analysis (Chapter Four). Appendix A defines the system boundaries used in conducting this analysis, and Appendix B lists the specific components that constitute the air conditioning systems installed on individual ships of the LPH-2 and LHA-1 Classes. Appendix C provides summary shipalt information for two shipalts affecting LPH-2 Class installation configurations. Appendix D provides MDS part data on selected parts of the air conditioning system equipments. Appendix E presents corrosion-control information applicable to selected equipments of the air conditioning, heating, and ventilation systems. Appendix F is a list of the sources of information used in performing this analysis.

CONTENTS (continued)

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the air conditioning, heating, and ventilation systems installed on LHA-1 and LPH-2 Class ships. These systems were selected for analysis by PERA (ASC) on the basis of their mission criticality and historical maintenance burden. Data from sources mentioned in Section 1.2 were used to identify, define, and analyze maintenance requirements that will significantly affect the systems' operational availability and material condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major steps of the analysis were as follows:

- Task 1: Compile data and prepare maintenance history profile
- Task 2: Analyze problems and causes
- Task 3: Analyze solutions to problems
- Task 4: Document SEA results

The following sections briefly describe each of the major tasks.

2.2 TASK 1: COMPILE DATA AND PREPARE MAINTENANCE HISTORY PROFILE

During Task 1, the configuration, boundaries, and functions of the system were defined; maintenance, engineering, and operating data were collected; and the maintenance history profile was prepared, describing the corrective maintenance historically performed. These items provided basic reference data for the remaining SEA tasks.

2.2.1 Collect Data

The analysis began with the collection of data on the historical maintenance requirements of each system. The resulting data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a current equipment configuration summary, and a summary of historical maintenance requirements. A library was also assembled from appropriate technical manuals, PMS requirements, SARPs, and copies of previously completed analyses of functionally similar equipments installed on EOC program ships.

The MDS data bank was compiled by examining all MDS data reported from May 1976 through June 1981 for Hulls LHA-1 through LHA-5, and 1 January 1971 through March 1981 for Hulls LPH-2, LPH-3, LPH-7, LPH-9, LPH-10, LPH-11, and LPH-12 (a total of 12 ships).

CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the period of 1 January 1976 through 22 April 1981 for LHA-1 Class ships and 1 January 1978 through 22 April 1981 for LPH-2 Class ships. CASREPs resulting from parts cannibalization of equipments by other ships were not considered.

2.2.2 Define System Configuration

Configuration information was obtained by reviewing available com configuration class lists (CCCLs), the type commander's coordinated shi board allowance lists (COSALs), shipalt records, and MDS data. Teleph calls to specific ships and cognizant technical personnel, as necessar confirmed system configuration.

2.2.3 Prepare Maintenance History Profile

The maintenance history profile was prepared from analysis of MDS and CASREP data and review of applicable PMS documentation and SARPs. The maintenance history profile is a working technical package describing the types of corrective and restorative maintenance historically performed on the system, the level of maintenance typically required to perform the work, an estimate of the man-hours required, and the approximate intervals at which these maintenance actions can be anticipated.

2.3 TASK 2: ANALYZE PROBLEMS AND CAUSES

In Task 2 the data summarized on the maintenance history profile forms were analyzed, together with the available engineering data, to identify maintenance, support, and design problems and their associated causes. The problems and their causes were confirmed and data related to additional problems were uncovered through discussion with ships' forces and Navy technical personnel when possible.

2.3.1 Analyze Data to Define Problems

Recurring maintenance requirements affecting the availability and material condition of the equipments constituting the system were identified by screening the maintenance history profiles developed in Task 1. Screening of the maintenance history profiles had two major objectives:

- Identification of recurring failure modes or problems that require IMA, depot, or other off-ship assistance for correction and are common to all engineering designs of the functionally similar equipments installed on the ship classes examined.

- Identification of recurring failure modes or problems that are either unique to or primarily associated with a particular equipment engineering design installed on a limited number of hulls.

Once the problems were identified, the previously completed EOC program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been previously identified on other ship classes. If such was the case, the need for additional detailed analysis was minimized.

2.3.2 Define Causes

Although it is presented as a separate subtask, the definition of problem causes was a continuing process that occurred concurrently with the definition of the problems. Concurrent effort was required for the following reasons:

- Problem causes were sometimes stated in the historical maintenance data.
- Causes or possible causes of problems were identified during discussions with Navy technical personnel or ships' forces.
- Problem causes had previously been identified by analysis of identical or functionally similar systems installed on other ship classes.

In general, the causes were grouped into three categories: maintenance strategy, design, and support.

2.3.3 Summarize Problems and Causes

The problems identified and the causes defined in Task 2 were summarized and carried forward to Task 3 for development of specific solutions. The summary descriptions included the following data:

- A statement of the problem and the most probable cause
- A summary of the pertinent maintenance history and engineering data, including man-hours, number of actions, and level of repair
- Other information affecting the problem, such as redesign work in process, applicable alterations, or the effects of maintenance availabilities

2.4 TASK 3: ANALYZE SOLUTIONS TO PROBLEMS

In Task 3 the problems identified in Task 2 were analyzed so that a recommendation could be made regarding a maintenance strategy, a support strategy, design changes for the associated equipments, or equipment that should be replaced.

2.4.1 Analyze Existing Solutions

The analysis of existing design solutions that might be applicable to the two ship classes under study had two basic objectives. The first was to determine whether the problem was known to the Navy technical community and whether or not a solution had been proposed or defined. To do so, currently authorized shipalts affecting the system or equipment under study were reviewed and, if necessary, interviews were conducted with Navy technical personnel. Where possible, the effectiveness of installed shipalts was assessed.

The second objective was to determine if the specific problem existed in other ship classes and, if it did, whether a solution had been defined and whether it was applicable to the problem associated with the ship classes under study. To meet this objective, previously completed analyses of functionally similar equipments installed on other ship classes were reviewed, and the various problems found were evaluated for similarity. If the problems were determined to be similar to those identified in this analysis, the previously developed solutions were assessed for applicability to the particular equipments installed on the ships under study. If found to be applicable, they were adopted and documented as recommendations in this report without further detailed analysis.

2.4.2 Analyze Potential Maintenance Strategies

Previously developed maintenance strategies for functionally similar equipments installed on other ship classes were reviewed for their applicability to equipment installations on the ships under study. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ship.

Where previously identified maintenance strategies did not apply to the ship classes under study, maintenance strategies that could possibly apply were analyzed by using reliability-centered maintenance (RCM) logic. This approach used the information developed during previous tasks to answer a series of simple yes-no questions, which led to specific decisions concerning the suitability of scheduling maintenance tasks. Three types of maintenance tasks could result from the decision process:

- On-condition task - Inspect equipment operation to detect either experienced or impending failures
- Scheduled rework task - Rework an item before an established maximum age or operating interval is exceeded
- Scheduled discard task - Discard an item before an established maximum age or operating interval is exceeded

The results of this process led to the development of the maintenance strategies recommended for the systems and equipments under study for which previously developed maintenance strategies were inadequate.

2.4.3 Analyze Potential Solutions to Integrated Logistics Support (ILS) Problems

Analysis of possible improvements to the ILS of the systems and equipments under study was limited to only those systems or equipments having maintenance history profiles that indicated the presence of such problems. Such problems are typically identified during review of MDS or CASREP data. Excessive downtime awaiting parts and the lack of authorized on-board spares as reported in CASREPs indicated the existence of ILS problems. MDS narratives were also used to identify ILS problems, since the deferral codes frequently indicated that a particular maintenance action was deferred for lack of spare parts, technical documentation, or training or experience on the equipment. Where ILS problems were identified, previously completed analyses of functionally similar systems or equipments were reviewed to determine if similar ILS problems had been identified. If they had, and if satisfactory solutions had been defined and recommended, those solutions were adopted and documented as recommendations in this report without further detailed analysis. Otherwise, further analysis was conducted to define an appropriate solution.

Each ILS problem was assessed in terms of its significance and the feasibility of successfully implementing a cost-effective solution. Only those solutions judged to be essential and cost-effective were recommended.

2.4.4 Select Effective Solutions

An effective solution was selected by the analyst on the basis of its merit or essentiality with respect to its projected cost and risk. All candidate solutions, whether resulting from this analysis or from previously conducted analyses of functionally similar equipments, that were judged to improve personnel safety or primary mission reliability were assessed on the basis of projected cost and feasibility. If these candidate solutions were not clearly feasible, or if their value, in terms of reduced maintenance burden or improved equipment reliability, was not significant, they were not recommended for implementation.

2.5 TASK 4: DOCUMENT SEA RESULTS

The Task 4 approach was to present the analysis results in a concise, logical format that included an introduction to the SEA objectives, a summary of the technical approach used, a presentation of the analysis results, and a section listing the specific conclusions and recommendations resulting from the analysis. Appendixes were included as necessary to show pertinent data affecting the system, including a table defining the configurations by allowance parts list (APL) number for each LHA-1 and LPH-2 Class hull included in the analysis.

CHAPTER THREE

ANALYSIS RESULTS

3.1 GENERAL SYSTEM BOUNDARIES AND DESCRIPTION

This chapter presents the results of the system engineering analysis for the air conditioning, heating, and ventilation systems for the LPH-2 and LHA-1 Classes of ships. The air conditioning, heating, and ventilation systems encompass six SWAB groups. The air conditioning equipments include the chilled water distribution system (514-1), the chilled water air conditioning plants (514-2), and self-contained air conditioning units (514-3). The heating system is covered by SWAB 511-1. The ventilation system includes nonmachinery-space ventilation (512-1) and machinery-space ventilation (513-1). Appendix A presents a breakdown of the major equipments in each SWAB category. Appendix B shows the APL configuration by hull for the major equipments covered by this analysis.

The air conditioning, heating, and ventilation systems constitute the environmental control system for the ship, provided for the purpose of keeping the crew mentally alert and physically fit. The air conditioning (A/C) circulating chilled water system provides chilled water to various cooling coils located throughout the ship in ducts or in designated air conditioning spaces. This circulating chilled water is also used to remove heat from heat exchangers in electronic cooling systems and auxiliary machinery. A sea water circulating system is used to remove heat from the air conditioning plants (chiller units).

The air conditioning, heating, and ventilation equipment for the LPH-2 and LHA-1 Class ships consists generally of motor-driven fans, preheaters and reheaters, cooling coils, air conditioning plants, circulating pumps, and the necessary piping and ducting to supply conditioned air at the proper temperature to environmentally controlled spaces. Thermostatic controls located in either the spaces or the ducts serving the spaces automatically regulate the temperature of the air supplied to the air conditioned spaces. The ventilation, heating, and air conditioning systems provide control and distribution of air throughout the ship to accomplish the following functions:

- Supply fresh outside air to the ship
- Exhaust stale and contaminated air from the ship

- Cool or heat ambient air for distribution to berthing, messing, office, medical, dental, and control spaces, as required
- Provide cooling air to ammunition storage and handling spaces and to electronic equipment rooms
- Control temperature and humidity for the LHA-1 Class troop climate conditioning room
- Circulate chilled water through heat exchangers to remove heat from electronic equipment and to chill potable drinking water

Locally controlled cooling coils and heaters are installed in spaces where local control or supplemental cooling or heating is desired. Circulating chilled water from the air conditioning chiller units is provided to various types of cooling coils throughout the ship. Ambient air is ducted into and exhausted from the main and auxiliary machinery spaces by large-capacity vaneaxial fans. Sufficient fresh air is supplied to vehicle stowage and hold areas, and contaminated air is exhausted from those areas to prevent concentrations of noxious gases from landing craft and motor vehicles.

More detailed descriptions of the systems are given in the individual system subsections of Section 3.2.

The air conditioning, heating, and ventilation systems were selected for analysis because of their contribution to the ship's maintenance burdens at all levels of repair. In terms of all maintenance-significant systems, the air conditioning, heating, and ventilation systems ranked fourth, twenty-ninth, and thirteenth, respectively, of 118 shipboard systems on the LPH-2 Class ships (see ARINC Research Publication 2652-11-1-2462), and seventeenth, thirtieth, and forty-second of 88 systems on the LHA-1 Class ships (see ARINC Research Publication 2653-01-TR-2552).

3.2 MAINTENANCE REQUIREMENT IDENTIFICATION

The maintenance requirements for the air conditioning, heating, and ventilation systems are addressed in two sections. Section 3.2.1 covers the air conditioning plants and chilled water and salt water circulating systems; Section 3.2.2 covers the heating and ventilation system. Section 3.2.3 provides a brief discussion of corrosion problems identified during the analysis that applies to the heating, ventilation, and air conditioning systems.

3.2.1 Air Conditioning

3.2.1.1 System Description

Air for the ventilation system's air conditioned spaces is cooled by a chilled water circulating system. Fresh water, cooled by mechanical refrigeration, is circulated through duct-type cooling coils, gravity-type cooling coils, and unit coolers located throughout the ship in or near the spaces served. Duct-type cooling coils are employed in the majority of spaces that require air conditioning. Gravity-type cooling coils are used in ammunition and missile storage areas. Unit-type cooling coils are used in spaces requiring air conditioning where only replenishment air is available.

The chilled water for the air conditioning chilled water circulating system is provided by independent chiller units (air conditioning plants). The LHA-1 Class ships all have four 300-ton-capacity air conditioning plants. The LPH-2 Class ships have various sizes and numbers of air conditioning plants. The current plant configuration by hull for both classes is shown in Table 3-1. There are two shipalts that affect the air conditioning plant configuration of the LPH-2, -3, -7, and -9. Shipalt LPH-255 (Revision I) replaces the 65- or 70-ton unit for zones 1 and 2 with a 150-ton unit; replaces the existing circulating pump for zones 1 and 2 with a larger-capacity (540 GPM) pump; air conditions a number of additional spaces; and accomplishes the associated piping and cabling. Shipalt LPH-585 provides the capability for extended operations in the tropics by installing an additional 150-ton plant and an additional salt water circulating pump, together with the necessary plumbing to air condition additional spaces. Appendix C summarizes the work accomplished by these two shipalts.

All of the A/C plants for both classes are of the vapor-compression chilled water circulating type. Heat from the air conditioned spaces is absorbed by the chilled water in the cooling coils and is removed by the primary refrigerant in the water chillers. In the larger plants (150 tons, 200 tons, and 300 tons) the compressors are of the centrifugal type that use R-11 (the 150-ton and 200-ton plants of the LPH-2 Class) or R-114 (the 300-ton plants of the LHA-1 Class) as the primary refrigerant. The smaller plants (65 tons, 70 tons, and 85 tons, LPH-2 Class) have compressors of the reciprocating type that use R-12 as the primary refrigerant.

In addition to the chiller units, the chilled water circulating system includes chilled water circulating pumps, pump motors and controllers, and necessary piping and fittings to circulate the chilled water through the cooling coils and heat exchangers located throughout the ship. The output of each chiller unit is pumped through a separate chilled water loop with cross-connection between the other chiller unit outputs so that the ship's air conditioning load can be carried by one or more air conditioning plants in an open-loop configuration or the individual loops can be segregated so that each plant cools a separate loop. In this manner, redundancy is provided such that, in most operating environments, the loss of one or more A/C plants can be absorbed without reduction in air conditioning services.

In addition to the A/C plants and the chilled water circulating systems, the A/C system includes sea water circulating systems, which are used to remove heat from the primary refrigerants by circulating sea water through the condensers in the air conditioning plants. The sea water circulating pumps take suction from seachests and discharge the sea water to the inlet of the condenser units. The discharge lines of each sea water circulating pump are cross-connected with the firemain system so that in the event of a pump failure, the firemain may be used to provide the sea water for the condensers.

Table 3-1. SUMMARY OF MDS DATA FOR AIR CONDITIONING PLANTS

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Ship Operating Years (SOY)	Average Interval Between JCNs (SOY)	JCNs	Man-Hours			Parts Cost (Dollars)	Average Man-Hours per Equipment per Ship Operating Year
							Ship's Force	IMA	Total		
325000245	Refrigeration Plant, Air Conditioning, 85-Ton Capacity	LPH-10	6	7.10	0.37	115	2,467	1,545	4,012	35,817	94
325000265	Refrigeration Plant, Air Conditioning 65-Ton Capacity	LPH-2	1	8.11	0.48	17	79	268	347	3,051	43
325000307	Refrigeration Plant, Air Conditioning 65-Ton Capacity	LPH-3	2	7.13	0.89	16	30	1,506	1,536	3,406	108
325010133	Refrigeration Plant, Air Conditioning 70-Ton Capacity	LPH-2 LPH-3	6 4	8.11 7.13	0.37 0.53	130 54	3,603 717	1,700 1,481	5,303 2,198	41,040 5,680	109 77
325010157/ 325010158	Refrigeration Plant, Air Conditioning 70-Ton Capacity	LPH-3 LPH-7 LPH-9	2 5 6	8.11 8.41 7.28	0.77 0.51 0.54	21 83 81	110 876 1,281	265 558 453	375 1,434 1,734	6,087 16,101 13,921	23 34 40
325010316/ 325010317	Refrigeration Plant, Air Conditioning 200-Ton Capacity	LPH-11	3	7.82	0.25	94	1,282	741	2,023	21,945	86
325010333	Refrigeration Plant, Air Conditioning 150-Ton Capacity	LPH-9	1	*	--	--	--	--	--	--	--
325010339	Refrigeration Plant, Air Conditioning 200-Ton Capacity	LPH-12	3	7.28	0.22	99	1,963	1,630	3,593	12,994	165
325010383B	Refrigeration Plant, Air Conditioning 300-Ton Capacity	LHA-1 LHA-2 LHA-3 LHA-4 LHA-5	4 4 4 4 4	3.63 2.74 1.94 1.38 --	1.45 0.73 0.97 0.17 --	10 15 8 32 18	79 35 27 141 97	168 0 0 0 0	247 50 27 141 97	4,272 812 2,046 458 0	17 5 3 26 --

(continued)

Table 3-1. (continued)

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Ship Operating Years (SOY)	Average Interval Between JCNs (SOY)	JCNs	Man-Hours Ship's Force	Man-Hours IMA	Man-Hours Total	Parts Cost (Dollars)	Average Man-Hours per Equipment per Ship Operating Year
Various	Chilled Water	LPH-2	7	8.11	2.84	20	213	136	349	370	6
	Circulating System	LPH-3	7	7.13	1.66	30	240	129	369	863	7
	(Includes pumps,	LPH-7	6	8.41	8.41	6	55	91	146	--	3
	motors, and motor	LPH-9	6	7.28	2.43	18	76	338	414	2,188	9
	controller burdens)	LPH-10	6	7.10	1.52	28	345	653	998	395	23
		LPH-11	3	7.82	0.78	30	111	1,282	1,393	6,116	59
		LPH-12	3	7.28	1.04	21	309	40	349	8,070	16
		LHA-1	4	3.63	3.63	4	32	8	40	9,157	3
		LHA-2	4	2.74	2.74	4	10	0	10	112	1
		LHA-3	4	1.94	1.55	5	44	0	44	1,856	6
		LHA-4	4	1.38	1.38	4	64	0	64	321	12
		LHA-5	4	--	--	--	--	--	--	--	--
Various	Salt water	LPH-2	5	8.11	2.13	19	289	365	654	958	16
	Circulating System	LPH-3	5	7.13	0.70	51	663	430	1,093	4,714	31
	(Includes pumps,	LPH-7	3	8.41	0.81	31	178	1,222	1,400	2,368	55
	motors, and motor	LPH-9	3	7.28	0.81	27	149	518	667	3,259	31
	controller burdens)	LPH-10	3	7.10	0.89	24	766	467	1,233	1,441	58
		LPH-11	3	7.82	0.76	31	297	1,686	1,983	12,868	85
		LPH-12	3	7.28	0.59	37	119	107	226	10,615	10
		LHA-1	4	3.63	2.42	6	0	0	0	6,000	0
		LHA-2	4	2.74	1.83	6	20	0	20	0	2
		LHA-3	4	1.94	0.55	14	20	0	20	6,369	3
		LHA-4	4	1.38	1.84	3	6	0	6	20	1
		LHA-5	4	--	--	--	--	--	--	--	--

The MDS data reported against the major equipments of the air conditioning systems were sorted and summarized to define the MDS-reported corrective maintenance man-hour burdens represented by the air conditioning systems on each ship. For this purpose, each A/C plant was treated as a single unit made up of the major components of the plants, including the condenser, compressor, compressor motor and controller, chiller, dehydrator, and flexible coupling. The combined equipments of each plant were treated as a single unit, since the loss of any one unit causes loss of that plant. Similarly, the burdens computed for the chilled water and salt water circulating systems represent the average combined burden of the pump, pump motor, and controller of each system. The significant reported data and the computed burdens in terms of average interval between JCNs and average man-hours per component operating year are summarized in Table 3-1. The A/C systems are addressed within each of the remaining sections of this analysis as three separate systems: the air conditioning plants, the chilled water distribution system, and the salt water circulating system.

3.2.1.2 Air Conditioning Plants

Review of the reported MDS data revealed that air conditioning plant corrective maintenance is generally reported against either the plant APL or the individual equipment APLs. That maintenance reported against the plant APL was usually for system-level repairs such as repair or replacement of temperature or pressure gauges and cleaning of the refrigerant system. Of all the maintenance actions reported against individual equipment APLs, more than 92 percent were attributable to five equipments: the compressors (58 percent), the compressor motors (14 percent), the compressor motor controllers (12 percent), the condensers (5 percent), and the chillers (3 percent). These equipments are addressed individually in the following paragraphs.

Compressor

On the basis of the reported MDS data, the compressors universally represent the greatest maintenance burden to the A/C plants. They also accounted for 13 of the 30 CASREPs reported against the A/C plants during the data period.

The purpose of the compressor is to pump the heat-laden low-pressure refrigerant vapor from the water chiller and discharge it at a high pressure to the condenser. There are two types of compressors installed on the ships under analysis. The smaller plants (85 tons and below) employ 8- or 12-cylinder reciprocating-type compressors. The cooling capacity of the compressors is controlled by the temperature of the water leaving the chiller. The capacity of the reciprocating compressors is controlled by a capacity control system that varies the number of cylinders allowed to compress refrigerant in response to the load requirement of the plant. The capacity of the centrifugal compressors is controlled by varying the position of radial pre-rotation vanes in the suction inlet to the impeller wheel, while the compressor is allowed to operate continuously at constant speed.

Part requisitions against individual compressor APLs appearing on at least two job control numbers (JCNs) were extracted from the MDS data (these are summarized in Appendix D). Exceptions were consumables such as gaskets, bolts, nuts, and packing. In view of the extent of the data period represented by the MDS data, parts ordered only once during the data period were not considered as having significant enough usage to warrant consideration. A part-demand frequency was computed for all the parts listed in Appendix D by dividing the total equipment operating years by the number of JCNs on which each part was ordered. Parts with multiple applications in a compressor (such as piston rings, valve disks, and cylinder sleeves in reciprocating compressors) are generally replaced in quantity. This is as expected since all of the cylinders of a reciprocating compressor receive the same wear and when the equipment is deteriorated by wear, restoration to original specifications would generally require replacement of all rings and bearings. Review of the part usage summaries indicates that the compressors are made of reliable parts. Review of the individaul APLs indicated that current onboard allowances are adequate to meet historical part demand. However, operating personnel on all ships visited indicated that they had difficulty in obtaining compressor internal parts (they mentioned rings, pistons, cylinder liners, and valves on reciprocating compressors, and carbon seals and bearings on centrifugal compressors).

The MDS data revealed that ship's force is generally capable of performing all repairs to the air conditioning compressors, including major overhaul. Further, ship personnel were critical of the quality of overhaul that equipments received from the shipyards and SIMAs. On one ship, for instance, they reported that shortly after a recent overhaul, two compressors that had been overhauled failed catastrophically -- one because a rag was left in the oil sump; the other because, during overhaul, sand had entered the compressor from the ventilation system during sand-blasting operations. Ship's force indicated that if they have the time and the parts, they prefer to overhaul their own equipment to ensure a high-quality overhaul.

The MDS narrative review indicated that the need for compressor corrective maintenance is generally determined by two types of failures:

- Noncatastrophic failures, in which the need for repair is determined by performance monitoring (e.g., abnormal operating pressures or temperature, erratic compressor operation, noise, or vibration).
- Catastrophic failures, causing complete plant shutdown and usually resulting in the preparation of a CASREP.

Factors leading to catastrophic failures of the compressor were identified from the MDS and CASREP narratives, from review of technical manuals, and from interviews with ship's force and technical personnel. These factors include refrigerant floodback to the compressor (liquid refrigerant returning to compressor) and wear and deterioration:

- Refrigerant Floodback. Refrigerant floodback to the compressor can result from improper start-up or refrigerant overcharge or, in some plants, improper adjustment of the thermal expansion valve that controls the quantity of liquid refrigerant that passes through the chiller tubes. There are several indications that floodback is occurring:

- •• The actual refrigerant suction temperature drops to the temperature corresponding to the existing suction pressure as indicated by the temperature and pressure scales on the suction pressure gauge.
- •• Compressor discharge temperature drops.
- •• Condensing pressure is low.
- •• There is a sudden loss of oil from the crankcase.

If liquid refrigerant is returning to the compressor, the cause must be isolated and corrected at once to prevent severe compressor damage. Liquid refrigerant, if permitted to return to the compressor over a period of time, even in small quantities, will cause lubrication problems due to the flushing of oil from wearing surfaces, particularly in the reciprocating compressors, where pistons, cylinder walls, rings, and bearings may all suffer premature failure.

- Wear and Deterioration. The extent of wear and deterioration of the compressor is a direct function of the amount of system use and the care with which the compressor is operated and maintained. Operational requirements of the ship dictate the amount of use, and little can be done to reduce normal wear. However, the single greatest controllable factor affecting compressor life is the care with which it is operated and maintained. For example, one of the *most common failures noted in the MDS data, shaft seal failure, is* usually the result of faulty lubrication due to contaminated oil. Dirt is most easily introduced into the compressor during installation or when the compressor is opened for repairs or overhaul. When the compressors are opened, internal components are also subjected to the possibility of corrosion, resulting in accelerated wear and further contamination of the oil. If the compressor is opened for repair, it is especially important to keep the refrigerant side of the system as clean and dry as possible. If the system has been opened for repairs that require removal of the refrigerant charge from the system, it is essential that the system be clean and thoroughly evacuated and dehydrated before recharging.

All but two of the 13 CASREPs reported against compressors, summarized in Table 3-2, were of C-2 severity; the two others were of C-3 severity because another A/C plant was down.

Review of the applicable PMS procedures for the plants reveals that the compressor preventive maintenance procedures consist primarily of testing the refrigerant system for leaks and testing and maintaining lube oil quality. The PMS and applicable technical manuals indicate that the compressors (both reciprocating and centrifugal) should be opened only if the system fails to function properly and repairs to the compressor are likely to be required.

Table 3-2. COMPRESSOR CASREP SUMMARIES			
Ship	APL	Plant Number	Summary
LPH-2	060950088	2	Backflooding caused by operating error resulted in extensive internal damage.
LPH-3	060150142	8	Unidentified mechanical failure; overhaul by SIMA.
	060950088	5	Piston seized; overhaul by contractor.
		2	Freon floodback damaged two suction valves, pistons, discharge valves, connecting rod bearings.
	060150142	8	Failed; 3 rods, pistons, main bearings, seal, and crankshaft damaged. Overhauled.
LPH-7	060950109	1	Connecting rod broke, causing severe damage to cylinders 7-11 and pistons. Overhauled by repair activity.
		5	Needs overhaul because of deteriorated condition. Bad suction and discharge valves, scored cylinder liners, bad unloader pistons, bad bearings, bad thermal expansion valve.
LPH-9	060950109	1	Replace shims and coupling.
LPH-10	060150120	3	Suction and discharge valves leaking.
LPH-11	060950101	1	Prerotating vanes and linkage sticking and binding. Overhaul by industrial activity.
	060950191	3	Will not turn. Gears binding.
	060950191	2	Lube oil relief valve worn. Contaminated oil damaged compressor. Overhaul by SRF Subic.
	060950191	3	Frozen; will not rotate.

A review of the available SARPs for the ships being analyzed, summarized in Table 3-3, revealed that 33 of the 46 compressors of the ships for which the SARPs were applicable were authorized for class B overhauls during the availabilities documented by the individual SARPs. Several types of justification were given for the need for class B overhauls in the CSMP entries identified in the individual SARPs. The most prevalent CSMP entry stated "air conditioning plant operates at reduced capacity." Reduced plant capacity can result from a number of problems, such as a scaled or leaking condenser or chiller or a worn compressor. Other referenced CSMP entries stated only that the shaft seal leaked. Still other CSMP entries cited a need for class B overhaul since the task was identified in the

Table 3-3. CLASS B SUMMARY (FROM SARPs) FOR A/C COMPRESSORS

Ship	ROH Date	Compressors Receiving Class B Overhaul
LPH-2	FY 81	7 of 7
LPH-3	FY 82	7 of 7
LPH-7	FY 79	3 of 6
LPH-9	FY 80	0 of 6
LPH-10	FY 80	6 of 6
LPH-11	FY 80	3 of 3
LPH-12	FY 80	1 of 3
LHA-1	FY 81	2 of 4
LHA-1	FY 82	4 of 4
Total		33 of 46

baseline SARP. Two of the authorized SARPs reviewed, one for the LPH-2 and one for the LPH-3, identified all seven of the compressors as requiring class B overhaul. The results of the Machinery Condition Analysis (MCA) performed on the air conditioning plants of those two ships were referenced in the SARPs as not supporting the general need for class B overhaul of the compressors. The MCA results specified only the need for renewing some of the shaft seals, together with some other minor class C repairs. It appears from the SARP review that the air conditioning plant compressors are increasingly receiving routine insurance-type class B overhauls with questionable justification of the need for overhaul.

It appears, then, that the current maintenance strategy for the compressors is to perform PMS, with an increasing trend toward routine periodic overhaul at ROH.

The following conclusions resulted from analysis of the available maintenance data on the air conditioning plant compressors:

- Review of part replacement rates, historical man-hour burdens, and CASREPs indicates that the compressors are generally reliable equipments.
- Given adequate time and replacement parts, ship's force is capable of most compressor repairs, including major overhaul.
- Compressor wearout is primarily a function of ship operations and the care with which the compressor is maintained; therefore, it cannot be predicted.
- Catastrophic failure of a compressor (or A/C plant in general) does not generally result in ship mission degradation, since in most operating environments not all of the A/C plants are required to be on line at the same time to meet all cooling requirements.
- Current compressor maintenance strategy is to perform PMS, with an increasing trend toward periodic overhaul at ROH. Justification for the routine overhaul appears questionable.
- Discussions with ship's force personnel indicate that on-board allowances of compressor internal parts are not being met.

Compressor Motor

Motors of several sizes are used in the different air conditioning plants to drive the compressors. The reciprocating compressors are coupled to their drivers through flexible couplings. The horsepower ratings of the individual motors of the reciprocating compressors are 75, 100, and 125, as defined by the installation configuration in Appendix B. The centrifugal-type compressors are coupled to their drive motors through a speed increaser, which steps up the drive speed from motor rpm to compressor rpm. The drive motors of the centrifugal compressors are rated at 200 hp and 300 hp as shown in Table B-1.

There were nine CASREPs, all of C-2 severity, against the compressor motors (see Table 3-4). Review of MDS narratives for the compressor motors revealed two repetitive maintenance actions experienced by the motors: bearing replacement and stator rewinding. These are described as follows:

- Bearing Replacement. Bearing replacement was one of the most frequent repair actions identified in the MDS data, although its occurrence on individual motors was rare. On LPH-2, for example, of the seven compressor motors, the only identified bearing replacements were two on compressor motor 3 and one on compressor motor 1 over a period of about eight ship operating years. Similar replacement

Ship	APL	Plant Number	Summary
LPH-2	174340814	5	Fan flade loosened on shaft and severed windings.
LPH-3	174340814	2	Windings shorted because of insulation breakdown.
	174340814	8	Windings shorted because of insulation breakdown.
	174340814	1	Windings shorted because of insulation breakdown.
LPH-11	174752206	--	Compressor motor grounded.
LHA-2	174031473B	1	Bearings wiped, causing bent coupling
	174031473B	3	Windings shorted.
LHA-1	174031473B	2	Windings shorted.
	174031473B	3	Windings shorted.

Table 3-4. COMPRESSOR MOTOR CASREP SUMMARIES

rates were experienced by the other ships analyzed. Bearing replacement is within ship's force capability and can generally be accomplished within 25 man-hours. One identified CASREP was caused by bearing failure. Bearings rarely fail catastrophically, since they are replaced when warning signs (such as noise or vibration) indicate the need for replacement prior to catastrophic failure. The bearings for the individual motors are stocked on board. On the basis of the foregoing discussion, bearing replacement is not considered a significant problem.

- Stator Rewinding. Seven of the nine identified CASREPs were attributed to failure of the stator windings and were deferred for outside repair activity. Stator winding repair involves rewinding, dipping, and baking of the stator, a task which requires IMA assistance. Review of the MDS data revealed that, like the need for bearing replacement, the need for stator winding was infrequent or nonexistent for specific motors. For example, on the LPH-2, which has seven compressors, only two motor rewinds were identified in 8.11 ship operating years of data, or an anticipated rewind rate during the operating cycle of approximately one per motor every 28 ship operating years. Impending stator winding failure can normally be predicted prior to breakdown by taking insulation-resistance readings and ensuring that the motor windings remain clean and dry; these checks are included in PMS requirements.

PMS for the compressor motors includes requirements for cleaning and inspecting, lubricating bearings, and checking insulation resistances.

From review of the MDS data reported against equipments in the periods shortly after overhaul, it was evident that a routine class B overhaul is no guarantee of subsequent reliable operation. For example, one compressor motor on the LPH-3, from plant number 6, was rewound, dipped, and baked in July 1976 because the motor had burned. Subsequently, the motor windings failed again in December 1976 and January 1977; both times they were rewound. In another case, on LPH-11, compressor motor 1 was rewound three times in a two-year period.

A review of SARPs (summarized in Table 3-5) indicated that 32 of 46 A/C plant compressor motors were authorized for class B overhaul. As in the case of the compressors, the MCAs for the LPH-2 and LPH-3 (both of which had class B overhauls authorized for all seven motors) supported overhaul of only two of the LPH-2 motors and none of the LPH-3 motors. The most common CSMP entries referenced in the SARPs stated that the motors had noisy bearings or dirty and oily windings -- problems that can be corrected by ship's force.

Table 3-5. CLASS B SUMMARIES (FROM SARPs) FOR A/C COMPRESSOR MOTORS

Ship	ROH Date	Motors Receiving Class B Overhaul
LPH-2	FY 81	7 of 7
LPH-3	FY 82	7 of 7
LPH-7	FY 79	1 of 6
LPH-9	FY 80	0 of 6
LPH-10	FY 80	6 of 6
LPH-11	FY 80	3 of 3
LPH-12	FY 80	2 of 3
LHA-1	FY 81	2 of 4
LHA-2	FY 82	4 of 4
Total		32 of 46

The following conclusions resulted from analysis of the available maintenance data on the compressor motors:

- The most frequently identified failure modes were bearing failure and stator winding failure. Bearing replacement is within ship's force capability, while repair of failed stator windings requires IMA assistance for rewinding, dipping, and baking the motors. Both failure modes can generally be predicted by monitoring noise and vibration levels and by performing PMS checks.
- Motor overhaul should be accomplished only as a corrective action; it should not be accomplished routinely as an insurance measure, since it has been demonstrated that motor overhaul is no guarantee against subsequent failure.
- The current maintenance strategy for the compressor motors is to perform PMS and on-condition maintenance and conduct a class B overhaul at ROH.

Compressor Motor Controllers

The compressor motor controllers contain the main power contacts and control relays that operate the compressor motor in response to signals from A/C plant safety and control switches.

Review of the MDS data revealed that motor controller repairs are normally effected by ship's force and usually require replacement of a failed part (e.g., resistors, switch, coils) or replacement of worn contacts. For many of the motor controllers no maintenance actions were reported during the data period. Only three parts were identified as having been replaced more than once; two of them were the same type of part in two different motor controllers. Demand frequencies for all parts were very low; consequently, no part-related problems were identified as attributable to motor controller failures.

Class B overhauls of A/C motor controllers identified from available SARPs are summarized in Table 3-6, which shows that 39 of 46 motor controllers were authorized for class B overhaul during the referenced availabilities. While the need for overhaul was substantiated for some of the controllers, in many cases it was not. This was evident in MCA comments, which did not support the overhauls.

The following conclusions resulted from analysis of the available maintenance data on the motor controllers:

- Most motor controller repairs are accomplished by ship's force and require replacement of a failed part.
- Motor controllers have historically been reliable, as evidenced by the fact that for many of the controllers no maintenance actions were reported during the data period and no compressor motor controller CASREPs were identified.
- A high percentage of the motor controllers are being routinely overhauled during ROH.

Table 3-6. CLASS B SUMMARIES (FROM SARPs) FOR A/C COMPRESSOR MOTOR CONTROLLERS

Ship	ROH Date	Controllers Receiving Class B Overhaul
LPH-2	FY 81	7 of 7
LPH-3	FY 82	7 of 7
LPH-7	FY 79	3 of 6
LPH-9	FY 80	2 of 6
LPH-10	FY 80	6 of 6
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	4 of 4
LHA-2	FY 82	4 of 4
Total		39 of 46

Condenser and Chiller

The function of the condenser is to transfer the heat of the compressed refrigerant gas to the sea water circulated through the tubes, converting the gas to refrigerant liquid. Inside the condenser shell, at the gas inlet, a perforated baffle plate prevents the high-velocity compressor discharge gas from impinging directly upon the tubes. The function of the chiller is to transfer the heat from the cooling water to the refrigerant. This changes the liquid refrigerant in the chiller to a gas as the heat is absorbed.

Review of the MDS data identified two types of maintenance actions performed on the condensers and chillers: cleaning of the chiller and condenser tubes or the shell, or both; and plugging or replacing of leaking chiller and condenser tubes. It is difficult to determine by any particular test whether possible lack of performance of the water chiller is due to fouled tubes alone or to a combination of problems. Problems that may be due to fouled tubes are indicated when, over a period of time, the cooling capacity decreases and the split temperature (difference between water leaving the cooler and the refrigerant temperature in the cooler) increases. A gradual drop-off in cooling capacity can also be caused by a gradual leak of refrigerant from the system or by a combination of fouled tubes and shortage of refrigerant charge. An excessive quantity of oil in the chiller can also contribute to erratic performance.

In a condenser, trouble due to fouled tubes is usually indicated by a steady rise in head pressure, over a period of time, accompanied by a steady rise in condensing temperature.

Fouling of the tubes can be due to deposits of two types:

- Rust or sludge that finds its way into the tubes and accumulates there. This material usually does not build up on the inner tube surfaces as scale, but it does interfere with heat transfer. Rust or sludge can generally be removed from the tubes by a thorough brushing.
- Scale due to mineral deposits. These deposits, even though very thin and scarcely detectable upon physical inspection, are highly resistant to heat transfer. They can be removed most effectively by circulating an acid solution through the tubes.

The air conditioning plant technical manual states that whenever the ship has been tied up in a harbor where water is heavily silted or otherwise contaminated, the sea water side of the condenser should be thoroughly flushed immediately upon the ship's returning to open seas. This flushing is easily accomplished by ship's force by permitting a maximum flow of water through the condenser for several minutes to dislodge and flush out any sediment that may have accumulated in the condenser tubes while the ship was in port.

PMS requirements for the air conditioning plants include a requirement to clean and inspect the sea water side of the condenser. For some plants this is a 36-month requirement. For all plants it is to be performed when the efficiency of the condenser has deteriorated. This deterioration can be determined by comparing the temperature of the water leaving the condenser with the condensing temperature of the refrigerant. When the difference between these two temperatures exceeds a certain limit (depending on the particular plant), fouled, scaled, or leaking tubes are indicated. If the condenser tube fouling consists of dirt or sludge, ship's force can usually remove it by draining the water sides of the condenser, removing the heads, and cleaning each tube with a soft-bristle bronze brush.

If the condenser tubes are fouled with a hard scale deposit, they must be acid-cleaned. The MDS data indicate that acid cleaning is usually accomplished by either IMA or depot-level personnel. If evidence of rusting and sludging of shells, particularly the cooler, is discovered after a tube has leaked an appreciable amount of water to the refrigerant side, the shells must also be acid-cleaned by the IMA or depot personnel.

The existence of condenser or chiller leaks can be positively identified by leak testing as described in the air conditioning plant technical manuals. If inspection indicates that the chiller or condenser has one or more leaking tubes, those tubes must be replaced. The MDS data suggest that tube replacement generally requires IMA or depot-level assistance. If it is not practical to replace the leaking tubes immediately, they can be plugged temporarily, an action that has been accomplished by ship's force. PMS instructions indicate, however, that no more than 10 percent of the total tubes should be plugged at any one time, or the condenser might suffer too great a loss of efficiency.

The review of SARP entries concerning condenser and chiller class B overhauls is summarized in Tables 3-7 and 3-8, respectively. The review indicated that a large proportion (35 of 46) of the condensers historically have been retubed during ROH, while few of the chillers (17 of 46) have been. The greater condenser overhaul requirement is attributed to its exposure to salt water and resulting corrosion.

One of the CASREPs reviewed resulted from a chiller failure, and three resulted from condenser failure. The one chiller failure resulted from warping of the chiller cover when excessive heat was applied to the chiller to accelerate defrosting. The three condenser CASREPs resulted from tube leaks caused by salt water corrosion/erosion.

Table 3-7. CLASS B SUMMARIES (FROM SARPs) FOR AIR CONDITIONING CONDENSERS

Ship	ROH Date	Condensers Receiving Class B Overhaul
LPH-2	FY 81	7 of 7
LPH-3	FY 82	7 of 7*
LPH-7	FY 79	3 of 6
LPH-9	FY 80	0 of 6
LPH-10	FY 80	6 of 6*
LPH-11	FY 80	3 of 3*
LHA-12	FY 80	3 of 3
LHA-1	FY 81	2 of 4
LHA-2	FY 82	4 of 4*
Total		35 of 46

*Condenser work included in work to clean, flush, pressure test, repair leaks for A/C plants.

Table 3-8. CLASS B SUMMARIES (FROM SARPs) FOR AIR CONDITIONING CHILLERS		
Ship	ROH Date	Chillers Receiving Class B Overhaul
LPH-2	FY 81	0 of 7
LPH-3	FY 82	7 of 7*
LPH-7	FY 79	0 of 6
LPH-9	FY 80	0 of 6
LPH-10	FY 80	6 of 6*
LPH-11	FY 80	1 of 3*
LPH-12	FY 80	3 of 3
LHA-1	FY 81	0 of 4
LHA-2	FY 82	0 of 4
Total		17 of 46

*Chiller work included in work to clean, flush, pressure test, repair leaks for A/C plants.

The following conclusions resulted from analysis of the available maintenance data on the A/C plant condensers and chillers:

- The two primary maintenance actions performed on the condenser and chiller are cleaning the tubes or shells, or both; and plugging or replacing leaking tubes.
- Ship's force is capable of brush-cleaning fouled condensers and chillers; however, acid cleaning requires IMA or depot assistance.
- While ship's force is capable of plugging tube leaks, most chiller and condenser repairs are performed with IMA or depot assistance.
- A large proportion of the condensers have been retubed during ROH, while few chillers have been retubed.
- The need for chiller and condenser cleaning and retubing can be determined by temperature-gauge readings that indicate chiller/ condenser efficiency and by leak testing.

3.2.1.3 Chilled Water Distribution System

The primary equipments of the chilled water distribution system are the chilled water pumps, motors, and motor controllers. The chilled water pumps take suction from the air conditioning unit outlets and discharge chilled water to the supply headers of the chilled water loops. The motor-driven circulating pumps have local motor controllers with ON/OFF pushbutton controls. The chilled water is circulated through cooling coils and heat exchangers that are connected through piping branches to the chilled water circulating loops. There is one chilled water distribution pump associated with each A/C plant.

Average reported annual combined ship's force and IMA man-hour burdens per pump unit (including pump, motor, and controller) are shown in Table 3-1. Table B-2 shows the chilled water distribution system configuration by APL. The MDS data indicated that approximately 52 percent of all maintenance actions reported against the pump units were reported against the pumps, 34 percent against the motors, and 14 percent against the controllers. The reported IMA man-hours were evenly divided between the pump and motor; none were reported against the controllers. Significant part-usage information reported against the pumps and motors is presented in Appendix D (Table D-2). That information includes all parts ordered on at least two JCNs. The pump, motor, and controller are discussed individually in the following paragraphs.

Chilled Water Pump

The chilled water pumps of the LPH-2 and LHA-1 Classes vary in capacity from 180 to 1550 GPM, as shown in Appendix B (Table B-2). The chilled water pumps of the LHAs, the LPH-11, and the LPH-12, as well as the new pump being added by Shipalt LPH-255K to the LPH-2, -3, -7, and -9, are all coupled to their drive motors through flexible couplings. All others are close-coupled.

Review of the MDS part requisition data summarized in Appendix D (Table D-2) indicates that two pumps on the LPH-2 Class ships (APLs 016110129 and 016110441) and the LHA-1 Class chilled water pump (APL 017030310) had repetitive requisitions for the same parts. The parts identified as having relatively large numbers of replacements were bearings and wearing rings; however, the individual demand frequencies for those parts were low. Ship's force is usually capable of replacing those parts. MDS narrative review revealed that while IMAs have provided occasional assistance in the overhauls of chilled water pumps, ship's force is capable of most repairs, including major overhaul. The data indicate that many of the chilled water pumps have operated virtually trouble-free during the operating cycles.

A review of the available SARPs, summarized in Table 3-9, indicated that 44 of 47 chilled water pumps were authorized for class B overhauls. As in the case of the A/C plant compressors, the justification for the need for class B overhaul was frequently questionable. For example, the MCAs for the LPH-2 and LPH-3 did not support the need for class B overhaul of 12 of the 14 pumps. Referenced JCNs indicated frequently that a pump required only repacking or possibly bearing replacement -- repair actions that are within the ship's force capabilities.

Table 3-9. CLASS B SUMMARIES (FROM SARPs) FOR CHILLED WATER PUMPS

Ship	ROH Date	Pumps Receiving Class B Overhaul
LPH-2	FY 81	7 of 7
LPH-3	FY 82	8 of 8
LPH-7	FY 79	6 of 6
LPH-9	FY 80	6 of 6
LPH-10	FY 80	6 of 6
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	1 of 4
LHA-2	FY 82	4 of 4
Total		44 of 47

One CASREP (of C-2 severity) was submitted against chilled water pumps. That CASREP resulted from failure of the thrust bearing.

PMS requirements for the chilled water pumps consist of inspecting the pump packing/mechanical seals, foundation bolts/fasteners, flexible coupling and internal parts, and lubricating moving parts.

The following conclusions resulted from analysis of the chilled water pump maintenance history:

- The most frequent failure modes experienced by the chilled water pumps were associated with replacements of bearings and wearing rings.
- Ship's force is capable of repairing chilled water pumps, including major overhaul.

- Chilled water pump failures have rarely affected the ship's ability to perform its mission, as demonstrated by the fact that only one CASREP was identified as resulting from failure of a chilled water pump, and that was of C-2 severity.
- Current chilled water pump maintenance strategy is to perform PMS and routinely overhaul at ROH. Justification for routine overhaul of the pumps was questionable.

Chilled Water Pump Motors

The air conditioning chilled water pump motors of the LPH-2 and LHA-1 Classes vary in horsepower rating from 15 to 150, as shown in Appendix B (Table B-2). All the motors operate on 3-phase 440 V 60 Hz power and rotate at either 1,750 or 3,500 rpm (approximately).

Review of the MDS narrative transactions and part data revealed, as expected, the same two repetitive failure modes experienced by the compressor motors: bearing failure and stator winding failure. Eight CASREPs (C-2 severity) were issued against the chilled water pump motors. Four of the identified CASREPs were attributed to bearing failures, which in some instances caused subsequent overheating and shorting of the motor windings. Appendix D (Table D-2) indicates that the interval between demands during the operating cycle for the most frequently replaced bearings ranged from about 4 to about 35 ship operating years. Thus it can be concluded that the need for bearing replacement varies from ship to ship, and even between different motors on the same ship. MDS data suggest that bearing replacement is within ship's force capability. Review of the applicable APLs indicates that the on-board allowances for the bearings are adequate to support the demand rates. Consequently, bearing replacement is not considered a major problem.

Two of the CASREPs initiated against chilled water pump motors were attributed directly to stator winding failure. The most frequently identified need for outside assistance for motor work was associated with cleaning, rewinding, dipping, and baking the motor -- an action that is within ship's force capabilities, at least for the smaller motors (up to about 25 horsepower). Like the occurrence of bearing replacement, the occurrence of motor rewinds on the chilled water pump motors varied widely between ships and between identical pumps on the same ship. The need for motor rewinds can generally be determined prior to catastrophic failure by means of PMS checks.

The PMS requirements for the chilled water pump motors are the same general requirements as for all ac motors: clean and inspect, lubricate, and check insulation resistance.

Review of the available SARPs, summarized in Table 3-10, indicates that 45 of 47 chilled water pump motors were authorized for class B overhaul during the overhauls for which the SARPs were applicable. MCA comments on LPH-2 and LPH-3 did not support overhaul of 13 of the 14 motors. Referenced JCNs also frequently supported repairs to only one motor, rather than all

Table 3-10. CLASS B SUMMARIES (FROM SARPs) FOR CHILLED WATER PUMP MOTORS		
Ship	ROH Date	Motors Receiving Class B Overhaul
LPH-2	FY 81	7 of 7
LPH-3	FY 82	8 of 8
LPH-7	FY 79	6 of 6
LPH-9	FY 80	6 of 6
LPH-10	FY 80	6 of 6
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	2 of 4
LHA-2	FY 82	4 of 4
Total		45 of 47

motors as indicated in the SARP. Frequently, the referenced JCN indicated only the need for bearing replacement. It is concluded that the current maintenance strategy for the chilled water pump motors includes routine overhaul at ROH.

The following conclusions resulted from analysis of the chilled water pump motor maintenance history:

- The most frequent failure modes experienced by the chilled water pump motors were bearing failure and stator winding failure.
- Bearing replacement is within ship's force capability. Motor rewinding of the smaller motors is within ship's force capability, while the larger motors usually require IMA assistance.
- Chilled water pump motor failures have resulted in 8 CASREPs of severity C-2 over the approximate 63 ship operating years, indicating that motor failures have rarely affected the ship's ability to perform its mission.
- The current chilled water pump motor maintenance strategy is to perform PMS with routine overhaul at ROH.

Chilled Water Pump Motor Controller

The motor controllers provide the means for starting and stopping the chilled water circulation pumps. Configuration information, by ship, is provided in Appendix B.

Review of MDS and CASREP data revealed that chilled water pump motor controllers represent generally minor maintenance burdens; for many of the controllers no maintenance actions were reported during the data period. The only maintenance actions reported against controllers were ship's force cleaning. No IMA man-hours were reported against the controllers. Review of the MDS part data summaries showed no significant repetitive part usage.

No CASREPs were reported against the chilled water pump motor controllers. The results of the review of available SARPs is summarized in Table 3-11, which shows that 36 of 47 chilled water motor controllers were authorized for class B overhaul. Referenced JCNs did not substantiate the need for overhaul. None of the eight authorized controller overhauls for the LPH-3 were supported by the MCA. Referenced JCNs in some cases indicated that the CSMP was derived strictly from the baseline SARP.

Table 3-11. CLASS B SUMMARIES (FROM SARPs) FOR CHILLED WATER PUMP MOTOR CONTROLLERS

Ship	ROH Date	Controllers Receiving Class B Overhaul
LPH-2	FY 81	1 of 7
LPH-3	FY 82	8 of 8
LPH-7	FY 79	6 of 6
LPH-9	FY 80	4 of 6
LPH-10	FY 80	6 of 6
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	4 of 4
LHA-2	FY 82	1 of 4
Total		36 of 47

The following conclusions resulted from analysis of the available maintenance data on the chilled water pump motor controllers:

- Chilled water pump motor controller maintenance consists of minor routine-type repairs within ship's force capability.

- Chilled water pump motor controller performance has historically been reliable, as evidenced by the fact that for many of the controllers no maintenance actions were reported during the data period and no CASREPs were submitted.
- A high percentage of the motor controllers appear to be receiving routine overhaul at ROH.

3.2.1.4 Salt Water Circulating System

The primary equipments of the salt water circulating system include the salt water circulating pumps, motors, and controllers. The salt water circulating pumps take suction from seachests and discharge the sea water to the inlets of the air conditioning plant condenser units in order to remove heat from the primary refrigerants circulating through the condensers. The discharge lines of the salt water circulating pumps are cross-connected with the firemain so that the firemain can provide the sea water for the condensers in the event of failure of the salt water circulating pump.

Average reported annual combined ship's force and IMA man-hour burdens per pump unit (including pump, motor, and controller) are shown in Table 3-1. The salt water circulating system configuration by APL is presented in Appendix B (Table B-3). Review of the MDS data indicated that approximately 74 percent of all maintenance actions reported against the pump units were reported against the pumps, 22 percent against the motors, and 4 percent against the controllers. Approximately 73 percent of the IMA man-hours were expended on pump repairs, with the remaining man-hours reported against the motors. Pertinent parts usage information reported against the salt water circulating system is presented in Appendix D (Table D-3). Two CASREPs were submitted for the salt water circulating systems during the data period analyzed. The pump, motor, and controller are discussed individually in the following paragraphs.

Salt Water Circulating Pumps

The salt water circulating pumps of the LPH-2 and LHA-1 Classes vary in capacity from 110 to 1,500 GPM, as shown in Appendix B. Those of the LPH-11, LPH-12, and LHA-1 Class ships are coupled to their drive motors by flexible couplings. All others are close-coupled. Review of the MDS part requisition data summarized in Appendix D (Table D-3) revealed that of the 15 different APLs applicable to the pumps of the LPH-2 and LHA-1 Classes, 8 APLs had requisitions for the same parts on more than one JCN. The parts identified with relatively high replacement rates were bearings, wearing rings, and shaft sleeves. As in the case of the chilled water pumps, the data indicated that ship's force is usually capable of most repairs, including major overhaul. Occasional assistance has been requested from IMAs for such work as straightening bent pump shafts.

One CASREP (C-2) was initiated against the salt water circulating pumps. Since the salt water circulating system is backed up by the ship's firemain, few CASREPs result from salt water circulating pump failures.

Review of the available SARPs, summarized in Table 3-12, indicated that 33 of 36 salt water circulating pumps were authorized for class B overhaul. The need for overhaul usually could not be substantiated from the referenced JCNs. The referenced JCN in some cases revealed CSMP entries for class B overhaul that were based on the fact that the baseline SARP authorized the overhaul as a routine item. MCA comments for the LPH-3, on which all six pumps were authorized for class B overhaul, supported only the overhaul for pump number 5. Other referenced JCNs indicated only that bearings were noisy or wearing rings required replacement -- repair needs that are within ship's force capability.

Table 3-12. CLASS B SUMMARIES (FROM SARPs) FOR SALT WATER CIRCULATING PUMPS

Ship	ROH Date	Pumps Receiving Class B Overhaul
LPH-2	FY 81	5 of 5
LPH-3	FY 82	6 of 6
LPH-7	FY 79	3 of 4
LPH-9	FY 80	3 of 4
LPH-10	FY 80	3 of 3
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	3 of 4
LHA-2	FY 82	4 of 4
Total		33 of 36

PMS requirements for salt water pumps are essentially the same as for the chilled water pumps: inspect pump packing/mechanical seals, foundation bolts and fasteners, flexible couplings, and internal parts; and lubricate moving parts.

The conclusions drawn from analysis of the salt water circulating pump maintenance history are the same as those for the chilled water pump (see Section 3.2.1.3).

Salt Water Circulating Pump Motor and Motor Controller

The salt water circulating pump motors of the LPH-2 and LHA-1 Classes vary in horsepower rating from 7.5 to 100, as shown in Appendix B. All of the motors operate on 3-phase 440 V 60 Hz power and rotate at either 1,750 or 3,500 rpm (approximately).

The maintenance history analysis revealed the same repetitive types of repairs found on the motors and controllers of the compressors and chilled water pumps. As in the case of the other motors and controllers, there were no identified problems with part support; repair requirements for individual motors varied from ship to ship and between installations within the same ship; there were no identified CASREPs caused by salt water circulating pump motor or controller failures; and most repairs were within ship's force capability, with the exception of motor rewinds and overhaul of the larger motors (over approximately 25 horsepower).

Review of available SARPs, summarized in Tables 3-13 and 3-14, indicated that 31 of 36 salt water circulating pump motors and 29 of 36 controllers were authorized for class B overhauls. There was a lack of substantiating evidence for the need for overhaul.

Table 3-13. CLASS B SUMMARIES (FROM SARPs) FOR SALT WATER CIRCULATING PUMP MOTORS

Ship	ROH Date	Motors Receiving Class B Overhaul
LPH-2	FY 81	4 of 5
LPH-3	FY 82	6 of 6
LPH-7	FY 79	3 of 4
LPH-9	FY 80	2 of 4
LPH-10	FY 80	3 of 3
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	3 of 4
LHA-2	FY 82	4 of 4
Total		31 of 36

Table 3-14. CLASS B SUMMARIES (FROM SARPs) FOR SALT WATER CIRCULATING PUMP MOTOR CONTROLLERS

Ship	ROH Date	Motors Receiving Class B Overhaul
LPH-2	FY 81	4 of 5
LPH-3	FY 82	6 of 6
LPH-4	FY 79	3 of 4
LPH-9	FY 80	2 of 4
LPH-10	FY 80	3 of 3
LPH-11	FY 80	3 of 3
LPH-12	FY 80	3 of 3
LHA-1	FY 81	4 of 4
LHA-2	FY 82	4 of 4
Total		29 of 36

The conclusions drawn from analysis of the salt water circulating pump motor maintenance history are the same as those for the chilled water pump motor (see Section 3.2.1.3).

3.2.2 Ventilation and Heating

The forced air ventilation system comprises supply, exhaust, and recirculating fans that are motor-driven and are both remotely and locally controlled. Essentially, the supply fans take fresh air from weather deck inlets and distribute the air through ducts to the ship's compartments and spaces. The exhaust fans remove stale and contaminated air from the ship. The recirculating fan systems take air from a compartment, filter and condition it with heat or cold as required to maintain the desired temperature in the compartment, and return the conditioned air to the compartment. Replenishment air for recirculating systems is obtained from a supply fan system that discharges air toward the recirculating air intake. Electrostatic precipitators furnish additional clean-air protection to the spaces that contain critical electronic equipment and are supplied with recirculated air.

In spaces furnished with mechanical ventilation, heating is accomplished by duct-mounted steam heaters (preheaters and reheaters) or by electrical duct heaters. Spaces that are not furnished with mechanical ventilation and require heating have unit steam heaters that rely on convection air flow across the heating coils. In addition, spaces that have only a ventilation exhaust system are furnished with electrical radiant space heaters to increase their temperature levels.

There are enormous quanities of heating and ventilation equipments and significant differences in configuration between the ships under analysis. In addition, initial review of the MDS data reported against the heating and ventilation system equipments revealed that more than half of the reported maintenance actions and more than half of the ship's force and IMA man-hours were reported against APLs that were "not listed" or "unknown." For these reasons, it was not considered appropriate to present (in Appendix B) an APL configuration by hull for the heating and ventilation equipments.

The narrative transactions on heating system equipments under APLs "not listed" or "unknown" included primarily relagging of piping and ducting, repairs to steam piping and valves, repairs to unit heaters, repairs or replacement of thermostats, and repairs to preheaters and reheaters. The transactions on ventilation system equipments under APLs "not listed" or "unknown" included primarily replacement of corroded or broken vent screens, repairs to ventilation system ducting, repairs to ventilation motors and motor controllers, cleaning of ventilation ducting, and replacement of lagging. Of the equipments for which maintenance was reported by APL, only one type of equipment was determined to be a significant contributor to the ventilation and heating system corrective maintenance burden: the electric motors that drive ventilation fans. These motors accounted for approximately 73 percent of ship's force man-hours and 83 percent of the IMA man-hours reported against ventilation system equipments in maintenance actions in which APLs were identified.

Review of MDS narratives revealed that the same types of recurring motor maintenance actions were experienced across both classes. Two significant failure symptoms were repeatedly reported: excessive noise and vibration, and burned stator windings. Excessive noise and vibration are normally indicative of worn bearings or an unbalanced rotor. Motor bearings are routinely replaced by ship's force, and spare parts are normally on board. However, IMA assistance is usually required for motor balancing. Burned stator windings were the result of excessive moisture in the space, seized bearings, or normal deterioration. The MDS data indicate that in some cases the motor rewinds were accomplished by ship's force and that in other cases IMA assistance was required.

A review of parts summaries showed that motor bearings were the only frequently ordered parts. In addition to being replaced to reduce noise and vibration, bearings were routinely replaced as a matter of convenience in conjunction with repairs requiring that the motor be opened (including rotor balancing and rewind). Review of the individual APLs indicated that the current on-board bearing allowances, as specified in the applicable APLs, are sufficient to support the replacement rates experienced, and no part-related problems were noted.

During the data period four ships of the LPH-2 Class and two ships of the LHA-1 Class submitted five CASREPs and two CASREPs, respectively, for ventilation fan motors. Six of the CASREPs were submitted for burned windings, and one was submitted for a worn bearing housing. All seven CASREPs were of severity C-2.

Planned maintenance requirements for ventilation fan motors specify that motors be cleaned and inspected only when they are removed for corrective maintenance and that idle motors (those not operated in the past 30 days) be operated monthly.

Review of the work listed in available SARPs for the heating systems (SWAB 511) revealed that work accomplished during ROH has historically consisted of miscellaneous repairs to various heaters, preheaters, and reheaters, and repair or replacement of thermostatic valves and thermostats. Estimated repair expenditures ranged from 17 man-days to 154 man-days. Itemized work for the ventilation system for nonmachinery spaces consisted primarily of class B overhauls or class C repairs to ventilation system fans, motors, and motor controllers; and repair or replacement of vent screens, ventilation ducting, and insulation. Estimated labor expenditures ranged from 54 man-days to 1,302 man-days. Itemized work for the ventilation system for machinery spaces consisted primarily of class B overhauls to selected ventilation system fans, motors, and motor controllers. Authorized man-day expenditures ranged from none on two ships to 511 man-days. There was no identified work that was preauthorized, as in the case of the air conditioning systems -- that is, the heating and ventilation systems currently are maintained with an on-condition maintenance strategy.

The following conclusions resulted from analysis of available maintenance data on heating and ventilation system equipments:

- Most of the ship's force and IMA maintenance burden is centered on general system repairs to many different equipments throughout the system; repairs to heaters, preheaters, and reheaters; replacement of corroded or broken vent screens; repairs to vent motors; and repair or replacement of ducting and lagging.
- Ship's force is capable of most heating and ventilation system repairs.
- Heating and ventilation system failures have rarely affected a ship's capability to perform its missions, as indicated by the fact that only seven CASREPs, all of severity C-2, were initiated against heating and ventilation system equipments during the data period analyzed.
- Most depot-level repair work was the same type of work as that accomplished by ship's force and IMAs.

- The current maintenance strategy for the heating and ventilation equipments is one of on-condition maintenance, in which repairs needed during the operating cycle are made by ship's force with occasional IMA assistance. CSMP and POT&I deficiencies are corrected during ROH by ship's force, with the assistance of IMAs and shipyards as necessary.

3.2.3 Corrosion Control

During review of the MDS data and available SARPs, a number of corrosion problems were cited for ventilation system vent screens and fasteners and ducting, and for air conditioning system machinery foundations. The burden placed on ship's force personnel in correcting corrosion-related problems can be substantial. Appendix E presents a listing of NAVSEA-approved corrosion-control systems applicable to these problems, as well as descriptions of tasks recommended for accomplishment during maintenance availabilities as the problems are identified.

3.3 RECOMMENDED MAINTENANCE STRATEGY

In Section 3.2, the maintenance histories and current maintenance strategies applicable to the air conditioning, heating, and ventilation systems of the LPH-2 and LHA-1 Classes were analyzed. Basically, it was found that during the ship's operating cycle, the air conditioning systems are being maintained according to an on-condition maintenance strategy. However, the available data suggest that there is a trend toward performing routine overhauls of the air conditioning system equipments during ROH. The evidence for such a trend comes from several observations: (1) the review of referenced JCNs in the available SARPs frequently indicated that only minor repairs were necessary to correct existing deficiencies; and (2) MCA comments frequently discounted the need for class B overhaul of equipments authorized for overhaul. It appeared that the listing of a task in the baseline SARP was becoming the sole justification for accomplishment of the task.

There is no question that the air conditioning system equipment overhauls have resulted in very high man-day and dollar expenditures during ROH. In the performance of class B overhaul-type work (not counting specific class C repair work) the man-day expenditures for the air conditioning system equipments ranged from 477 man-days to 4,989 man-days in the LPH-2 Class and from 1,008 to 1,902 man-days in the LHA-1 Class, with averages of 1,724 man-days for the LPH-2 Class and 1,455 man-days for the LHA-1 Class. With man-day costs in the order of $300 per day, overhaul costs of air conditioning plants are averaging between $450,000 and $500,000 at ROH, again not counting specific class C type repairs. Unfortunately, it is difficult to determine from the available data which (if any) equipments have been overhauled at ROH without actually needing it. However, the available data suggest that this has happended in many cases.

During the review of the maintenance histories of the air conditioning, heating, and ventilation systems, it was found that ship's force is capable of most repairs to system equipments, including major overhaul. However, it is generally accepted that the A Division on these classes of ships is pressed for manpower, and it is not the intent of this report to recommend the transfer of overhaul-type work, which appears to be becoming routine at every ROH, from the shipyard to the ship's force/IMA level. Overhaul of major equipments of the air conditioning systems, particularly the large-capacity compressors and pumps, to class B standards should be accomplished in an industrial environment. During ship visits, ship's force frequently criticized the quality of equipment overhauls performed by shipyards; they can help ensure high-quality overhaul by assigning personnel to maintain close contact with the shipyard repair shops, keep track of repair progress and repair quality, and closely observe post-overhaul performance tests.

In the development of the maintenance strategy for the air conditioning equipments, the following factors must be considered:

- Routine overhaul of a properly operating air conditioning plant can lead to refrigerant-loop contamination and can expose the compressor internal components to corrosion and subsequent accelerated wear.
- The primary failure modes of the compressors and chilled water and salt water circulating pumps (failure of shaft seals, bearings, and wearing rings) occur infrequently, are within ship's force capability to correct, and occur at an unpredictable rate that varies from one equipment to the next.
- Gaining access to equipments to remove them frequently involves significant plumbing work on freon, chilled water, and salt water systems, and can introduce problems where none existed previously.
- Many of the catastrophic equipment failures identified have been attributed to operator error, poor maintenance, or outside causes (e.g., motor shorted by leaking plumbing) -- events that are unrelated to the time of the most recent equipment overhaul.
- Man-day expenditures for routine overhauls are high. It has not been demonstrated that overhaul results in improved equipment reliability.
- The need for repairs can usually be assessed prior to equipment failure by inspections or performance monitoring.

In the light of these factors, it is recommended than an on-condition maintenance strategy be adopted for the equipments of the air conditioning systems. Essentially, this strategy is now being employed in the maintenance of the heating and ventilation systems; that is, repairs are being made as determined to be necessary on the basis of CSMP and material inspections, including POT&I, MCA, and INSURV.

If an on-condition maintenance strategy is employed, it is anticipated that most repairs during an operating cycle will be accomplished by ship's force with occasional assistance at the IMA and depot. It is also anticipated that over an extended period of time, an accumulation of repairs will result in an eventual need for overhaul to class B standards to assure the retention of tolerances between wearing parts. Consequently, for the purposes of overhaul planning, it is estimated that the motor-driven equipment of the air conditioning systems, including the compressors and the chilled water and salt water circulating pumps and their drivers, will require overhaul at 10-year intervals. In effect, the recommendation is to extend the overhaul cycle of these equipments from 5 years to 10 years. There is little risk in doubling the time between overhauls, for several reasons. Only in the most extreme operating conditions does the loss of an air conditioning plant (or chilled water pump) adversely affect cooling requirements. Even then, the systems are cross-connected in such a way that the loss of one or more plants results in a system realignment so that air conditioning is still provided to vital spaces. Salt water circulating pumps are backed up by connections to the ship's firemain. Consequently, as observed in the limited number of CASREPs on air conditioning system equipments, failures rarely have an immediate impact on total ship air conditioning requirements.

The following actions are recommended as a result of this analysis:

- Include engineered tasks in the LPH-2 and LHA-1 Class CMPS for a depot facility to accomplish class B overhaul of the air conditioning compressor and the chilled water and salt water circulating pumps, and their drivers and controllers, every 10 years. It is recommended that pumps and their drivers and controllers be overhauled as a unit and that a post-overhaul shore-based demonstration test be conducted on the units before they are reinstalled. The following man-hour estimates, based on typical SARP estimates, are provided for these tasks:

  - Compressor - 75 man-days
  - Compressor motor - 20 man-days
  - Chilled water pumps (including motors) - 45 man-days
  - Salt water pumps (including motors) - 45 man-days

  In conjunction with overhaul of the compressors, it is recommended that the shipyard clean and flush, pressure-test, correct any defects in, and recharge the refrigerant side of the system and conduct an operational test of the air conditioning plant. An estimated 100 man-days per plant should be reserved for this task at the 10-year point.

- The analysis revealed that a large proportion of the condensers are being routinely overhauled at ROH even though there are very few MDS data entries for condenser repairs. Some of the applicable PMS requirements to clean and inspect the condenser schedule the inspection at 36 months or as a conditional requirement based on the monitoring of condenser efficiency. Other PMS requirements make the inspection a situational requirement only, based on the efficiency monitoring. It is recommended that this task be accomplished on all condensers every 36 months and that 100 IMA man-hours be reserved for acid cleaning or replacement of leaking tubes that inspection may show to be necessary. The man-hour estimate is based on typical MDS data entries for similar tasks.

- In maintaining the air conditioning, heating, and ventilation systems according to an on-condition maintenance strategy, man-hours should be reserved for class C repairs to equipments (including valves, plumbing, and ventilation ducting) at depot-level ROH. For this purpose, a man-hour estimate was computed from available SARP data. Since there was no apparent correlation between man-day expenditures and ship class, the estimates apply to both the LPH-2 and LHA-1 Classes. The estimates, by SWAB, are as follows:

SWAB No.	Title	Man-Day Estimate
511-1	Compartment Heating	60
512-1	Ventilation System, Nonmachinery Propulsion Spaces	300
513-1	Ventilation System, Machinery Space	150
514-1	Water, Chilled, Cooling, Distribution	110
514-2	Air Conditioning Plants	400

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions resulted from this analysis:

- Review of part replacement rates, historical man-hour burdens, and CASREPs indicates that the air conditioning system equipments, including compressors and pumps and their associated drivers, are reliable equipments.
- Given adequate time and replacement parts, ship's force is capable of most air conditioning system repairs, including major overhaul.
- Wearout of system components, including compressors and pumps and their associated drivers, is primarily a function of ship operations and the care with which the system is maintained. Consequently, equipment wearout varies from ship to ship, and even between installations within the same ship, and therefore cannot be accurately predicted.
- Catastrophic failure of an air conditioning plant does not normally result in degraded air conditioning output, since in most operating environments not all of the air conditioning plants are required to be on line to meet full cooling requirements.
- The most frequent failure modes associated with the motors of the compressors and chilled water and salt water circulating pumps were bearing failure and stator winding failure. Bearing replacement is within ship's force capability, while repair of failed stator windings for motors larger than about 25 horsepower frequently requires IMA assistance in rewinding, dipping, and baking the motors. Both failure modes can usually be prevented by monitoring noise and vibration levels and by performing PMS checks.
- Routine overhaul of properly operating equipment is not recommended, since it has been demonstrated that overhaul is no guarantee against subsequent failure.
- The current maintenance strategy for the air conditioning system equipments is to perform PMS and routinely overhaul at the time of ship ROH.

- Most depot-level repair work associated with the heating and ventilation systems is similar to the work normally performed by ship's force and IMAs and consists of general system repairs to many different equipments throughout the system: repairs to heaters, preheaters, and reheaters; replacement of corroded or broken vent screens; repairs to various ventilation motors; and repair or replacement of ducting and lagging.
- Current maintenance strategy for the heating and ventilation system equipments is one of on-condition maintenance, whereby repairs needed during the operating cycle are made by ship's force, with occasional IMA assistance, and CSMP and POT&I deficiencies are corrected during ROH by ship's force, with IMA and shipyard assistance as necessary.

4.2 RECOMMENDATIONS

Recommendations for scheduled corrective and restorative maintenance actions that are to be accomplished by depots or IMAs are summarized in Table 4-1. These recommended maintenance requirements should be incorporated in the LHA-1 Class and LPH-2 Class CMPs. The types of maintenance tasks are as follows:

- E Tasks - Engineered work items that should be carefully considered for accomplishment at the proposed frequency to enable the ship to fulfill its mission. The tasks result from either a long history of experience in system operation or a System Engineering Analysis. The E tasks are generally limited to the ship's critical systems.
- R Tasks - Routine work items accomplished whenever the opportunity is presented (such as drydock work) or for repetitive efforts to support industrial work such as staging, temporary services, and technical support.
- M Tasks - Mandatory work items accomplished to comply with NAVSEA and Type Commander instructions.
- I Tasks - Inspections performed to comply with NAVSEA or Type Commander instructions.
- T Tasks - Tests or inspections performed during one maintenance availability in order to define maintenance requirements for a subsequent availability. T tasks may also include certain tests and inspections to be performed during the operational period before the beginning of a scheduled maintenance availability.
- Q Tasks - Qualified estimates. These consist of all maintenance actions to be performed on condition; they represent a reservation for manpower and are generally related to the accomplishment of corrective maintenance.

Table 4-1. RECOMMENDED DEPOT AND IMA CORRECTIVE AND RESTORATIVE ACTIONS

Task Number			Component or System	Quantity per Ship	Task Description	Level of Repair	Repair Estimate (Man-Days)	Task Frequency* (Months)	Reference Section
Task Type	SWAB	Number							
Q	511-1	1	Heating System	--	Accomplish class C repairs to the heating system as determined to be necessary by POT&I and CSMP.	D	60 per ship	60	3.2.2 3.3
Q	512-1	1	Ventilation System	--	Accomplish class C repairs to non-machinery space ventilation system as determined to be necessary by POT&I and CSMP.	D	300 per ship	60	3.2.2 3.3
Q	513-1	1	Ventilation System	--	Accomplish class C repairs to machinery space ventilation system as determined to be necessary by POT&I and CSMP.	D	150 per ship	60	3.2.2 3.3
E	514-1	1	Air Conditioning, Chilled Water Cooling Distribution	LPH: varies from 3 to 8 LHA: 4	Accomplish class B overhaul of the chilled water pumps, motors, and controllers.	D	45 per unit	120	3.2.1.3 3.3
Q	514-1	1	Air Conditioning, Chilled Water Cooling Distribution	LPH: varies from 3 to 8 LHA: 4	Accomplish class C repairs to the chilled water distribution system, including repair and calibration of gauges, thermometers, and valves, as determined to be necessary by POT&I and CSMP.	D	110 per ship	60	3.2.1.3 3.3
E	514-2	1	Air Conditioning Plants	LPH: varies from 3 to 8 LHA: 4	Accomplish class B overhaul of the air conditioning plant compressors.	D	75 per unit	120	3.2.1.2 3.3
E	514-2	2	Air Conditioning Plants	LPH: varies from 3 to 8 LHA: 4	Accomplish class B overhaul of the air conditioning plant compressor motors.	D	20 per unit	120	3.2.1.2 3.3
E	514-2	3	Air Conditioning Plants	LPH: varies from 3 to 6 LHA: 4	Accomplish class B overhaul of the air conditioning plant salt water circulating pumps, motors, and controllers.	D	45 per unit	120	3.2.1.4 3.3
E	514-2	4	Air Conditioning Plants	LPH: varies from 3 to 8 LHA: 4	Clean and flush, pressure test, correct defects as necessary, and recharge the refrigerant side of the air conditioning plants.	D	100 per system	120	3.2.1.2 3.3
Q	514-2	1	Air Conditioning Plants	LPH: varies from 3 to 8 LHA: 4	Accomplish class C repairs to the air conditioning plants as determined to be necessary by POT&I and CSMP.	D	400 per ship	60	3.2.1.2 3.3
Q	514-2	2	Air Conditioning Plants	LPH: varies from 3 to 8 LHA: 4	Accomplish class C repairs and/or cleaning of air conditioning plant condensers on the basis of PMS inspection.	I	12 per unit	36	3.2.1.2 3.3

*See Section 4.2 for definition of task frequency for specific task types.

Other improvements to the air conditioning, heating, and ventilation system equipments are categorized as follows:

- Design Improvements
  - Recommended shipalts, ordalts, and field changes
  - Recommended equipment redesign or replacement
- Maintenance Strategy Improvements
  - PMS changes
  - Policy
- Support Improvements
  - ILS improvements
  - Maintenance-capability improvements
- Other

These recommended improvements are summarized in Table 4-2.

Table 4-2. RECOMMENDED IMPROVEMENTS

Component	No.	Recommendation	Reference Section
		Maintenance Strategy Improvements	
Air Conditioning System	1	Maintain all equipments with an on-condition maintenance strategy. Anticipate need for class B overhaul of major equipments (compressors, pumps, and drivers) at 120 months.	3.3
Condenser		Adopt 36-month inspection of the sea water side of the condenser for all plants.	3.3
		Support Improvements	
Compressors	2	Ensure that on-board allowances of compressor internal components are met.	3.2.1.2

APPENDIX A

SYSTEM BOUNDARIES FOR AIR CONDITIONING,
HEATING, AND VENTILATION SYSTEMS
INSTALLED ON LPH-2 AND LHA-1 CLASS SHIPS

This appendix comprises portions of the SWAB description pages excerpted from a copy of Ship Work Authorization Boundaries for Surface Ships, NAVSEA 0909-LP-098-6100, dated March 1981. It defines the boundaries of the air conditioning, heating, and ventilation system and was used as a primary reference source in establishing the system boundaries for this analysis.

The major components subjected to analysis in this report are listed below within their respective SWAB groups:

SWAB 511-1:

SWLIN 51111 Title: Heating System

Includes authorized work for:

Piping, valves, traps, thermo controls, heater units in all compartments of ship.

Associated Equipment:

Controllers	Regulators
Convection heaters	Solenoid valves
Foundations	Steam traps and strainer (comb)
Hangers	Switches
Motorized valves	Thermostats
Piping	Unit heaters
Radiant heaters	

SWAB 512-1:

SWLIN 51211 Title: Ventilation System, Nonmachinery Propulsion System

Includes authorized work for:

Ventilation systems serving outside of machinery propulsion spaces, to include sick bay and isolation wards. Provides for surveys, repairs, and balancing as authorized by customer.

Associated Equipment:

Controllers	Insulation
Cooling coils	Magnehelic gauges
Dehumidifiers	Motors
Dehydrators	Operating gear
Ducts and Fittings	Plenums
Fans	Shutters
Filters	Switches
Flame arrestors	Vent heaters
Grease interceptors	Vent valves
Hangers	

SWAB 513-1

SWLIN 51311 Title: Ventilation System, Machinery Space

Includes authorized work for:

Ventilation system in machinery spaces. Provides for surveys, repairs, and balancing as authorized by customer.

Associated Equipment:

Cooling coils	Foundations
Controllers	Heaters
Dampers	Insulation on ducts
Drain piping	Motors
Ducts and fittings	Operating gear
Fans	Switches
Filters	Valves

SWAB 514-1

SWLIN 51411 Title: Water, Chilled, Cooling Distribution

Includes authorized work for:

Ship's chilled water piping systems, valves, circulating pumps.

Associated Equipment:

Controllers	Pumps
Expansion tank	Pressure gauges
Filter	Solenoids
Flow gauges	Strainer
Foundations	Temperature regulators
Insulated hangers	Unit coolers
Operating gear	Valves

SWAB 514-2

SWLIN 51421 Title: Chilled Water Air Conditioning Plants

Includes authorized work for:

Unitary refrigeration for ship air conditioning system cooling. The cycle from coolant liquid receiver to expansion cycle to heat evaporation cycle to compression cycle to condenser cycle. Provides for removal, repairs, installation, and testing.

A/C Plant Unitary Types:

R-12 Chilled water
R-22 Direct expansion
R-114 Chilled water
Lithium bromide absorption type
Steam jet - vacuum - chilled water
Air-cycle type

Associated Equipment:

Chillers	Meters, flow rate
Compressors	Reducers
Condenser	Salt water cooling piping
Controllers	Salt water pumps
Dehydrators	Solenoids
Fans	Strainers
Filters	Switches
Foundations	Traps
Freon piping	Water regulating valves
Gauges	Valves
Motors	

SWAB 514-3

SWLIN 51431 Title: Air Conditioning Units, Self-Contained

Includes authorized work for:

Mechanical cooling self-contained air conditioners.

Associated Equipment:

Compressors	Motors
Ducts associated with self-contained A/C unit	Resilient mounts
	Salt water cooling
Fans	Solenoids
Foundations	Switches
Gauges	Thermometers
Heat exchangers	Valves

APPRNDIX B

INSTALLATION CONFIGURATION OF AIR CONDITIONING SYSTEM EQUIPMENTS FOR LPH-2 AND LHA-1 CLASS SHIPS

The air conditioning systems discussed in this report are composed principally of the components listed in Tables B-1, B-2, and B-3. The table provides detailed information regarding the individual component nomenclature, APL number, hull applicability, and number of components installed on each hull. In some instances it appears from the table that particular key components are not installed on some of the ships. In those instances, one of the following conditions exists:

- The component has no separate APL.
- The component is not listed in the applicable type commander's COSAL and no data were reported in MDS or CASREP data for the component.

Table B-1. COMPONENTS OF THE AIR CONDITIONING PLANTS

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Refrigeration Plant Air Conditioning Cap. 85-ton	325000245										6		
Condensor Rfg. Wtr. Cld., Cap. 380 GPM 655 Sq. Ft.	043010170										6		
Compressor Rfg. Vert Opn.	060150120										6		
Starter Motor Mag LVP Sz 4 440V 1 Spd. 1 Wdg.	151405121										6		
Motor AC 440V 100 HP 1770 RPM	175503592										6		
Chiller Rfg. Wtr. Cap. 250 GPM	323010030										6		
Refrigeration Plant Air Conditioning Cap. 65-ton	325000265						1						
Condenser Rfg. Wtr. Cld. Cap. 270 GPM 462 Sq. Ft.	043010177						1						
Compressor Rfg. Vert Opn.	060150094						1						
Starter Motor Mag LVP Sz 4 440V 1 Spd. 1 Wdg.	151207861						1						
Motor AC 440V 75 HP 1770 RPM	174180235						1						
Chiller Rfg. Wtr. Cap. 195 GPM	323050034						1						
Refrigeration Plant Air Conditioning Cap. 65-ton	325000307							2					
Condenser Rfg. Wtr. Cld., Cap. 270 GPM 462 Sq. Ft.	043010177							2					
Compressor Rfg. Vert. Opn.	060150094							1					
Compressor Rfg. Vert. Opn.	060150142							1					
Starter Motor Mag LVP Sz 4 440V 1 Spd. 1 Wdg.	151207009							2					
Motor AC 440V 75 HP 1770 RPM	174180235							2					
Chiller Rfg. Water	323050048							2					
Coupling Shaft Flex Max. Bore 2.375 Insr. Disc. Ty.	780030008							2					

(continued)

Table B-1. (continued)

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Refrigeration Plant Air Conditioning Cap. 70-ton	325010133						6	4					
Condenser Rfg. Wtr. Cld. Cap. 397 GPM	043020137						6	4					
Compressor Rfg. Ty VW Opn.	060950088						3	4					
Compressor Rfg. Ty VW Opn.	060950109						3						
Starter Motor Mag LVP Sz 4 440V 1 Spd. 1 Wdg.	151204104						4	3					
Starter Motor Mag LVP Sz 5 440V 1 Spd. 1 Wdg.	151204365						2	1					
Motor AC 440V 75 HP 1755 RPM	174340814						2	2					
Motor AC 440V 125 HP 1765 RPM	174750902						3	2					
Motor AC 440V 60 HP 1760 RPM	174753598						1						
Chiller Rfg. Wtr. Cap. 210 GPM	323020010						6	3					
Chiller Rfg. Wtr. Cap. 175 GPM	323040010							1					
Coupling Shaft Flex. Max. Bore 2.547 Insr.	780030069						6	4					
Refrigeration Plant Air Conditioning Cap. 70-ton LH	325010157							1	2	3			
Condenser Rfg. Wtr. Cld.	043020154							1	2	3			
Compressor Rfg. Ty W Opn.	060950109							1	2	3			
Starter Motor Mag LVP Sz 5 440V 1 Spd. 1 Wdg.	151204365							1	2	3			
Motor AC 440V 125 HP 1765 RPM	174750902							1	2	3			
Chiller Rfg. Wtr. Cap. 210 GPM	323040013							1	2	3			
Coupling Shaft Flex. Max. Bore 2.547 Insr.	780030069								2	3			
Coupling Shaft Flex. Max. Bore 3.125 Insr.	780030074							1					

(continued)

Table B-1. (continued)

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Refrigeration Plant Air Conditioning Cap. 70-ton RH	325010158							1	3	3			
Condenser Rfg. Wtr. Cld.	043020154							1	3	3			
Compressor Rfg. Ty W Opn.	060950109							1	3	3			
Starter Motor Mag LVP Sz 5 440V 1 Spd. 1 Wdg.	151204365							1	3	3			
Motor AC 440V 125 HP 1765 RPM	174750902							1	3	3			
Chiller Rfg. Wtr. Cap. 210 GPM	323040013							1	3	3			
Coupling Shaft Flex. Max. Bore 2.547 Insr.	780030069								3	3			
Coupling Shaft Flex. Max. Bore 3.125 Insr.	780030074							1					
Refrigeration Plant Air Conditioning Cap. 200-ton	325010316											2	
Refrigeration Plant Air Conditioning Cap. 200-ton	325010317											1	
Condenser Rfg. Wtr. Cld. 1182 Sq. Ft.	043020257											3	
Compressor Rfg. Ctfgl. Opn.	060950191											3	
Controller AC Mag LVP Sz 3 440V 2 Spd. 2 Wdg.	151207891											3	
Motor AC 440V 200 HP 3535 RPM	174752206											3	
Chiller Rfg. Wtr.	321550017											3	
Refrigeration Plant Air Conditioning Cap. 150-ton	325010333									1			
Condenser Chiller Rfg.	043020264									1			
Compressor Rfg. Ctfgl. Semi-Hermetic	060950201									1			
Starter Motor Mag LVP HP 440V 1 RPM, 1 Wdg.										1			
Motor AC 440 V HP RPM,										1			

(continued)

Table B-1. (continued)

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Refrigeration Plant Air Conditioning Cap. 200-ton	325010339												3
Condenser Rfg. WCLD 1182 Sq. Ft.	043020270												3
Compressor Rfg. Ctfgl. Semi-Hermetic	060950203												3
Controller AC Mag LVP Spcl. 440V 2 Spd. 2 Wdg.	151207891												3
Motor AC 440V 200 HP 3535 RPM	174752206												3
Chiller Rfg. Wtr.	321550021												3
Refrigeration Plant Air Conditioning Cap. 300-ton	325010383B	4	4	4	4	4							
Condenser Water-Cooled 1350 GPM	043020281B	4	4	4	4	4							
Compressor Rfg. Ctfgl.	060950215B	4	4	4	4	4							
Controller AC Mag LVP Sz 6 440V	151406663B	4	4	4	4	4							
Motor AC 440V 300 HP 3550 RPM	174031473B	4	4	4	4	4							
Chiller Rfg. Wtr.	321550022B	4	4	4	4	4							

Table B-2. COMPONENTS OF THE AIR CONDITIONING *CHILLED* H_2O DISTRIBUTION

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Pump CTFGL, 210 GPM, 75 PSI, 3500 RPM, MCC	016050076								6				
Pump CTFGL, 200 GPM, 50 PSI, 3500 RPM, MCC	016050090						1						
Pump CTFGL, 210 GPM, 75 PSI, 3510 RPM, MCC	016110129						6	4					
Pump CTFGL, 800 GPM, 75 PSI, 3500 RPM, MD	016110441											3	
Pump CTFGL, 800 GPM, 75 PSI, 3530 RPM, MD	016110465												3
Pump CTFGL, 400 GPM, 48 PSI, 3500 RPM, MCC	016120200							1					
Pump CTFGL, 180 GPM, 72 PSI, 3500 RPM, MCC	016120353							2					
Pump CTFGL, 550 GPM, 75 PSI, 1750 RPM, MD	016150598									1			
Pump CTFGL, 550 GPM, 75 PSI, 1750 RPM	016150740									1			
Pump CTFGL, 210 GPM, 57 PSI, 3500 RPM, MCC	017030029									6			
Pump CTFGL, 250 GPM, 75 PSI, 3500 RPM, MCC	017030129										6		
Pump CTFGL, 1350 GPM, 125 PSI	017030310B	4	4	4	4	4							
Starter Motor Mag LVP Sz 3 440V	151207998												3
Starter Motor Mag LVP Sz 3 440V	151208509									1			
Starter Motor Mag LVP Sz 2 440V	151404060										6		
Starter Motor Mag LVP Sz 5	151406620B	4	4	4	4	4							
Starter Motor Mag LVP Sz 2 440V	151801593								6				
Starter Motor Mag LVP Sz 1 440V	151801807						1						

(continued)

Table B-2. (continued)

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Starter Motor Mag LVP Sz 2 440V	151901103						6	4					
Starter Motor Mag LVP Sz 2 440V	151903497							1					
Starter Motor Mag LVP Sz 2 440V	151903527											3	
Starter Motor Mag LVP Sz 3 440V	151903536							1					
Motor AC 440V 150 HP 3565 RPM	174031484B	4	4	4	4	4							
Motor AC 440V 50 HP 3530 RPM	174180172											3	
Motor AC 440V 50 HP 1775 RPM	174180197									1			
Motor AC 440V 20 HP 3500 RPM	174180240						1						
Motor AC 440V 20 HP 3500 RPM	174750273						1	1	6	6			
Motor AC 440V 50 HP 3530 RPM	174751239												3
Motor AC 440V 20 HP 3520 RPM	174801351						5	4					
Motor AC 440V 20 HP 3545 RPM	175503589										6		
Motor AC 440V 15 HP 3535 RPM	175504203							2					
Coupling Shaft Flex Max Bore 2.125 Grid	780200014									1			
Coupling Shaft Flex Max Bore 1.875 Grid	782350005											3	2
Coupling Shaft Flex Max Bore 2.375 Grid	782350006												1

Table B-3. COMPONENTS OF THE AIR CONDITIONING SALT WATER CIRCULATING SYSTEM

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
A/C Salt Water Circ. Pump													
Pump CTFGL, 800 GPM, 50 PSI, 1750 RPM MD VLT	016020936									1			
Pump CTFGL, 300 GPM, 34 PSI, 3500 RPM, MCC	016031091								2				
Pump CTFGL, 700 GPM, 34 PSI, 3500 RPM, MCC VLT	016050067								1				
Pump CTFGL, 450 GPM, 35 PSI, 3500 RPM, MCC VLT	016050176						1						
Pump CTFGL, 110 GPM, 56 PSI, 3500 RPM	[illegible]050219											1	
Pump CTFGL, 110 GPM, 56 PSI, 3500 RPM, MCC	016050222											1	
Pump CTFGL, 700 GPM, 35 PSI, 3500 RPM, MCC VLT	016110130						4	3					
Pump CTFGL, 1000 GPM, 35 PSI, 1750 RPM, MD VLT	016110440											3	
Pump CTFGL, 1000 GPM, 35 PSI, 1760 RPM, MD VLT	016110464												3
Pump CTFGL, 485 GPM, 40 PSI, 3500 RPM, MCC VLT	016120349							2					
Pump CTFGL, 700 GPM, 34 PSI, 3500 RPM, MCC VLT	017030030									2			
Pump CTFGL, 800 GPM, 35 PSI, 3500 RPM, MCC VLT	017030130										3		
Pump CTFGL, 1500 GPM, 50 PSI, 3600 RPM	017030311B	3	3	3	3	3							
Pump CTFGL, 1500 GPM, 50 PSI, 3600 RPM	017030372B	1	1	1	1	1							
Pump CTFGL, GPM, PSI, 3500 RPM, MCC	017030537									1			
Starter Motor Mag LVP Sz 3 440V	151205355									1			
Starter Motor Mag LVP Sz 3 440V	151208509												3
Starter Motor Mag LVP Sz 2 440V	151209109							2					
Starter Motor Mag LVP Sz 0 440V	151404650											1	
Starter Motor Mag LVP Sz 2 440V	151404665										3		

(continued)

Table B-3. (continued)

Nomenclature (As Listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Starter Motor Mag LVP Sz 4 440V	15140633B	4	4	4	4	4							
Starter Motor Mag LVP Sz 2 440V	151801592								3				
Starter Motor Mag LVP Sz 4 440V	151801615						1						
Starter Motor Mag LVP Sz 2 440V	151902121						4	3					
Starter Motor Mag LVP Sz 3 440V	151903527											3	
Motor AC 440V 20 HP 3600 RPM	173870033									1			
Motor AC 440V 100 HP 3570 RPM	174031485B	4	4	4	4	4							
Motor AC 440V 30 HP 1760 RPM	174180183									1		3	
Motor AC 440V 7.5 HP 3500 RPM	174180222											1	
Motor AC 440V 15 HP 3525 RPM	174180224						1						
Motor AC 440V 25 HP 3525 RPM	174750608									3			
Motor AC 440V 30 HP 1765 RPM	174751760												3
Motor AC 440V 25 HP 3500 RPM	174801700						4	3					
Motor AC 440V 15 HP 3450 RPM	174900070								2				
Motor AC 440V 25 HP 3545 RPM	175503591										3		
Motor AC 440V 20 HP 3540 RPM	175504202							2					
Motor AC 440V 25 HP 3500 RPM	175730001								1				
Coupling Shaft Bore 1.25 Taper	780130051	4	4	4	4	4							
Coupling Shaft Flex. Bore 2.375 Grid	782350006											3	3

APPENDIX C

SHIPALT SUMMARIES:
S/A LPH-255 AND S/A LPH-585

This appendix summarizes shipalts that have an impact on the reliability and maintainability of the air conditioning systems installed on LPH-2 Class ships.

Shipalt LPH-0255K, revision 1

Upgrade air conditioning systems, which includes the following:

- Replace air conditioning units as follows:
  - •• LPH-2 and -3, 150-ton units for 63-ton unit zones 1 and 2.
  - •• LPH-7, 150-ton unit for 70-ton unit zones 1 and 2.
  - •• LPH-9, 150-ton unit for 80-ton unit zones 1 and 2
- Install a new chilled water system main, with isolation valves, between foremost and aftermost air conditioning plant.
- Replace existing circulating pumps in zones 1 and 2 with 540-gallon-per-minute pumps and add one of the removed pumps in zone 3.
- Increase chilled water flow to cooling coils to produce a space design condition of 80 degrees farenheit.
  - •• Install air conditioning in the following spaces:

06-63-1C	02-131-1-Q	3-17-0-L
06-67-1C	01-37	3-15-0-L
06-71-1C	01-39-2-Q	3-162-2-L
03-59-1C	01-36-1-Q	3-19-1-E
03-67-1-Q	01-55-1-Q	3-115-1-E
02-7-2-Q	01-59-1-Q	3-129-1-L
02-55-3-Q	1-3-2-A	E-129-3-L
02-63-5-C	1-64-1-Q	4-46-0-A
02-67-5-Q	2-9-1-Q	4-46-1-A
02-99-5-C	2-11-1-Q	4-63-1-Q
02-115-8-C	2-63-6-Q	4-100-1-Q
02-131-2-Q	02-71-2-Q	4-96-1-A

The following work is accomplished by this shipalt in other systems:

System	Work Description
185	Provide foundations for air conditioning units and pumps.
321	Provide power as required.

Shipalt LPH-0585K

Upgrade air conditioning system to provide the capability for extended operations in the tropics, which includes the following:

- Install one 150-ton centrifugal air conditioning plant in storeroom 3-85-8.

- Provide six-inch cooling water cross-connecting piping between existing and new unit with a six-inch supply and return main on the second deck between frames 55 and 114. Provide isolation valves to divide mains into zones.
- Air condition the following spaces:

Radar rooms	Carpenter shop
UHF radio rooms	Electric service shop
Flight deck and lighting control	I.C. shop
Announcing amplifier room	Butcher shop
Crypto repair shop	Vegetable preparation room
Radar switchboard room	Prison cells and vestibule
Radio transmitter rooms	Switchgear rooms
GFCS Mk 70 control rooms	Main issue room
BPDSMS control rooms	Aviation issue room
Conflagration station	Troop armory
Hobby shop	Ships armory
Fire control shop	Technical library
Ordnance shop	Repair parts issue
Teletypewriter shop	Financial office

The following work is accomplished by this shipalt in other systems:

System	Work Description
167	Install watertight hatch on 3rd deck, frames 17-18 port.
185	Install foundations for new equipment.
321	Provide power to air conditioning unit, recirculating systems, and circulating pump.
331	Provide lighting supplies for cooling coils, heaters, unit coolers, and fans.
432	Install a dial telephone in air conditioning machinery room.
524	Install a salt water circulating pump and piping for air conditioning unit.
621	Replace expanded metal bulkheads with metal joiner bulkheads in air conditioned spaces.

APPENDIX D

MDS PARTS USAGE DATA SUMMARY

This appendix presents parts usage data for all parts of the air conditioning systems, including the air conditioning plants (Table D-1), the chilled water circulating pumps (Table D-2), and the salt water circulating pumps (Table D-3) that were ordered on more than one JCN.

The demand frequency is computed by dividing the total equipment operating years by the number of JCNs; it represents the average operating years between requests for a given part.

Table D-1. MDS PARTS USAGE DATA SUMMARY FOR AIR CONDITIONING PLANT (ALL PARTS ORDERED ON MORE THAN ONE JCN, EXCLUDING EXPENDABLES SUCH AS GASKETS, BOLTS, NUTS, PACKING)

APL	Applicable Ships	Total Number of Equipments	Total Equipment Operating Time (Ship Operating Years)	NIIN	Nomenclature	Total Replaced	Total JCNs	Quantity per APL	Demand Frequency (Ship Operating Years)
060150094	2	2	15.2	0767263	Bearing-Pump Mn End	2	2	1	7.6
				3320032	Disk-Dschg. Vlv	14	2	12	7.6
				3934897	Valve-Cont.	2	2	1	7.6
				5224315	Disk-W	24	2	12	7.6
				5299569	Ring-Pstn	31	3	24	5.1
				6782841	Valve-Cap Cont Aux	3	3	1	5.1
06050120	1	6	42.6	0566763	Piston-Compr	32	5	12	8.5
				0767263	Bearing-Pump Mn End	5	3	1	14.2
				2789740	Pin-Pstn	7	3	12	14.2
				2880878	Bearing-Up and Low	5	4	1	10.7
				3320032	Disk-Dschg Vlv	32	2	12	21.3
				3393435	Bearing-Mn Shl	8	4	2	10.7
				3934897	Valve-Cont	9	3	1	14.2
				5224315	Disk-Vl	44	3	12	14.2
				6473619	Sleeve-Cyl	27	4	12	10.7
				6618669	Bearing-Mn Se	6	4	1	10.7
				6782841	Valve-Cap Cont Aux	2	2	1	21.3
				7989149	Seat-Dschg Vlv	7	2	12	21.3
				8307676	Valve-Plate Assy	33	5	6	8.5
060950088	2	7	52.9	0363914	Cage Assy-Dschg	7	2	8	26.5
				0806783	Spacer-Ring	16	2	8	26.5
				3383290	Sleeve-Cyl LH	4	2	2	26.5
				3743215	Valve Assy-Opns	2	2	1	26.5
				3743219	Sleeve-Unl RH	8	2	4	26.5
				3768253	Piston Assy	16	2	8	26.5
				3863206	Sleeve-Cyl	5	3	2	17.6
				3863207	Rod Assy-Conn	31	4	8	13.2
				3994744	Seal Assy-Shft	11	9	1	5.9
				4695290	Ring-Pstn	20	2	12	26.5
				5166169	Bearing-Mn	4	4	1	13.2
				5299569	Ring-Pstn	5	3	24	17.6
				6787378	Valve Plt Assy-Suct	33	4	8	13.2
				8165290	Crankshaft	2	2	1	26.5
				8455809	Bearing-Slv	4	4	1	13.2

(continued)

Table D-1. (continued)

APL	Applicable Ships	Total Number of Equipments	Total Equipment Operating Time (Ship Operating Years)	NIIN	Nomenclature	Total Replaced	Total JCNs	Quantity per APL	Demand Frequency (Ship Operating Years)
060950109	4	16	124.3	0363914	Cage Assy-Dschg	62	10	12	12.4
				0806783	Spacer-Ring	61	8	12	15.5
				2889305	Pump-Rty Pwr Drvr	7	5	1	24.9
				3383290	Sleeve-Cyl LH	38	11	4	11.3
				3743206	Sleeve-Cyl	21	8	4	15.5
				3743215	Valve Assy-Oprs	7	5	1	24.9
				3743219	Sleeve-Unl RH	28	7	4	17.8
				3768253	Piston Assy	85	14	12	8.9
				3863205	Push Rod-Unl	17	6	4	20.7
				3863206	Piston-Unl	18	7	4	17.8
				3863207	Rod Assy-Con	69	9	12	13.8
				3994744	Seal Assy-Shft	21	16	1	7.8
				4695290	Ring-Pstn	3	3	12	41.4
				5166169	Bearing-Mn	6	6	1	20.7
				6787378	Valve-Plate Assy	121	12	12	10.4
				6790708	Bearing-Sleeve	7	5	1	24.9
				8164885	Crankshaft	7	7	1	17.8
				8455809	Bearing-Sleeve	6	6	1	20.7
				9215424	Ring-Dschg Vlv	47	6	12	20.7
060950191	1	3	23.5	0228961	Bearing-Gr Frt	4	4	1	5.9
				0228962	Bearing-Slv	4	4	1	5.9
				0228965	Bearing-Sleeve	3	3	1	7.8
				9650396	Bearing-Slv Pnn Gr	3	3	1	7.8
				9787244	Ring-Imp Se	6	6	1	3.9
060950203	1	3	21.8	0228956	Pump-Ctfgl Oil	3	3	1	7.3
				0228962	Bearing-Slv	3	3	1	7.3
				0228965	Bearing-Sleeve	4	4	1	5.5
				0665745	Ring-Shft Seal	7	6	1	3.6
				9787244	Ring-Imp Se	4	4	1	5.5
151204104	2	7	53.8	1021055	Resistor-Fxd 1.5K	3	2	1	26.9
				8234460	Relay Timing	3	2	1	26.9
151204365	3	13	100.0	1021055	Resistor-Fxd 1.5K	2	2	1	50.0

Table D-2. MDS PARTS USAGE DATA SUMMARY FOR CHILLED WATER DISTRIBUTION SYSTEM (ALL PARTS ORDERED ON MORE THAN ONE JCN, EXCLUDING EXPENDABLES SUCH AS GASKETS, BOLTS, NUTS, PACKING)

APL	Applicable Ships	Total Number of Equipments	Total Equipment Operating Time (Ship Operating Years)	NIIN	Nomenclature	Total Replaced	Total JCNs	Quantity per APL	Demand Frequency (Ship Operating Years)
016110129	2	10	77.18	1193368	Deflector, Dirt and Liq	4	3	1	25.7
				3933486	Sleeve, Shft Pmp	7	4	1	19.3
				5809197	Ring-Wrg Csg	10	6	2	12.9
				5809198	Ring-Wrg Imp	14	7	2	11.0
016110441	1	3	23.46	5543087	Bearing-B Ann	7	2	1	11.7
				5545238	Bearing-B Ann	5	2	1	11.7
				5850644	Deflector, Dirt and Liq	5	2	1	11.7
				6720103	Seal Assy-Pln	9	5	2	4.7
				8333142	Ring-Wrg Imp Os	10	3	2	7.8
				9324882	Ring-Wrg Csg Us	8	2	2	11.7
017030310B	5	20	38.76	0407588	Ring, Casing Wearing	3	2	2	19.4
				1988771	Sleeve, Shaft Pmp	6	2	2	19.4
				4270139	Shaft	2	2	1	19.4
				4323856	Seal, Mech	7	3	2	12.9
174180172	1	3	23.46	1556266	Bearing-B Ann	7	4	2	5.9
				5543359	Bearing-B Ann	6	3	2	7.8
174751239	1	3	21.84	5186808	Bearing-B Ann	10	5	2	4.4
174801351	2	9	69.07	1565048	Bearing-B Ann	2	2	1	34.5
				1588269	Bearing-B Ann	3	3	1	23.0
175503589	1	6	42.60	1556226	Bearing-B Ann	4	2	1	21.3

ble D-3. MDS PARTS
JCN, EXCLU

	Total Number of Equipments	(Shi
	2	
	1	
.J130	2	

APPENDIX E

CORROSION-CONTROL TECHNIQUES

Table E-1 presents the recommended work (SARP) statements for applying NAVSEA-approved corrosion-control techniques. Table E-2 presents specific guidance items for applying the corrosion-control techniques to common components within the heating, ventilation, and air conditioning systems.

Table E-1. RECOMMENDED CORROSION CONTROL SARP STATEMENTS

SWAB	Area/Components	Recommended SARP Statement	Alternate Corrosion-Control System(s)
5121	Ventilation Systems	When vent terminations are replaced or represerved, apply wire sprayed aluminum with low-temperature sealer.	Apply polyamide epoxy paint.
5121	Ventilation Systems	When vent screens are replaced or represerved, apply polyamide epoxy paint. Apply powdered coating. Use fasteners treated with ceramic coatings or use improved fasteners as applicable.	Treat with ceramic coatings. Apply strippable coatings to fasteners.
5121	Ventilation Systems	When sponson void access openings are represerved, apply polyamide epoxy paint.	Apply topcoat.
5131	Machinery Space Ventilation	When vent duct is removed or replaced, apply polyamide epoxy paint after assembly and prior to installation. Cover welded seams and duct after installation with polyamide epoxy and touch up other areas requiring it. Use fasteners treated with ceramic coatings or use improved fasteners as applicable.	Apply topcoat. Apply strippable coats to fasteners.
5142	Air Conditioning Plant	When air conditioning plants are removed from the ship for overhaul or replacement, apply wire sprayed aluminum with low-temperature sealer to unit foundations and bedplates. Apply polysulfide sealant to faying surfaces. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item 1 applies to machinery foundations, bedplates, and fasteners.	Apply polyamide epoxy paint. Apply strippable coatings to fasteners.

Item Number	Equipment	Guidance
		Table E-2. CORROSION-CONTROL GUIDANCE ITEMS
1	Machinery Foundations and Bedplates	When a new foundation or bedplate is installed or a bedplate is removed as part of machinery overhaul, or a foundation is located topside, abrasive-blast the foundation and mating structure surface to white metal (SSPC-SP5), and then apply 7-10 mils of WSA low-temperature sealer (MIL-P-23377) and two-coat polyamide epoxy (MIL-P-24441) system. For machinery foundations and bedplates located in machinery spaces and subjected to temperatures above 175°F, use WSA with high-temperature sealer (DOD-P-24555). Use fasteners treated with ceramic coatings or use improved fasteners.
2	Piping and Hangers	In areas exposed to the weather and in machinery spaces (where piping is replaced) abrasive-blast ferrous piping and pipe hangers/brackets to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature), and polyamide epoxy coating (MIL-P-24441). If piping is not replaced, apply three-coat polyamide epoxy system (MIL-P-24441). Treat fasteners with ceramic coating (MIL-C-81751) or use CRES fasteners.
3	Valves	Abrasive-blast valve exterior to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature of fluid or if steam valve), and polyamide epoxy coating (MIL-P-24441). Technical Manual NAVSEA S6435-AE-MMA-010/W, *Sprayed CTT, External Preservation of Steam Valves Using Wire Sprayed Aluminum Coatings*, provides detailed guidance. Upgrade/treat fasteners with ceramic coating (MIL-C-81751) or replace with CRES fasteners and apply polysulfide sealant (MIL-S-81733).

APPENDIX F

SOURCES OF INFORMATION

The specific sources of information used in this analysis are as follows:

1. Generation IV MDS narrative and part data for the LHA-1 and LPH-2 Class ships for the periods 1 May 1976 through 30 June 1981, and 1 January 1971 through 31 March 1981, respectively.

2. CASREPs for the same ships for the periods 1 January 1976 through 22 April 1981 and 1 January 1978 through 22 April 1981, respectively.

3. Maintenance index pages (MIPs) and corresponding maintenance requirement cards (MRCs) for the air conditioning, heating, and ventilation systems (various).

4. NAVSHIP Technical Manuals (various as applicable to LPH-2 and LHA-1 Class air conditioning plants).

5. Ship Alteration and Repair Packages (SARPs):

   - LPH-2, dated 6/8/82
   - LPH-3, dated 3/11/82
   - LPH-7, dated 10/31/80
   - LPH-9, dated 8/18/80
   - LPH-10, dated 1/9/81
   - LPH-11, dated 10/23/81
   - LPH-12, dated 5/15/81
   - LHA-1, dated FY 78 RAV
   - LHA-2, dated 6/13/83 (COH)
   - LHA-1, dated FY 81 (COH)
   - LHA-3, dated 1/15/82 SRA
   - LHA-2, dated 7/3/81 SRA

6. Ship Alteration Information Manuals for LHA-1 and LPH-2 Class Ships.

7. COMNAVSURFLANT and COMNAVSURFPAC Type Commander's Coordinated Shipboard Allowance Lists (COSALs), dated July 1981 and June 1981, respectively.

8. COMNAVSURFLANTINST 9000.1, *NAVSURFLANT Maintenance Manual*, 12 June 1975, through change 5 dated 27 February 1978.

9. COMNAVSURFPACINST 4700.1, *COMNAVSURFPAC Ship and Craft Material Maintenance Manual*, Volume I, 6 June 1975.

10. OPNAVINST 4790.4, *Material Maintenance Management (3-M) Manual*, Volumes I, II, and III, June 1973.

11. *FF-1052 Class Chilled Water Air Conditioning System Review of Experience, SMA 206-514*, March 1977, ARINC Research Publication 1646-03-7-1590.

12. *CG-16 and CG-26 Class Auxiliary Systems Review of Experience*, SMA 1626-500, September 1979, ARINC Research Publication 1671-04-2-2051.

13. Common Class Configuration Lists (CCCL) for LHA-1 and LPH-2.

14. Ship Work Authorization Boundaries (SWABs) for Surface Ships, March 1981.

15. Class Maintenance Plans (CMPs) for FF-1052, DDG-37, CG-16, CG-26, and LHA-1 Class ships.

16. Repair Profile for LPH-2 Class ships.

17. Results of ARINC Research Corporation visits to LPH-7 (USS GUADALCANAL) and LPH-12 (USS INCHON) on 20-21 April 1982.

18. Results of ARINC Research Corporation visit to LHA-2 (USS SAIPAN) on 4 June 1982.

19. Ship Information Books (SIBs) applicable to LPH-2 and LHA-1 Class ships.

LME

-8