

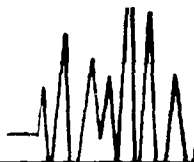
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**SYSTEM ENGINEERING ANALYSIS OF
TOPSIDE CRANES
INSTALLED ON
AD, AR, AND AS CLASS SHIPS**

February 1982

**Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
COMBAT SUPPORT SHIPS
HUNTERS POINT NAVAL SHIPYARD
SAN FRANCISCO, CALIFORNIA
under Contract N00189-81-D-0126-FJ06**

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by
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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 topside boat, airplane, repair, missile, and traveling and bridge cranes installed on AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. The report was developed for PERA (CSS) under Delivery Order FJ06 of Navy Contract N00189-81-D-0126.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect 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 strategy and specific maintenance actions best suited to meeting EOC goals.

The major findings and conclusions of the SEA for AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class topside boat, airplane, repair, missile, and traveling and bridge cranes are summarized as follows:

- Since no single crane system, equipment, or component was responsible for a majority of the corrective maintenance actions performed, the cranes should continue to be maintained on a run-to-failure basis, with preventive maintenance and repairs performed by ship's force with outside assistance as required. However, emphasis should be placed on the following:
 - Ship's force should perform preventive maintenance in accordance with PMS requirements and the following recommended changes:
 - NAVSEA should establish consistent requirements for the same brake types.

- NAVSEA should standardize the inspection of foundation bolts to an annual basis instead of cyclic.
- NAVSEA should add a maintenance requirement for hydraulically operated cranes to renew flexible hydraulic hoses and fittings.
- Corrective maintenance should continue to be performed to the piece-part level by ship's force.
- Class B overhauls should continue to be performed on the hydraulic system, electrical system, brake system, motors and pumps, mechanical linkages, and fairlead blocks during future ROHs.
- Motor controllers, structural components, gears and reducers, cable reels, and bearings should receive class C repairs during future overhauls.
- Outside assistance is required for the following:
 - Accomplishing wet or dry MPI of crane hooks annually or as needed
 - Accomplishing dye penetrant tests of brake drums during ROH or as needed
 - Performing weight tests during ROH or as needed
- NAVSEA should perform supportability analyses to determine the availability of repair parts for the cranes on the AD-14, AD-37, AR-5, AS-11, AS-19, and AS-31 Class ships.
- NAVSEA should provide the TYCOM with supportability analysis results for appropriate action.
- NAVSEA should review the electrical system designs to define revisions needed to make exposed electrical components weatherproof and moistureproof. Specific emphasis should be placed on limit and neutral switches, load cell sensors, breakers, and electrical contact points.
- Since a large number of JCNs for gears, reducers, and brakes reported moisture or water as contributing to the failure, NAVSEA should review the weatherproofing design of the cranes. Access panels, doors, and protective covers and guards should be reviewed to determine the need for the application of gaskets or seals and dog or tie-down features.
- Since general corrosion is a factor in structural failures, NAVSEA should determine the technical feasibility and cost-effectiveness of applying state-of-the-art corrosion-control measures or paint systems.
- NAVSEA should review the AD-14, AD-37, AR-5, AS-11, AS-19, and AS-33 Class ship crane technical manuals; ensure that manuals reflect changes to the crane; and, where missing, add troubleshooting and maintenance procedures. This effort should be accomplished only for cranes and ships that will not be deactivated in the near future.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Mobile Logistic Support Force (MLSF) 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 topside boat, airplane, repair, missile, and traveling and bridge cranes installed on AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. Ship's work authorization boundaries (SWAB) included in this analysis are 588-2, aircraft and helicopter support facilities; 589-1, rotating cranes; 589-2, cranes and hoists; and 792-2, special weapons handling equipment. The analysis considers only the systems and equipments installed and the documentation effective as of 30 September 1981. The subject crane systems were selected for analysis by PERA (CSS) on the basis of their 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, and Destroyer Engineered Operating Cycle (DDEOC) system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on DDEOC 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 topside cranes as installed on individual ships of the ship classes under study. Appendix C summarizes component commonality among the cranes reviewed. Appendix D summarizes the installation redundancy of the topside boat, airplane, missile, repair, and traveling and bridge cranes on all ship classes reviewed. Appendix E presents the major crane system failures reported in CASREPs. Appendix F lists all sources of information used in the analysis.

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the topside boat, airplane, repair, missile, and traveling and bridge cranes installed on AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. These systems were selected for analysis by PERA (CSS) 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 system's operational availability and material condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major tasks 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 these 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 to describe 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 DDEOC Program ships.

The MDS data bank was compiled by examining all MDS data reported from 1 January 1975 through 31 July 1981 for hulls AD-14, AD-15, AD-17, AD-18, AD-19, AD-37, and AD-38; AR-5, AR-6, AR-7, and AR-8; and AS-11, AS-12, AS-16, AS-18, AS-19, AS-31, AS-32, AS-33, AS-34, AS-37, AS-39, and AS-40 (a total of 23 ships). Data on AS-36 were not included in the analysis; they were inadvertently omitted from the data base because of an error in the unit identification code used to request the data initially. No effort was made to reorder the data, because the limited potential for improvement of the MDS data bank did not warrant the expenditure of time and funds necessary to obtain and integrate AS-36 data. This omission does not affect the analysis results.

CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the period 1 January 1978 through 31 July 1981. 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 common configuration class lists (CCCLs), the type commander's coordinated ship-board allowance lists (COSALs), shipalt records, and MDS data. Telephone calls to specific ships and cognizant technical personnel, as necessary, 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 identified 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 DDEOC Program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been 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, concurrent with definition of the problems. Concurrent effort was required for one or more of 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 progress, applicable alterations, or the effects of availabilities

2.4 TASK 3: DEVELOP 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 may be applicable to the nine 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.

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 ship classes 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 ship classes under study. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ships.

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 ILS 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 equipment configurations by allowance parts list (APL) number for each AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class hull included in the analysis.

CHAPTER THREE

RESULTS

3.1 SYSTEM BOUNDARIES AND DESCRIPTION

The topside boat, airplane, repair, missile, and traveling and bridge cranes discussed in this report are composed of various equipments included within SWAB groups 588-2, 589-1, 589-2, and 792-2. All the major equipments listed in Appendix A were examined to identify maintenance requirements. The major components examined and discussed in this report are listed by APL number in Appendix B. Minor components such as boom bumpers, small valves, and heating/ventilating systems were not examined in detail, because past experience has shown that these components are not maintenance- or mission-critical and are usually repaired or replaced as needed by ship's force and thus require no periodic repairs.

Several types of crane systems of varying lifting capabilities are installed on AD, AR, and AS Class ships: boat, airplane, repair, missile, and traveling and bridge cranes for handling cargo, stores, and ammunition. (See Appendix B for specific configuration, applicability, and size information for the crane systems.) In general, all cranes provide some combination of hoisting or lowering of load hooks; topping (luffing) -- raising and lowering of the boom; rotating; slewing (swinging); revolving; or traveling. Depending on the crane, some of the motions can be carried on simultaneously or in any combination. Cranes consist primarily of a combination of fixed structural members; booms and jib extensions; an operator's cab or station with all controls and gauges; electrical motors; hydraulic motors and pumps; speed reducers and gears; electromechanical or hydraulic brakes; protective and safety devices, including emergency stop switches, overtravel limit switches, boom angle indicators (visual and audible), overload coils or switches, and warning lights for overheat conditions; electrical circuitry to all controls, switches, and lighting; and, in the case of traveling and bridge cranes, travel trucks. Appendix C shows the results of a crane component commonality analysis performed on all AD, AR, and AS Class ship topside, boat, repair, missile, and traveling and bridge cranes. Twenty-seven of the 34 cranes examined are sufficiently different to be considered "unique" cranes. The remaining are identical to one or more cranes. However, among the 27 unique cranes, there is some commonality of components, especially with respect to limit and neutral switches, brakes, starter motors and controllers, flexible couplings, AC motors, and windshield wipers.

For the purpose of this analysis, the cranes are considered functionally the same even though the designs (kingpost, gantry, traveling and bridge), manufacturers, and ages are different. Where there are differences in the maintenance experience, these differences are pointed out.

All cranes on board AD, AR, and AS Class ships provide primary support in logistics (LOG) and fleet support operations (FSO) and secondary support in the noncombat operations (NCO) supporting mission areas. In the AD-14 Class each ship is equipped with two airplane and boat cranes and, with the exception of AD-19, two topside paravane and stores cranes (AD-19 has no topside paravane and stores cranes). Consequently, in the event of a casualty to one of the cranes, the other crane is available to fulfill system requirements (see Appendix D, installation redundancy of cranes).

Similarly, as shown in Table D-1, there is 100 percent crane redundancy in the AD-37, AR-5, AS-11, AS-19, and AS-33 Classes. In the AS-36 Class, the AS-36 has one boat crane and the AS-37 has one boat and missile crane. Each of these ships has two topside cargo and sail cranes. Consequently, in the event of a casualty to the larger cranes, these ships have no redundancy for any lift above 10,000 pounds. Similarly, in the AS-39 Class, there is redundancy for the cargo and sail cranes and no redundancy for the 60,000-pound repair and boat cranes.

3.2 MAINTENANCE REQUIREMENT IDENTIFICATION

Maintenance data were initially screened to identify the possible existence of significant maintenance-related problems of the boat, airplane, repair, missile, and traveling and bridge cranes as discussed in Section 2.3. Maintenance burden data for the cranes are summarized in Table 3-1, which shows that the annual maintenance man-hour burden for the cranes ranged between 2 man-hours and 778 man-hours per crane per operating year. These values include the maintenance man-hour burdens for the cranes and for the motors, pumps, controls, brakes, bearings, shafts, switches, hoists, and drums associated with each crane. Data for the cranes and components were grouped because some ships report maintenance data against the parent crane APL and some against the individual equipment/component APL. This grouping was performed so that the functionally similar equipment groups could be compared across all cranes.

The two man-hours per crane per operating year occurred because only two JCNs were reported on the boat and missile crane, APL 572330002, installed on the AS-37. This particular crane was originally installed on the AS-33 and was subsequently installed on the AS-37 upon installation of new cranes for the AS-33. Similar actions are planned for installing the remaining AS-33 95,000-pound cranes on the AS-36. The AS-37 boat and missile crane is identical to the crane installed on the AS-34, which experienced a maintenance burden of 144 man-hours per operating year. Hence the maintenance burden and problems reported for AS-34 will be considered applicable to the AS-37.

Table 3-1. SUMMARY OF MDS DATA FOR TOPSIDE BOAT, AIRPLANE, REPAIR, MISSILE, AND TRAVELING CRANES FOR AD, AR, AS CLASS SHIPS												
AFL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Time (Years)	Ships Reported	JCNs	Man-Hours			Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating Year
								Ship's Force	INA	Total		
571010001	Airplane and Boat Crane 11,050/10,650/28,000 pounds	AD-14-15	2	4	11.37	2	112	1,463	2,614	4,077	11,781	179
572330039*	Airplane and Boat Crane 20,000/40,000 pounds	AD-14	2	2	3.01	1	15	403	65	468	1,137	78
571020001	Paravane and Stores Crane 10,500/ / pounds	AD-14-15	2	4	11.37	2	37	210	305	839	839	23
571880006**	Airplane and Boat Crane 45,000/22,500/ / pounds	AD-17-18	2	4	11.62	2	148	1,575	2,139	3,714	12,418	160
571020007	Paravane and Stores Crane 10,500/ pounds	AD-17-18 AS-16	2	6	17.37	3	109	1,485	2,818	4,303	14,625	124
571880003*+,**	Airplane and Boat Crane 45,000/18,000/45,000 pounds	AD-19 AS-19	2 1	4	11.05	2	358	5,706	7,213	12,919	5,148	585
571880004*+,**	Airplane and Boat Crane 45,000/18,000/45,000 pounds	AS-19	1									
572330030**	Kingpost Crane 60,000 pounds	AD-37-38	2	4	10.98	2	98	3,247	3,969	7,216	26,764	329
572330036**	Crane 7,000/12,000 pounds	AD-37-38	2	4	10.98	2	142	2,514	2,239	4,753	21,085	216
572350002**	Bridge Crane, 4000 pounds	AD-37-38	2	4	10.98	2	27	86	282	368	--	17
571010002	Airplane and Boat Crane 45,000/45,000/16,000 pounds	AR-5	2	2	5.74	1	133	1,365	1,579	2,944	5,900	256
571860002**	Airplane and Boat Crane 45,000/45,000/18,000 pounds	AR-6-7	2	4	11.41	2	94	3,450	449	3,899	3,349	171
571860003**	Airplane and Boat Crane 45,000/45,000/18,000 pounds	AR-8	2	2	5.59	1	106	3,184	2,995	6,179	11,124	553
578880040*	Airplane and Boat Crane 45,000/18,000/45,000 pounds	AS-11	2	2	4.79	1	25	144	7,309	7,453	20,121	778

(continued)

Table 3-1. (continued)											
APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Time (Years)	Ships Reported	JCNs	Man-Hours		Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating Year
								Ship's Force	IMA		
571400010 ¹	Parawane and Stores Crane 8,900/2,200 ¹ pounds	AS-11	}	8	23.50	3	30	704	851	1,555	33
571400011 ¹	Parawane and Stores Crane 8,900/2,200 ¹ pounds	AS-12									
571400012 ¹	Parawane and Stores Crane 8,900/2,200 ¹ pounds	AS-18-19									
57100001	Airplane and Boat Crane 45,000/18,000/45,000 pounds	AS-12	}	2	5.99	1	42	446	2,699	3,145	263
572570000 ¹	Pedestal Crane, Petrolbone 50,000 pounds	AS-18									
572450001	Boat and Missile Crane 95,000 pounds	AS-11-12									
570800031 ¹	Boat and Missile Crane 115,000 pounds	AS-11	}	2	4.83	1	17	186	1,000	1,186	123
571190002 ¹	Cargo Crane 5,000 pounds	AS-11-12									
571190003 ¹	Cargo Crane 5,000 pounds	AS-11-12									
571190004 ¹	Cargo Crane 5,000 pounds	AS-11-12	}	8	11.83	2	92	1,048	2,406	3,514	74
572400010 ¹	Boat and Missile Crane, RH 95,000 pounds	AS-14									
572400011 ¹	Boat and Missile Crane, LH 95,000 pounds	AS-14									
572000012 ¹	Gantry Crane 7,000 pounds	AS-14-15	}	8	11.50	2	179	3,905	6,617	10,522	228
572000013 ¹	Cargo and Sail Crane 10,000 pounds	AS-16-17									
572000014 ¹											

(continued)

Table 3-1. (continued)

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Time (Years)	Ships Reported	JCNs	Man-Hours			Parts Cost (Dollars)	Average Man-Hours per Equipment per Operating Year
								Ship's Force	IMA	Total		
572C8002*	Boat Crane 30,000 pounds	AS-36	1	1	6.01	1	11	38	286	324	181	54
572330002*,**	Boat and Missile Crane, LH 95,000 pounds	AS-37	1	1	2.72	1	2	4	--	4	--	2
572080001	Bridge and Traveling Missile Crane - 65,000 pounds	AS-19	1	1	5.67	1	13	47	624	671	236	118
572450003	Repair and Boat Crane 60,000 pounds	AS-39-40	1	2	2.26	2	21	300	684	984	4,159	435
572240005	Cargo and Sail Crane 10,000 pounds	AS-39-40	2	4	2.26	2	57	929	931	1,860	14,621	412
950004770*	Crane, Wheel Mounted Model 40SC	AS-39-40	1	2	.84	1	2	3	32	35	33	42
950424770	Crane Group	AS-39-40	1	2	2.26	0						

*Identifies cranes for which ship operating time has been adjusted to reflect first appearance of data in narratives.

**Identifies an obsolete component.

†Identifies cranes that are identical; therefore, the data have been combined for computational purposes.

‡Only AS-37 reporting.

#These cranes were originally installed on both AS-36 and AS-37, but the AS-37 boat crane has been replaced by a 95,000-pound boat and missile crane from AS-33. Data shown are those for AS-37. However, for purposes of analysis, it is assumed that the AS-36 boat crane experienced a maintenance history similar to that of the AS-37 boat crane.

##Crane originally on AS-33 per NAVSEA 5143. Subsequently installed on AS-37.

Note: Average man-hours per equipment per operating year is calculated as follows:

$$\frac{\text{Total Man-Hours}}{\text{Total Ship Operating Hours}} \div \frac{\text{Total Equipment Population}}{\text{Number of Ships}}$$

In general, the maintenance burden of the cranes increases with crane size. The maintenance burden range (with the exception of the AS-37) for the airplane, boat, repair, and missile cranes is from 54 to 778 man-hours per crane per operating year. These cranes have a lifting capacity ranging from 30,000 to 115,000 pounds. The maintenance burden range for all remaining cranes (traveling and bridge, cargo and sail, and paravane and stores), which have a lifting capacity of between 2,200 and 12,000 pounds, is 23 to 412 man-hours per crane per operating year. There is a correlation between maintenance burden and lifting capacity of the crane because the complexity of a crane and the number of its components generally increase with an increase in size or lifting capability, which one would normally expect to result in an increase in maintenance burden. This correlation is confirmed by an analysis of the mean corrective man-hours per repair (MCMR), which is total man-hours divided by the number of JCNs. It should be noted that this is a "best case" figure since it is being assumed that all JCNs have been completed, which is not the case. Cranes with a lifting capability of 30,000 to 115,000 pounds have a range of MCMR between 14 and 320 man-hours, with an overall average MCMR of 75 man-hours. The MCMR for cranes with a lifting capability of 2,200 to 12,000 pounds ranged from 23 to 59 man-hours, with an overall average of 43 man-hours.

Age is also a significant factor with respect to the maintenance burden of the cranes. In general, the older the crane, the higher the maintenance burden. The average annual maintenance man-hour burden for the older AD-14, AR-5, AS-11, AS-19, and AS-31 Class ships is 245 man-hours per crane per operating year, while the average is 186 man-hours per crane per operating year for the newer AD-37, AS-33, AS-36, and AS-39 Class ships. Every ship in the AD-14, AR-5, and AS-11 Classes was built prior to 1944 and, for the most part, the original cranes or modifications of the original cranes are still installed. Ships with the older cranes have reported the nonavailability of repair parts and material to perform PMS. These problems are discussed in greater detail in Section 3.2.4.

Evaluation of the crane's maintenance data showed that regardless of the size of the crane, the same problem areas plague all of them. These areas are categorized and defined in Table 3-2.

Each category was selected solely on the basis of the number of crane failures or malfunctions that could be directly attributed to that classification. (Note: Many individual problem areas are covered by each category, but no single problem, component, piece, or part within a category contributed to more than a third of the total problems reported within that category. If the contribution had exceeded one-third, a new category would have been created.)

Corrosion and moisture are reported as a separate category, since some failures were directly attributable to this problem area. In many cases, corrosion and moisture also were a contributing factor to the malfunction or failure in another category. For example, some of the hydraulic system contamination problems were the result of water in the lines, and some electrical failures were the result of moisture in a critical component. Corrosion of the crane structure was unanimously reported against all crane

Table 3-2. CRANE SYSTEM PROBLEM AREAS		
Category	Definition	Problem Areas
Hydraulic	All hydraulic components with the exception of pumps, brakes, and motors.	Leaks, contamination, worn seals, ruptured or pinched lines, broken line supports, too much or too little hydraulic pressure.
Brake	All hydraulic or electric brake components.	Worn linings, scored drums, misaligned brakes, slipping brakes.
Electrical	All cabling, neutral and limit switches, controls, wipers, heaters, lighting, relays, timers, coils, amplifiers, and transformers.	Defective or failed electrical components, open circuits, short circuits, limit or neutral switches not properly set.
Motors and Pumps	All hydraulic and electric motors and pumps, all motor controllers and starters, and all couplings.	Defective controllers, misaligned/defective couplings, and hydraulic and/or electrical problems associated directly with a pump or motor.
Gears, Reducers, Take-up Reels and Bearings	All gears, reducers, wire drums and take-up reels, shafts, and bearings with the exception of those installed in a motor or pump.	Failure of any of these components, misaligned gears or reducers, broken or stripped gear teeth, scored drums or take-up reels.
Structural Failure	All components not covered by any of the above systems. Primarily fixed structural members, booms and jib extensions, hooks, operator's cab, doors, foundations, bolts, pivot pins, and mechanical linkages.	Failure of any of these components, broken welds, stress cracks, bent members, warped doors and dogs, sheared pins or bolts, and bound linkages.
Corrosion and Moisture	Exposed surfaces, chipped or peeling paint, missing protective covers, and violated watertight enclosures.	Any failure to any system or component solely attributable to corrosion or moisture.
Other	Problem area not assignable to one of the above areas.	Any other failure or problem area resulting in crane downtime.

APLs in the MDS data. Motors and pumps were categorized separately from hydraulic or electrical systems because of the number of failures that were attributed directly to them.

Appendix E presents summary CASREP data for all the topside boat, airplane, repair, missile, and traveling and bridge cranes installed on the AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. The data are presented in terms of the categories shown in Table 3-2. Table E-1 shows the downtime, number of CASREPs, percentage of CASREPs, and total number of ships reporting against the failure mode.

Twenty ship alteration and repair packages (SARPs) were also reviewed to determine the types of repairs generally performed on cranes during an overhaul. The remainder of this chapter describes the analysis of the maintenance experience of the cranes with respect to the categories shown in Table 3-2, identifies maintenance-based conclusions, and provides discussions of technical documentation, supply support, training, and PMS. The recommended maintenance strategy for cranes is also discussed.

3.2.1 Crane Maintenance Categorization

As discussed in Chapter Two, the MDS data were reviewed to identify recurring maintenance actions that require periodic outside maintenance. Table 3-3 summarizes the repairs in terms of the categories shown in Table 3-2. In each of the first seven categories listed, the table shows that the IMA man-hours exceeded the ship's force man-hours, indicating that the ship's force requires outside assistance to maintain the cranes. This finding is supported both through discussions with ship's force operating personnel and by the large number of MDS narratives that had a deferral code of 6, indicating a lack of facilities or capabilities. Even though all AD, AR, and AS Class ships have a resident intermediate maintenance activity, discussion with ship's force personnel showed that ship work centers are treated as separate reporting activities from repair division, in the same way as nonresident activities requesting IMA assistance. Our review of MDS data supports this; therefore, it cannot be assumed that any AD, AR, or AS Class ship systems, specifically cranes, are handled any differently from any other nonresident reporting activity.

Hydraulic system, electrical system, and structural repairs accounted for 62 percent of all JCNs and man-hours reported, and 83 percent of all parts costs reported.

A comparison of Table 3-3 with the CASREP data in Appendix E shows that the percentages of JCNs and CASREPs per category are similar, with the exception of the structural and "other" categories. Visits to the AD-18 and AS-36 confirmed that the hydraulic and electrical systems were the most troublesome for the ship's force to repair. All of the categories are discussed in the following paragraphs.

Table 3-3. MAINTENANCE DATA SUMMARY FOR AD, AR, AND AS CLASS SHIPS								
Maintenance Category	Number of JCNs	Man-Hours			Percentage of JCNs	Average Man-Hours per JCN	Parts Cost (Dollars)	Average Cost per JCN
		Ship's Force	IMA	Total				
Hydraulic System	113	6,861	8,302	15,163	14	134	30,772	\$272
Electrical System	151	3,839	5,108	8,947	19	59	45,990	305
Structural	218	5,130	14,646	19,776	28	91	46,708	214
Brake System	63	807	1,586	2,393	8	38	2,230	35
Motors and Pumps	50	1,738	3,255	4,993	6	100	5,804	116
Corrosion and Moisture	44	1,918	2,231	4,149	6	94	3,864	88
Gears, Reducers, Wire Drums, Take-Up Reels, Shafts, and Bearings	101	2,436	6,066	8,502	13	84	12,319	122
Other	42	4,031	2,867	6,898	5	164	1,384	33
Total	782	26,760	44,061	70,821	99	91	149,071	\$191

3.2.1.1 Hydraulic System

Hydraulic system repairs accounted for 113 JCNs, 15,163 man-hours (6,861 ship's force and 8,302 IMA), and \$30,772 in parts costs. Outside assistance was required for 55 repairs, or about 49 percent of the JCNs reported. The average maintenance burden as shown in Table 3-3 is 134 man-hours per JCN. Narratives for the repairs that required outside assistance indicated one of the following reasons:

- Faulty hydraulic control, relief, and transfer valves
- Low or high pressure in the system
- Leaking pipe fittings and joints, caused by faulty gaskets, "O" rings, galled fittings, or stressed lines or fittings
- Faulty or missing pressure gauges
- Contamination of the hydraulic system, including sumps (water and/or metal particles); in some systems no hydraulic filtering system is installed, e.g., AR-6
- Broken or missing hydraulic line supports, brackets, or hangers

Ship operating personnel reported that they were capable of repairing most hydraulic system failures but that parts were not on board. (Parts availability is discussed further in Section 3.2.4.) As a result, ship's force personnel requested the IMA to fabricate the needed parts or "jury rig" a repair. Ship's force personnel often used Teflon tape to effect temporary hydraulic leak repairs until the correct "O" ring, gasket, or seal could be obtained.

CASREPs

Fourteen CASREPs were reported as hydraulic system-related failures. Eleven of these were of C-2 severity, and three were of C-3 severity. There were no C-4 severity CASREPs. CASREP failures were reported primarily for excessive leaks (six), contamination (two), and deteriorated parts (two). In general, hydraulic system failures have degraded the crane capabilities to meet mission requirements.

Shipalts AR-0760, AD-1201, and AS-1447 address hydraulic system improvements for the AR-5, AD-14, and AS-11 Class ships' boat and airplane cranes, respectively. Sufficient 3-M data are not yet available to determine the effect of these shipalts on maintenance burden or improvement in reliability.

SARPs

Thirteen of 20 AD, AR, and AS Class ship SARPs reviewed indicated one or more of the following types of repairs being performed on crane hydraulic systems during overhauls:

- Perform class B overhaul of hydraulic system (excluding motors and pumps)

- Ultrasonically test all piping and replace deteriorated piping
- Install new gaskets and seals
- Install new hydraulic filters
- Drain, flush, clean, refill, and pressure-test the hydraulic system

The average for all hydraulic system authorized repairs is 278 man-days.

Recommendations

It is recommended that hydraulic system repairs and actions documented under the SARP heading continue to be performed during future overhauls. Failure to do so will result in increased intracycle maintenance burdens for the cranes.

3.2.1.2 Electrical System

Electrical system repairs accounted for 151 JCNs, 8,947 man-hours (3,839 ship's force and 5,108 IMA), and \$45,990 in parts costs. Outside assistance was required for 61 repairs, or about 40 percent of the JCNs reported. The average maintenance burden for electrical system maintenance actions as shown in Table 3-3 is 59 man-hours per JCN. The narratives for repairs that required outside assistance indicated one of the following reasons:

- Misadjusted, failed, or obsolete limit or neutral switches
- Lighting problems, deteriorated cabling, broken and missing fixtures, and inadequate lighting (panel lights, replenishment at sea [RAS])
- Shorted or open circuits
- Failed circuit breakers, relays, bus bars, insulators, heater coils, load cell sensors, and resistors
- Deteriorated electrical power cables
- Missing or inoperative windshield wipers
- Uncalibrated boom angle indicators
- Worn or corroded electrical contacts
- Missing protective covers (primarily on neutral and limit switches)

AS-19 reported that the neutral interlocks on the airplane and boat crane are no longer COSAL-supported. Discussions with ship operating personnel revealed that most limit and neutral switches are exposed to the weather, thereby causing failure of electrical components, which results in overrun of the boom or excessive traveling out and possible failures in the structure itself or in one of the other systems. One AD reported that aligning the airplane and boat crane in the neutral position

required two people -- one to observe the neutral switch and one to turn the crane control wheel manually until the switch indicated neutral. AD-18 personnel recommended that neutral indicator lights be installed at the crane control station.

CASREPs

Twenty-eight CASREPs were reported as failures related to the electrical system. Twenty-three of these were of C-2 severity and four were of C-3 severity. One C-4 severity CASREP was reported on an AS airplane and boat crane because an electrical short circuit was causing repeated main power failures. CASREP failures were reported primarily for misadjusted or failed limit or neutral switches (4), other failed components (12), and shorted or open circuits (7). A contributing factor in all electrical system failures is the presence of moisture in a component or deterioration of insulation caused by constant exposure to the weather.

SARPs

Eleven out of 20 AD, AR, and AS Class ship SARPs reviewed showed a class B overhaul for the electrical system requiring an average of 167 man-days per crane. Three additional SARPs required replacing the crane limit switches at an average of 8 man-days per crane.

Recommendations

Because the electrical system can present significant safety hazards, and in order to reduce the intracycle maintenance burden for electrical problems, it is recommended that class B overhauls continue to be performed during future overhauls. In addition, NAVSEA should review the electrical system designs to define necessary revisions to make the components moisture-proof and reduce the maintenance burden. Revisions could be as simple as relocating exposed components or as complex as complete redesign. Emphasis should be placed on limit and neutral switches, load cell sensors, breakers, and electrical contact points.

3.2.1.3 Structural

Structural repairs accounted for 218 JCNs, 19,776 man-hours (5,130 ship's force and 14,646 IMA), and \$46,708 in parts costs. Outside assistance was required for 143 JCNs, or about 66 percent of the JCNs reported. The average maintenance burden as shown in Table 3-3 is 91 man-hours per JCN. The narratives for repairs that required outside assistance indicated one of the following reasons:

- Damaged or missing protective doors, coverings, access panels, screens, gaskets, and guards
- Damaged or missing ladders or catwalks
- Damaged or missing padeyes

- Bent or missing pivot pins, control linkage pins, or hook shifting pins
- Bent or cracked boom
- Missing, sheared, or deteriorated bolts
- Bent or cracked structural members
- Warped or distorted tracks and frozen track rollers
- Excessive play in manual control linkages
- Fairlead blocks and sheaves in need of overhaul
- Damaged hoist and topping wires
- Foundation in need of strengthening

In most cases, structural repairs required the fabrication of a component, e.g., pins, covers, ladders, or catwalks, that was beyond the capability of the ship's force. This requirement accounts for the apparent high percentage of JCNs requiring outside assistance. Electrical, hydraulic, and brake system failures, as well as corrosion and moisture, are also contributing factors in structural failures.

CASREPs

Ten CASREPs were reported as structure-related failures. All of these were of C-2 severity. Structural CASREP failures were reported primarily for bound mechanisms (two), worn components (three), and bent or cracked members (three).

SARPs

All 20 of the SARPs reviewed showed one or more of the following types of structural repairs currently being performed during overhauls:

- Remove, clean, and inspect hoist and topping cables
- Perform class B overhaul of mechanical linkages
- Disassemble, clean, and inspect sheave assemblies and install new bushings
- Align operator controls
- Perform class B overhaul of fairlead blocks
- Repair or replace damaged covers, ladders, catwalks, padeyes, and structural supports
- Perform magnetic-particle tests on all hooks
- Perform static and dynamic weight tests

The average class C structural repair requires 35 man-days per crane, and class B overhauls of fairleads and mechanical linkages require 48 man-days per crane.

Recommendations

To reduce the intracycle maintenance burden for structural repairs, it is recommended that class B overhauls continue to be performed for fair-lead blocks and mechanical linkages during future overhauls. It is also recommended that class C repairs continue to be performed for remaining actions identified under the SARP heading during future overhauls.

3.2.1.4 Brake Systems

Brake system repairs accounted for 63 JCNs, 2,393 man-hours (807 ship's force and 1,586 IMA), and \$2,230 in parts costs. Outside assistance was required for 33 JCNs, or about 52 percent of the JCNs reported. The average maintenance burden for the brake system is 38 man-hours per JCN. Narratives for the repairs that required outside assistance showed one of the following reasons:

- Brake slippage
- Missing or broken brake linkages
- Worn, scored, or out-of-round drums
- Worn, glazed, or oil-soaked brake shoes
- Broken springs

The brake systems are for the most part uncomplicated when compared with the other systems. As a result, when repairs are required and parts are available, the ship's force can make repairs without outside assistance.

CASREPs

Eight CASREPs were reported as brake system-related failures. Seven of these were of C-2 severity and one of C-3 severity. Brake system CASREPs were reported primarily for brake failure and slipping (five), and missing, broken, or loose control linkages (two). The brake system had no supply downtime. AD-18 operating personnel revealed that they have had trouble in the past obtaining replacement shoes for the airplane and boat crane because of age.

SARPs

Eleven of 20 AD, AR, and AS SARPs reviewed indicated that the brake systems undergo a class B overhaul during the ship overhaul. Dye penetrant tests are also being performed on brake drums during the overhaul. Class B overhaul of the crane brake system requires an average of 34 man-days, and the dye penetrant test requires an average of 5 man-days per crane.

Recommendations

Since the brake systems represent the primary safety devices on the crane, it is recommended that class B overhauls and brake drum dye penetrant

tests continue to be performed on the crane brake systems during future overhauls.

3.2.1.5 Motors and Pumps

Motor and pump repairs accounted for 50 JCNs, 4,993 man-hours (1,738 ship's force and 3,255 IMA), and \$5,804 in parts costs. The average maintenance burden is 100 hours per JCN. Outside assistance was required for 23 repairs, or 46 percent of JCNs reported. Narratives for repairs requiring outside assistance indicated one of the following reasons:

- Pump or motor requiring a class B overhaul
- Sheared drive coupling
- Misaligned shafts and couplings
- Excessive bearing wear
- Frozen pump or motor
- Excessive leaks at pump or motor
- Excessive pump noise
- Deterioration of coupling spring packs
- Worn key or keyway

Ship operating personnel said that they were not aware of any specific repetitive motor and pump problems in cranes installed on the ships.

CASREPs

Eleven CASREPs were reported as motor-related and pump-related failures. Nine of these were of C-2 severity and two were of C-3 severity. Pump and motor CASREP failures were reported primarily for internal part failure (six), failed pump (two), and damaged coupling (two).

SARPs

Motor and pump repairs currently being performed during overhaul include the following:

- Fourteen of 20 SARPs reviewed indicated class B overhauls for electric and hydraulic motors and pumps requiring an average of 72 man-days per crane.
- Nine of 20 SARPs reviewed indicated class B overhaul for motor controllers requiring an average of 34 man-days per crane.

Recommendations

To reduce the motor and pump maintenance burden during the ship's intracycle, it is recommended that motors and pumps continue to receive

class B overhauls during shipyard availabilities. It is further recommended that motor controllers receive class C repairs during overhaul on the basis of POT&I results. It is estimated that class C repairs to motor controllers will require 23 man-days per crane.

3.2.1.6 Corrosion and Moisture (C&M)

Corrosion and moisture repairs accounted for 44 JCNs, 4,149 man-hours (1,918 ship's force and 2,231 IMA), and \$3,864 in parts cost. The average maintenance burden for C&M repairs is 94 man-hours per JCN. Outside assistance was required for 22 repairs, or 50 percent of JCNs reported. Corrosion- and moisture-related repairs were reported in narratives for all ships analyzed and were influencing failure factors in all crane systems. Narratives for repairs requiring outside assistance indicated one of the following reasons:

- Corrosion, chipped paint, rust, and pitted surfaces on interior and exterior of crane
- Rusted and pitted brake drums and cable take-up reels
- Corrosion and deterioration of foundations and foundation fasteners
- Rust and deterioration of hand rails, ladders, and catwalks
- Moisture damage to motors, controllers switches, fuse blocks, and control panels

AD-18 and AS-36 ship operating personnel reported that corrosion of the cranes is a severe problem requiring constant attention. They said that many part failures could be attributed to moisture and that many critical crane components were not adequately protected from the elements. Examples provided included limit and neutral switches, brakes, gears and reducers, and motors and pumps. AD-18 shipboard personnel recommended that all exposed metal surfaces be aluminum-flame-coated to eliminate structural problems such as rust, pitting, and deteriorating fasteners and welds.

CASREPs

Eight CASREPs were directly related to corrosion and moisture problems. Three of these CASREPs were of C-2 severity and four were of C-3 severity. There were no C-4 severity CASREPs. Water or moisture in pumps or motors accounted for five CASREPs; moisture in a transformer caused a class C fire, which resulted in the loss of the transformer; and a mid-boom bolt on an AS boat and missile crane was sheared as a result of corrosion.

SARPs

Fifteen of 20 SARPs reviewed showed corrosion repairs being performed during overhaul; these consisted of chipping, wire brushing, cleaning, and painting crane interior and exterior rusted areas. Chipping, wire brushing, cleaning, and painting averaged 23 man-days per crane.

Recommendations

It is recommended that chipping, wirebrushing, cleaning, and painting continue to be performed as needed. It is further recommended that NAVSEA review the weatherproofing design of the cranes. Access panels, doors, protective covers, and guards should be reviewed to determine the need for the application of gaskets or seals and dog or tie-down features. NAVSEA should also investigate the feasibility and cost-effectiveness of applying state-of-the-art corrosion-control measures or paint systems to the cranes. Examples of corrosion measures that should be considered are as follows:

- Applying wire-sprayed aluminum and a polyamide epoxy coating to foundations, foundation bedplates, booms, kingposts, and large sheaves
- Applying ceramic metallic coatings, sealants, and topcoatings to bolts, other fastener components, pipe and hydraulic line hangers, and electrical connection boxes

3.2.1.7 Gears and Reducers, Cable Reels, and Bearings

Repairs to gears and reducers, cable and take-up reels, shafts, and bearings accounted for 101 JCNs, 8,502 man-hours (2,436 ship's force and 6,066 IMA), and \$12,319 in parts costs. The average maintenance burden as shown in Table 3-3 is 84 man-hours per JCN. Outside assistance was required for 49 JCNs, or about 48 percent of the total JCNs for this category of problems. Narratives for repairs requiring outside assistance indicated one of the following:

- Worn gears and reducers or chipped and broken teeth
- Excessive play or backlash in gear boxes or vibration
- Gearcase oil leakage
- Excessive vibration in cable drums or take-up reels
- Contaminated gear cases
- Worn keys and keyways
- Worn take-up reel clutches
- Excessive bearing wear
- Gear misalignment
- Pitted and worn slip rings on take-up reel

CASREPs

Thirteen CASREPs were reported as gear and reducer, cable reel, shaft, and bearing failures. Ten CASREPs were of C-2 severity and three were of C-3 severity. CASREP failures were reported for component failure (seven), excessive play in gears (two), and excessive wear of cable reels and bearings (two).

SARPs

Thirteen of 20 SARPs reviewed showed the following repairs currently being performed on gears and reducers, cable reels, and bearings during overhauls:

- Open, inspect, clean the sump, fill with new oil, install seals, and align leaking gears and reducers.
- Clean, inspect, and measure tolerances of gears and reducers, bearings, and cable reels.

Gear and reducer, cable reel, and bearing repairs averaged 64 man-days per crane.

Recommendations

To reduce the maintenance burden for gears and reducers, cable reels, and bearings between overhauls, it is recommended that on the basis of POT&I results, class C repairs identified under the SARP heading continue to be performed during future overhauls.

3.2.1.8 Other

The "Other" category accounted for the 42 remaining JCNs, 6,898 man-hours (4,031 ship's force and 2,867 IMA), and \$1,384 in parts costs. The average maintenance burden was 164 man-hours per JCN. Outside assistance was required for 23 JCNs, or about 55 percent of those reported. Narratives indicated some of the following:

- Unavailability of repair parts (APL 571400012 reported by AS-18)
- Overhaul of crane in accordance with AD-1201 (APL 571880006 reported by AD-18; Shipalt AD-1201 currently being performed)
- Accomplishment of Shipalt AR-760K (APL 571010002) reported by AR-5 (this shipalt scheduled for ROH commencing 29 January 1982)
- Requests for POT&I, shipyard overhaul, and certification
- Erratic operation
- Unreliability
- Safety hazards: leaks, nonskid surfaces not installed at operator's station, missing lights, missing nameplate data, incorrect crane lube chart

This category accounted for all remaining JCNs that did not fit into one of the previous categories. Narratives tended to be general and yet continued to emphasize the general state of disrepair of cranes, and hence dissatisfaction of ship operating personnel.

CASREPs

Seventeen CASREPs could not appropriately be included in one of the previous seven categories. Fourteen CASREPs were of C-2 severity and three were of C-3 severity. CASREPs were reported for component failure, with no specific component identified (two); crane hit by lightning (one); wire problems (bird-caging) (three); crane stall with full load (one); and general wear and tear (two). One AR reported a delay in completing the overhaul of both boat and airplane cranes caused by the late assignment of crane work during the last regular overhaul.

3.2.2 Maintenance Conclusions

The general condition of the cranes is best described as marginally satisfactory. Hydraulically operated cranes experience many nagging problems, primarily associated with leaks. The electrical system experiences failures occurring in most cases because the components are not weatherproofed. The failure of structures as a result of their location on the 02 level can be attributed directly to exposure to the elements or the failure of a hydraulic, electrical, or brake component, which itself may not be weatherproofed, causing an undue stress on the structure. Failures in one system or classification have a tendency to spill over to other systems, thereby degrading the entire crane.

Since no single crane system, equipment, or component was responsible for a majority of the corrective maintenance actions, the cranes should continue to be maintained on a run-to-failure basis between overhauls with repairs made by ship's force and with outside assistance as required. During overhauls, the cranes should continue to receive class B overhauls of hydraulic system, electrical system, motors and pumps, brakes, mechanical linkages, and fairlead blocks. Class C repair recommendations identified in Sections 3.2.1.1 through 3.2.1.7 should also be performed during overhaul.

The remaining recommendations discussed in the preceding sections could result in high expenditures of funds if adopted. For that reason, it is suggested that these recommendations be applied only to cranes that have a minimum remaining planned service life of five years.

3.2.3 Technical Manuals

A review of crane technical manuals indicates that maintenance and operation content ranges from inadequate to good. Some of the manuals are basically instructions for operating the crane, providing little if any information on maintenance and troubleshooting. In addition, the manuals contain no tables of contents, are of poor legibility, and have not been updated to reflect any changes to the cranes. Examples of inadequate manuals are as follows:

- NAVSHIPS 317-0020, *Instruction Book for Paravane and Stores Crane* (applicable to AD-14, AD-15, AD-17, and AD-18)
- NAVSHIPS 317-0028, *Instruction Manual for Paravane and Stores Crane* (applicable to AS-11, AS-12, AS-18, and AS-19)

- NAVSHIPS 320-0917, *Instruction and Parts Manual for Cargo and Torpedo Cranes* (applicable to AS-31 and AS-32)
- NAVSHIPS 317-0032, *Instructions for Care and Operation of Boat and Airplane Crane Machinery* (applicable to AD-19, AR-8, and AS-19)
- NAVSHIPS 317-0060, *Instructions for Installation, Operation, and Maintenance of U.S. Navy Type Cranes for AR-6 and AR-7*

Ship operating personnel on board the AD-18 reported that their copy of the boat and airplane manual is a third-generation photocopy and is illegible. AS-36 ship operating personnel revealed that the crane manuals do not reflect the latest changes to the crane configurations and are not specific enough for ship's force use. Additional information concerning maintenance procedures and troubleshooting would assist ship's force in becoming more self-sufficient and would reduce the requests for outside assistance. It is recommended that NAVSEA review crane technical manuals for the AD-14, AD-37, AR-5, AS-11, AS-19, and AS-33 Class ships; update the manuals to reflect changes to the crane; and add troubleshooting and maintenance procedures to those that contain none. These actions should be taken only for cranes and ships that will not be deactivated in the near future.

Examples of good-quality technical manuals include the following:

- NAVSHIPS Technical Manual S9583-AA-MMO-010/30 Ton, *30-Ton Repair and Boat Crane* (applicable to AS-39 and AS-40)
- NAVSHIPS Technical Manual 0920-051-2010, *Operation and Maintenance Instructions for 47.5 Ton Capacity Boat and Missile Crane* (applicable to AS-31 and AS-32)

3.2.4 Supply Support

A double asterisk (**) next to an APL number in Table 3-1 identifies cranes that are obsolete in terms of supply support. The APL in each case contains a statement designating the crane as obsolete. The obsolete cranes are the original cranes installed on the older AD, AR, and AS Class ships. As a result of obsolescence or age, the manufacturer generally no longer provides parts support, making repair parts difficult to obtain. Parts usage data do not reflect the unavailability of certain crane parts, because the MDS shows part issues and not part requisitions. Ship operating personnel are then forced to attempt one or more of the following:

- "Jury rig" a repair part until a permanent solution can be found.
- Obtain a replacement part from the manufacturer. It may be either the same part (rarely) or a newer one having the same form, fit, and function.
- Request outside assistance from an IMA or shipyard in fabricating a replacement part. Most of the JCNs requiring outside assistance to effect structural repairs and repairs to gears and reducers required the fabrication of parts, including gears, linkages, pins,

spacers, access panels, protective covers, and bushings. Electrical and hydraulic system repairs often required the IMA to fabricate electromechanical limit and neutral switches and stops, as well as hydraulic lines, seals, and gaskets.

- Where possible, cannibalize parts from another crane to keep at least one crane operational.

Ship operating personnel on AD-18 and AS-36 reported that parts are hard to obtain and usually have an extremely long lead time, and that many crane repair parts are not carried on board. They said that parts in greatest demand include limit switches, mechanical seals, and "O" rings. The availability of these types of repair parts would assist ship's force in becoming more self-sufficient and would reduce the requests for outside assistance. The following supply support-related actions are recommended:

- NAVSEA should determine the supportability of the obsolete cranes. Factors that should be examined include parts availability, alternate sources of parts, and the identification and availability of parts having the same form, fit, or function
- NAVSEA should provide the TYCOM with supportability analysis results for appropriate action.

3.2.5 Training

One AS revealed that the lack of formal training for personnel in the division (including petty officers first class) has caused several crane casualties. Specific casualties were not identified. Training courses are available, but the personnel are also responsible for maintaining the elevators, hoists, conveyors, and deck handling equipment, as well as the cranes. Consequently, the ship cannot afford to spare people for attendance at schools. The full extent of the training problem of all AD, AR, and AS Class ships analyzed is unknown. However, the TYCOM should review the training situation to ensure that NEC-qualified personnel are on board to maintain and repair the cranes.

3.2.6 PMS Requirements

Table 3-4 identifies the maintenance index pages (MIPs) reviewed. These MIPs are representative of all cranes installed on the AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. An A-069 on the MIP designates a boat, airplane, missile, or repair crane; and an A-159 generally designates a traveling and bridge or smaller cargo crane.

A substantial amount of preventive maintenance is required for all cranes, encompassing all aspects of inspection, cleaning, adjustment, and lubrication. The same periodicity is not always specified for similar equipment or components on the crane. An example is provided by brakes, of which there are several types: thruster, magnetic, electric, manual hydraulic; PMS requirements vary for similar brakes. Of the eight MIPs

Table 3-4. REVIEW OF CRANE MIPs FOR AD, AR, AND AS SHIP CLASSES

MIP	APL Applicability	Nomenclature
A-069/006-60	571010001, 571010002	Boat and airplane crane
A-159/007-50	571020001	Paravane and stores crane
A-159/007-60	571020007	Paravane and stores crane
A-159/041-50	571190002, 571190003, 571190004, 572080012	Cargo crane
A-159/008-80	571400010, 571400011, 571400012	Paravane and stores crane
A-069/048-50	571860002, 571860003	Airplane and boat crane
A-069/015-60	571880003, 571880004	Airplane and boat crane
A-069/003-60	571880006	Airplane and boat crane
A-069/010-60	571900001	Airplane and boat crane
A-069/045-50	578880040	Airplane and boat crane
WS-057/090-21	572080001	Bridge and traveling crane
A-159/016-AO	572080016	Cargo and sail crane
A-069/043-60	572080022	Boat crane
A-159/042-89	572240005	Cargo and sail crane
A-069/004-60	572330001, 572330002	Boat and missile crane
A-069/025-60	572330030	Kingpost crane
A-203/001-70	572330036	Crane
A-069/036-68	572330039	Airplane and boat crane
A-069/030-99	572450001	Boat and missile crane
A-069/047-70	572450003	Boat and repair crane

reviewed that required cleaning, inspecting, and adjusting of magnetic brakes, one required the task to be performed monthly, three quarterly, one semiannually, and three annually. Similarly, of the seven MIPs requiring cleaning, inspecting, and adjusting of thruster brakes, one required the task to be performed monthly, three quarterly, and three annually. NAVSEA should review the PMS requirements for the brakes and establish consistent requirements for similar types.

The periodicity of the PMS requirement to inspect foundation bolts for all applicable cranes varies between annual and cyclic. Since the cranes have experienced loose bolts, deteriorated or corroded bolts, and corrosion-related failures of the structure, it is recommended that the inspection of foundation bolts be performed annually.

Outside assistance is required for the following tasks:

- Wet or dry magnetic-particle inspection (MPI) of crane hooks -- to be accomplished annually or whenever the crane is suspected of being overloaded
- Dye penetrant test of brake drums -- to be accomplished during each shipyard overhaul or as required

Ship's force personnel said that they are satisfied with crane PMS requirements. Their only observation was that they were not capable of weight-testing the airplane and boat crane and required outside assistance to perform the test. Weight tests are required on all cranes every 48 months, during ROH, or after major repair or modification, whichever occurs first. Normally, these 23 ships, being IMA activities, are capable of weight-testing the cranes. However, it is recommended that ship's force allocate time for weight-testing, especially following major repairs. Some ship's force personnel reported that the cargo and sail cranes were in use daily from 0530 hours until the end of the day, which was generally after 2000 hours, and therefore could not be taken out of service for PMS. They reported that PMS was then usually performed on the weekends or not at all.

NAVSHIPS Technical Manual 0901-480-0002, Chapter 9480 (piping systems), specifies that hydraulic hoses or fittings must be replaced when there is any sign of leakage or potential failure. Section 9480.165 of this NSTM also specifies that all flexible hoses are to be replaced every five years (+6 months). Since two-thirds of the JCNs reported as hydraulic system repairs involved leaks and approximately half the CASREPs for hydraulic systems involved leaks, it is recommended that the following maintenance requirement be added to the MIPs for hydraulically operated cranes:

<u>Maintenance Requirement</u>	<u>Periodicity Code</u>
Renew flexible hydraulic hoses and fittings. NOTE: Accomplish during regular overhaul, every 60 months, or at any sign of leak or potential failure, whichever occurs first.	60M-R

3.3 MAINTENANCE STRATEGY

The results of this analysis indicate that no single crane system, equipment, or component was responsible for a majority of the corrective maintenance actions during the data period examined, but many corrective maintenance actions and man-hours were necessary to keep the cranes operational. Repairs to the cranes will be required during the operational cycle and ROH. Specific operational cycle repair cannot be defined until a failure occurs; however, specific class B overhauls and repairs can be accomplished at the depot level, reducing the ship's force and IMA workloads. Class B overhauls should continue to be performed during future ROHs for the hydraulic system, electrical system, motors and pumps, brakes, mechanical linkages, and fairlead blocks.

It can be expected that repairs will be required during the operating cycles at random intervals and that they can normally be completed by ship's force with IMA assistance. The amount of IMA assistance will depend to a great extent on the availability of repair parts; nonavailability of repair parts may make it necessary to fabricate parts, resulting in continued long downtimes and the degradation of the capability to meet mission requirements. Fabrication of structural parts such as ladders and catwalks by the IMA or shipyard will continue to be required, since these are not considered repair parts and consequently are not stocked.

On the basis of the findings of this analysis, it is recommended that the maintenance strategy for the cranes continue to be run-to-failure, with emphasis on the following:

- Ship's force performs preventive maintenance in accordance with PMS requirements and the recommended changes to PMS.
- Corrective maintenance continues to be performed to the piece-part replacement level by ship's force.
- Outside assistance is required for the following:
 - Wet or dry MPI of crane hooks annually or as needed
 - Dye penetrant test of brake drums during ROH or as needed
 - Weight tests (may require assistance for larger boat, airplane, missile, and repair cranes) each 48 months, during ROH, or after major repair or modification
- Class B overhauls of the hydraulic system, electrical system, brake system, motors and pumps, mechanical linkages, and fairlead blocks continue to be performed during ROHs.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The cranes can be best described as marginally satisfactory. Hydraulically operated cranes experience many nagging problems, primarily associated with leaks. The electrical system experiences failures, most of which occur because many of the components are not weatherproofed. Failure of structures as a result of their location on the 02 level can be attributed directly to exposure to the elements or the failure of a hydraulic, electrical, or brake component, which itself may not be weatherproofed, causing an undue stress on the structure. Failures in one system or classification have a tendency to spill over to other systems, thereby degrading the entire crane.

Additional conclusions of the analysis are as follows:

- Corrosion and moisture are significant problems with respect to the crane structure and all crane systems. Weatherproofing for most of the cranes is virtually nonexistent.
- Spare parts for the cranes are not carried on board and are virtually nonexistent for the older cranes, making it necessary for IMA and depot activities to fabricate them.
- Technical manuals constitute a problem because many of them do not provide troubleshooting or maintenance procedures. Some have not been updated to reflect changes to the configuration of the cranes, and some are virtually illegible because of age.
- Since no single crane system, equipment, or component was responsible for a majority of the corrective maintenance actions, the cranes should continue to be maintained on a run-to-failure basis, with preventive maintenance and repairs performed by ship's force with outside assistance as required. Class B overhauls of the hydraulic system, electrical system, brake system, motors and pumps, mechanical linkages, and fairlead blocks should continue to be performed during future ROHs.

4.2 RECOMMENDATIONS

Recommendations for scheduled corrective and restorative maintenance actions, which are to be accomplished by depots or IMAs, are summarized in Table 4-1. Improvements for the topside boat, airplane, repair, missile, and traveling and bridge crane equipment 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

These recommended improvements are summarized in Table 4-2.

TABLE 4-1. RECOMMENDED INA AND DEPOT CORRECTIVE AND RESTORATIVE MAINTENANCE ACTIONS:
TOPSIDE BOAT, AIRPLANE, REPAIR, MISSILE, AND TRAVELING AND BRIDGE CRANES

Task Number		No.	Component or System	Qty. Per Ship	Task Description	LOP	Est. per crane	Task Frequency	Reference Section
Task Type	Digit SWAB								
I	58821 58911 58921 79221	1	Crane Hooks	Varies	As required by the PMS, accomplish wet or dry magnetic particle inspection of crane hooks.	I	5 MD per crane	A or when crane is suspected of overload-line	3.2.6
I	58821 58911 58921 79221	2	Brake Drums	Varies	As required by the PMS, accomplish dye penetrant test of brake drums.	I	5 MD per crane	PCM, and as needed.	3.2.6
I	58821 58911 58921 79221	3	Weight Test	Varies	As required by the PMS, accomplish weight testing of the crane.	I	25 MD per crane	48-month PCM, or after major repair or modification.	3.2.6
I	58821 58911 58921 79221	4	Flexible Hydraulic Hoses and Fittings	Varies	Renew flexible hydraulic hoses and fittings.	I	40 MD per crane	PCM, or as needed.	3.2.6
E	58821 58911 58921 79221	5	Hydraulic System	Varies	Class B overhaul the hydraulic system (excluding motors and pumps), including: * Ultrasonically test all piping and replace deteriorated piping * Install new gaskets and seals * Install new hydraulic filters * Drain, flush, clean, refill and pressure-test the hydraulic system.	E	275 MD per crane	PCM	3.2.1.1
E	58821 58911 58921 79221	6	Electrical System	Varies	Class B overhaul the electrical system to include replacing the limit switches.	E	167 MD per crane	PCM	3.2.1.2
E	58821 58911 58921 79221	7	Structural System	Varies	Class B overhaul all mechanical linkages and fairlead blocks.	E	48 MD per crane	PCM	3.2.1.3
E	58821 58911 58921 79221	8	Structural System	Varies	Based on PMS results, perform class C repairs consisting of aligning all operator controls and repairing or replacing damaged rollers, ladders, catwalks, ladders, and structural supports.	E	35 MD per crane	PCM, or as needed	3.2.1.3
E	58821 58911 58921 79221	9	Brake System	Varies	Class B overhaul the brake system.	E	34 MD per crane	PCM	3.2.1.4
E	58821 58911 58921 79221	10	Motors and Pumps	Varies	Class B overhaul motors and pumps.	E	72 MD per crane	PCM	3.2.1.5
E	58821 58911 58921 79221	11	Motor Controllers	Varies	Class C repair motor controllers.	E	23 MD per crane	PCM	3.2.1.5
E	58821 58911 58921 79221	12	Crane	Varies	Strip, wirebrush, clean, and paint rust areas.	E	21 MD per crane	PCM, or as needed	3.2.1.6
E	58821 58911 58921 79221	13	Gears and Reducers, Cable Reels and Bearings	Varies	perform class C repairs, including: * For leaking gears and reducers - open, inspect, clean the sump, fill with new oil, install seals, and align. * Clean, inspect, and measure tolerances.	E	64 MD per crane	PCM	3.2.1.7

Table 4-2. RECOMMENDED IMPROVEMENTS TO TOPSIDE BOAT, AIRPLANE, REPAIR, MISSILE, AND TRAVELING AND BRIDGE CRANES

Component	Number	Recommendation	LOR	Periodicity	Reference Section
Design - Redesign or Replacement					
Crane Electrical Systems	1	Review the electrical system designs to define revisions necessary to make the components weather- and moistureproof, thereby improving reliability and reducing the maintenance burden. Specific emphasis should be placed on limit and neutral switches, load cell sensors, circuit breakers, and electrical contacts.	NAVSEA	--	3.2.1.2 3.2.2
Cranes	2	Determine the technical feasibility and cost-effectiveness of applying state-of-the-art corrosion-control measures or paint systems to the cranes.	NAVSEA	--	3.2.1.6 3.2.2
Access Panels, Doors, Protective Covers and Guards	3	Review the weatherproofing design of the cranes to determine the need for applying gaskets or seals and dog or tie-down features.	NAVSEA	--	3.2.1.6 3.2.2
Design - Shipalts					
Neutral Indicator Lights	4	Analyze the control station on each crane to determine the need for neutral indicator lights (AD-18 recommendation) and develop a shipalt for installation.	NAVSEA	--	3.2.1.2 3.2.2
Maintenance Strategy Improvements - PMS Changes					
Crane Brake Systems	5	Establish consistent requirements for the same brake types.	NAVSEA	--	3.2.6
Foundation Bolts	6	Standardize the inspection of foundation bolts to Annual rather than Cyclic periodicity.	Ship's Force	A	3.2.6
Maintenance Strategy Improvements - Policy					
Cranes	7	During the intracycle, maintain cranes in accordance with PMS (existing and as modified by this report's recommendations) and a run-to-failure strategy, with ship's force making repairs and IMAs providing assistance as necessary.	--	--	3.2.6
Support Improvements - ILS Improvements					
Crane Supportability	8	Because of age and lack of availability of repair parts, perform supportability analyses on the AD-14, AD-37, AR-5, AS-11, AS-19, and AS-31 ship classes to determine the availability of repair parts and the usefulness of technical documentation (drawings and manuals).	NAVSEA	--	3.2.2 3.2.4
Crane Technical Manuals	9	Review the AD-14, AD-37, AR-5, AS-11, AS-19, and AS-33 technical manuals; add maintenance and troubleshooting procedures to technical manuals; and ensure that all manuals reflect changes to the crane configurations.	NAVSEA	--	3.2.3

APPENDIX A

SYSTEM BOUNDARIES FOR TOPSIDE CRANES INSTALLED ON AD, AR, AND AS 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-098-6010, dated March 1981. It defines the boundaries of the boat, airplane, repair, missile, and traveling cranes, 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 588-2

SWLIN: 58821 Title: Handling and Support Facilities, Aircraft/
Helicopter

Includes authorized work for:

Handling, Servicing, and Stowage of Aircraft and Helicopters

Associated Equipment:

Crash cranes	*Nitrogen charging cart
Controllers	Operating gear
Drive gears	Rack gears
*Fuel piping	*Retractable hanger
*Hanger doors	*Tie-down devices
*Helicopter grounding system	*Tow bars
*Hose reels	*Towing bridles
*Hoses	*Tow tractors
Meters	Valves
Motors	*Water piping

Asterisks (*) identify associated equipment that was not applicable and hence not considered during this analysis.

SWAB 589-1

SWLIN: 58911 Title: Cranes, Rotating

Includes authorized work for:

Structural, Mechanical, Electrical, and Hydraulic
Components of the Rotating Crane

Associated Equipment:

Bearings	Limit switches
Blocks	Machinery house assembly
Booms	Manual controls
Brakes	Piping
Bumpers	Pumps
Cables	Rotating gears
Consoles	Sheaves
Controllers	Speed reducers
Control levers	Switches
Foundations	Wire rope drums
Hooks	Wiring from controller to electric components
Kingposts	

SWAB 589-2

SWLIN: 58921 Title: Cranes and Hoists

Includes authorized work for:

Structural, Mechanical, Electrical, and Hydraulic
Components of Bridge Cranes, Monorail Hoist Systems, and Side Port Hoists

Associated Equipment:

Accumulators	Ladders	Speed reducers
Brakes	Load blocks	Switches
Bridge	Locking devices	*Tow bars
Bumpers	*Monorails	Tracks
Collector assembly	Motors (electrical and hydraulic)	*Trolley buses
Controller	Operating gear	*Trolleys
Control levers	Operator's cab	*Trucks
Control panels	Piping	Valves
Foundations	Pumps	Winches
Gears	Sheaves	Wire rope
Hoist assemblies		Wiring

Asterisks (*) identify associated equipment that was not applicable
and hence not considered during this analysis.

SWAB 792-2

SWLIN: 79221 Title: Handling Equipment, Special Weapons

Includes authorized work for:

Handling Equipment

All electrical/mechanical special weapons handling equipments with all their internal parts; local and remote controls; indication, hoisting, safety, power, and operating equipments, with all interconnecting cables. Include air and hydraulic systems integral with equipments. Include cable from power source. Include lighting integral with equipments.

Associated Equipment:

*Air hoses	Motors
Bi-rail hoists	Piping
*Bomb trucks	Pumps
Bridge cranes	*Rail interlocks
Bridge crane track	*Strongbacks
Controllers	*Trolley hoists
*Fork lift trucks	*Trolley hoist tracks
Foundations	Valves
*Handling equipment stowage	*Weapon handling adapters
Hoist controls	

Asterisks (*) identify associated equipment that was not applicable and hence not considered during this analysis.

APPENDIX B

INSTALLATION CONFIGURATION OF BOAT, AIRPLANE, REPAIR, MISSILE, AND TRAVELING AND BRIDGE CRANES FOR AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, AND AS-39 CLASS SHIPS

The boat, airplane, repair, missile, and traveling and bridge cranes discussed in this report are composed principally of the components listed in Table B-1. 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 that component.

NOTE: The cranes installed on the AS-41 are listed in Table B-1. However, this ship was not included in the analysis, because it was commissioned after the cut-off date for the MDS and CASREP data reporting period.

Table B-1. INSTALLATION CONFIGURATIONS OF BOAT, AIRPLANE, REPAIR, MISSILE, AND TRAVELING AND BRIDGE CRANES FOR AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, AND AS-39 CLASS SHIPS													
Nomenclature (As listed on AF-1)	AF-1/CIC	Quantity by Hull Number											
		AD-14	AD-15	AD-17	AD-18	AD-19	AD-37	AD-38	AR-5	AR-6	AR-7	AR-8	AS-11
AIRPLANE & BOAT CRANE, 11050/10650/ 28000 LBS	571010001	2	2										
AIRPLANE & BOAT CRANE, 20000/40000 LBS	572330039	2											
LIMIT SWITCH, 69841147A	212102403	12					16	16					
PARAVANE & STORES CRANE, 10500/ / LBS	571020001	2	2										
AC MOTOR 440V 40HP	175501227	2	2	2	2								
AXIAL PISTON PUMP 850 PSI GPM	520010124	2	2										
AIRPLANE & BOAT CRANE, 45000/ 22500/ LBS	571880006			2	2								
GEAR ASSY SPD DECR 5.727 TO 1	692C26003			2	2								
FLEX SHFT COUPLING MAX BORE 3.250	780030054			2	2	2							
FLEX SHFT COUPLING MAX BORE 2.250	780030055			4	4	2							
FLEX SHFT COUPLING MAX BORE 2.250	780030056			4	4	4							
FLEX SHFT COUPLING MAX BORE 2.312	780030064			4	4	2							
FLEX SHFT COUPLING MAX BORE 3.000	780030065			2	2	2							
PARAVANE & STORES CRANE, 10500/ / LBS	571020007			2	2								
STARTER MOTOR, MAG LVP S23 440V WTPR	151400003			2	2								
CONTROLLER, AC, MAG LVP S22 440V WTPR	151400006			2	2								
AC MOTOR, 2SPD 440V 20/10/HP	175501117			2	2								

(continued)

Table B-1. (continued)

Nomenclature (As listed on AFL)	APL/CID	Quantity by Hull Number																								
		AS-14	AD-15	AD-17	AD-18	AD-19	AD-37	AD-38	FR-5	AR-6	AR-7	AR-8	AS-11	AS-12	AS-16	AS-18	AS-19	AS-31	AS-32	AS-33	AS-34	AS-36	AS-37	AS-39	AS-40	AS-41
ELECTRIC THRUSTER BRAKE, 11.0 INCH 440VAC DRPR	800050005			2	2										2											
AIRPLANE & ROAT CRANE, CAP 45000/ 18000/45000 LBS	571880003					2											1									
AXIAL PISTON PUMP, GPM 557 PSI VDEL	016010195					6											6									
AXIAL PISTON MOTOR, IN LBS/100 PSI	016010196					2											2									
AXIAL PISTON MOTOR, IN LBS/100 PSI	016010197					4											4									
AXIAL PISTON PUMP, GPM 586 PSI VDEL	016010198					2											2									
AXIAL PISTON MOTOR, IN LBS/100 PSI	016010199					2											2									
STARTER MOTOR, MAG LVP SZ4 440V WTFR	151401155					2											2									
STARTER MOTOR, MAG LVP SZ4 440V WTFR	151401156																	2								
STARTER MOTOR, MAG LVP SZ4 440V WTFR	151401158					2											2									
AC MOTOR, 440V 60 HP	175501285					2												2								
AC MOTOR, 440V 75 HP	175501314					2												2								
FOOT SWITCH, CR 2940-1 JJB	212400739					6											6									
FLEX SHAFT COUPLING, MAX BORE 2.125	780030063					4											4									
ELECTRIC THRUSTER BRAKE, IN 440VAC	800050006					4											4									
ELECTRIC THRUSTER BRAKE, 19.0 IN 440VAC	800050007					2											2									
ELECTRIC THRUSTER BRAKE, 14.0 IN 440VAC	800050008					4											4									

(continued)

Table B-1. (continued)

Nomenclature (As listed on APL)	APL/CID	Quantity by Hull Number																								
		AD-14	AD-15	AD-17	AD-18	AD-19	AD-37	AD-38	FR-5	AR-6	AR-7	AR-8	AS-11	AS-12	AS-16	AS-18	AS-19	AS-31	AS-32	AS-33	AS-34	AS-36	AS-37	AS-39	AS-40	AS-41
KINGPOST CRANE, 60000 LBS	572330030						2	2																		
ELECT. SPACE HEATER, 120/240VAC TYPE V	074000404						4	4																		
ARMATURE RELAY, 110V 3 POLE S45A481W B.	19890046						2	2																		
LIMIT SWITCH 10310H100-1	212102919						4	4										4	4							
1 ELEMENT SWITCH, S1151130	212900158						8	8																		
14 INCH FLOODLIGHT	232660006						4	4																		
FLUORESCENT LIGHTING FIXTURE, MS17150-13.2	049990011						2	2																		
ELECTRIC WINDSHIELD WIPER	350050013						4	4																		
CYLINDER ACT LIN 5.000 BORE 57.000 STNK 3000 PSI	854160037						4	4																		
CRANE 7000/12000 LB	572330036						2	2																		
AC MOTOR 440V 15 HP	174802804						2	2																		
AC MOTOR 440V 20 HP	174802811						2	2																		
AC MOTOR 440V 25 HP	174802835						2	2																		
AC MOTOR 440V 30 HP	174802836						2	2																		
LIMIT SWITCH, S569D410C01	212901002						2	2																		
SWITCH ASSY, 3 ELMT 3PSN S373D688C12	212902163						2	2																		
CABLE REELING MACHINE, 12000 LB WTRP HST	550200072						2	2																		

(continued)

Table B-1. (continued)

Nomenclature (As listed on APL)	Alt./CID	Quantity by Hull Number																								
		AD-14	AD-15	AD-17	AD-19	AD-19	AD-37	AD-38	AK-5	AR-6	AR-7	AR-8	AS-11	AS-12	AS-16	AS-18	AS-19	AS-31	AS-32	AS-33	AS-34	AS-36	AS-37	AS-39	AS-40	AS-41
TUPPING CONTROL SE84600-10	616140034						2	2																		
TRAVERSE CONTROL SE84600-11	616140036						2	2																		
GEAR ASSY SPD DECR AUX EQPT 33.000 TO 1.000 RATIO	692060098						2	2																		
BRIDGE CRANE	572350002						2	2																		
AIRPLANE & BOAT CRANE 45000/45000/ 16000 LBS	571010002								2																	
STARTER MTR, MAG LVP SZ5 440VAC WTPR	151400747								2	2	2	2														
STARTER MTR, MAG LVP SZ4 440VAC WTPR	151400795								2	2	2	2														
AC MOTOR 440V 70HP	175501296								2	2	2	2														
AC MOTOR 440V 150HP	175501348								2	2	2	2														
AXIAL PISTON MOTOR, IN LBS/100 PSI	520010029								4	4	4	4														
ELECTRIC BRAKE TORQUE MTR, 19.0 IN 440VAC DRPR	800050103								6			6														
ELECTRIC BRAKE THRUSTER, 14.0 IN 440VAC DRPR	800050129								4	4	4	4														
AIRPLANE & BOAT CRANE, 45000/45000/ 18000 LBS	571860002									2	2															
AXIAL PISTON MOTOR, IN LBS/100 PSI	520010074									6	6	6														
ELECTRIC BRAKE TORQUE MOTOR, 19.0 IN 440VAC DRPR	800050036									6	6															
AIRPLANE & BOAT CRANE, 45000/45000/ 18000 LBS	571860003											2														

(continued)

Table B-1. (continued)

Table B-1. (continued)																											
Nomenclature (As listed on APL)	APL/CID	Quantity by Hull Number																									
		AD-14	AD-15	AD-17	AD-18	AD-19	AD-37	AD-38	AR-5	AR-6	AR-7	AR-8	AS-11	AS-12	AS-16	AS-18	AS-19	AS-31	AS-32	AS-33	AS-34	AS-36	AS-37	AS-39	AS-40	AS-41	
AIRPLANE & BOAT CRANE, 45000/18000/ 45000 LBS	578880040											2															
ELECTRIC BRAKE TORQUE MOTOR, 10.0 IN 440VAC DRPR	800020044											4	4														
PARAVANE & STORES CRANE, 8960/2200/ LBS	571400010											2															
AC CONTROLLER, MAG LVP, SZ2 440V WTPR	151400860											2	2			2	2										
AC CONTROLLER, MAG LVP, SZ2 440V WTPR	151400861											2	2			2	2										
AC MOTOR, 3SPD 440V 20/5/5HP	175501119											2	2			2	2										
AIRPLANE & BOAT CRANE, 45000/18000/ 45000 LBS	571900001													2													
STARTER MOTOR, MAG LVP, SZ 440VAC WTPR	151201035													2													
CONTROLLER MOTOR, MAG LVP, SZ4 440VAC WTPR	151201053													4													
AC MOTOR, 440V 75HP	174750203													2													
AC MOTOR, 440V 100HP	174750204													2													
ELECTRIC BRAKE TORQUE MOTOR, 20.0 IN 440VAC DRPR	800020195													6													
PARAVANE & STORES CRANE, 8960/2200/ LBS	571400011													2													
AIRPLANE & BOAT CRANE, 45000/18000/ 45000 LBS	571880004																										
PEDESTAL CRANE	572570006																										

1 (IDENTICAL TO 571880003)

2

(continued)

Table B-1. (continued)

Nomenclature (As listed on APL)		APL/CID	Quantity by Hull Number																								
			AD-14	AD-15	AD-17	AD-18	AD-19	AD-37	AD-38	AR-5	AR-6	AR-7	AR-8	AS-11	AS-12	AS-16	AS-18	AS-19	AS-31	AS-32	AS-33	AS-34	AS-36	AS-37	AS-39	AS-40	AS-41
PARAVANE & STORE CRANE 8960/2200/ LBS		571400012															2	2									
BOAT & MISSILE CRANE, 95000 LBS		572150091																	2	2							
ELECTRIC SPACE HEATER 120VAC		074000008																	2	2							
AC MOTOR, 440V 50HP		174802538																	2	2		2		1			
AC MOTOR, 440V 75HP		174802541																	2	2		2		1			
AC MOTOR, 440V 3HP		174802757																	4	4							
LIMIT SWITCH, S582D884G04		212902188																	8	8							
ELECTRIC WINDOW WIPER		350050017																	4	4							
DUAL HOIST CONTROL, SE84601-5		616140037																	4	4							
CONTROL TOPPING DRIVE ASSY, SE84601-8		616140038																	4	4							
CONTROL SWING DRIVE ASSY, SE84601-11		616140039																	4	4							
CARGO CRANE, 5000 LBS		571190002																	2								
FLEX SHAFT COUPLING, MAX BORE 2.500		780320001																	5	3							
CARGO CRANE, 5000 LBS		571190004																	2	2							
CARGO CRANE, 5000 LBS		571190003																	1	1							
BOAT & MISSILE CRANE, 115,000 LBS		578880043																		2							
BOAT & MISSILE CRANE, 95,000 LBS RH		572330001																			1						
AC MOTOR 440V 60HP		174802539																				2		1			
AC MOTOR 440V 50HP		174802540																				4		2			

(continued)

Table B-1. (continued)

Nomenclature Listed on APL	APL/CID	Quantity by Hull Number															
		AD-14	AD-15	AD-17	AD-19	AD-37	AD-38	AR-5	AR-6	AR-7	AR-8	AS-11	AS-12	AS-16	AS-18	AS-19	AS-31
ELECTRIC WINDOW WIPER	350050006																
BOAT & MISSILE CRANE, 95000 LBS LH	572330002																
GANTRY CRANE, 7000 LBS	572080012																
ROTARY SWITCH, L100WNC2MLA01-18	210310022																
LIMIT SWITCH, 9007-AW-48	212830461																
CABLE REELING MACHINE, MOTOR DRIVEN	550390001																
INLET CHECK VALVE, .25IPS 5000 PSI	882034254																
NEEDLE VALVE, .25IPS 5000 PSI	882232242																
CARGO & SAIL CRANE, 10000 LBS	572080016																
DC MOTOR 240V 30HP	172503188																
DC MOTOR 240V 15HP	172503189																
DC MOTOR 240V 15HP	172503190																
DC MOTOR 240V 50HP	172503191																
MOTOR GENERATOR, 440V 75HP 40KW	181800098																
BOAT CRANE, 30000 LBS	572080022																
STARTER MOTOR, MAG LVP, SZ4 440V DRPR	175504137																
REPAIR & BOAT CRANE 60000 LBS	572450003																
BRIDGE & TRAVELING CRANE, 65000 LBS	572080001																
CARGO & SAIL CRANE, 10000 LBS	572240005																
CRANE, WHEEL MOUNTED MODEL 40SC	950004770																
CRANE GROUP	950424770																

APPENDIX C

CRANE COMPONENT COMMONALITY

A component commonality analysis was conducted on the 34 topside boat, airplane, repair, missile, and traveling and bridge cranes installed on board the AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. The purpose of the analysis was twofold: (1) to determine if any commonality of components existed among the cranes, and (2) to attempt to correlate component commonality to recurring problem areas reported in the 3-M data -- that is, identify the bad actors. The results of this comparison are shown in Table C-1.

The results of the analysis show that the following cranes are identical even though they have different APLs:

- 5,000-pound cargo crane reported under APLs 571190002, 571190003, and 571190004
- 45,000-pound airplane and boat crane reported under APLs 571860002 and 571860003
- 8,960-pound paravane and stores crane reported under APLs 571400010, 571400011, and 571400012
- 45,000-pound airplane and boat crane reported under APLs 571880003 and 571880004
- 95,000-pound boat and missile crane reported under APLs 572330001 and 572330002

Of the 34 topside boat, airplane, repair, missile, and traveling and bridge cranes analyzed, 27 are sufficiently different to be considered "unique" cranes.

The analysis further shows that on the unique cranes there is some commonality of components. The commonality usually occurs with limit and neutral switches, brakes, motor starters and controllers, flexible couplings, AC motors, and windshield wipers.

Table C-1. CRANE COMPONENT COMPARISONS		
APL	Nomenclature	Results
571010001 vs. 571010002	Airplane and boat crane 11,050/10,650/28,000 lbs. 45,000/45,000/16,000 lbs.	3 components on APL 571010001, 9 components on APL 571010002. No similarity of components.
571020001 vs. 571020007	Paravane and stores crane, 10,500/ / lbs.	3 components on APL 571020001, 9 components on APL 571020007. No similarity of components.
571190002 vs. 571190003 vs. 571190004	Cargo crane, 5,000 lbs.	All 3 components on each APL are the same. Cranes are identical.
571860002 vs. 571860003	Airplane and boat crane 45,000/45,000/18,000 lbs.	9 components on each APL - only difference is one component, an electric brake torque motor. APL 571860002 lists 800050036 (900 LBFT) and APL 571860003 lists 800050103.
571400010 vs. 571400011 vs. 571400012	Paravane and stores crane, 8,960/2,200/ lbs.	All 5 components on each APL are the same. Cranes are identical.
571880003 vs. 571880004 vs. 571880006	Airplane and boat crane, 45,000/18,000/45,000 lbs. 45,000/18,000/45,000 lbs.	571880003 and 571880004 have the same 22 components on each APL. These cranes are identical. 571880006 has 15 components on the APL. 5 flexible shaft couplings are identical to those on 57180003/4.
571900001 578880040	Airplane and boat crane 45,000/18,000/45,000 lbs. 45,000/18,000/45,000 lbs.	571900001 has 16 components listed on the APL. 578880040 has 4 components listed on the APL. 3 of the 4 components are identical. Only difference is a flexible shaft coupling.
572330001 vs. 572330002	Boat and missile crane, 95,000 lbs.	All 11 components on each APL are the same. Cranes are identical.
572330030 vs. 572330036	Kingpost crane, 60,000 lbs. Crane, 7,000/12,000 lbs.	572330030 has 30 components listed on the APL; 572330036 has 43 components listed on APL. Only 9 components are identical.
572330039	Airplane and boat crane, 20,000/40,000 lbs.	31 components listed on APL. Only 2 components common to 572330030.
572450001	Boat and missile crane, 95,000 lbs.	26 components listed on APL. 4 components are identical to those on 572330001 and 572330002.
578880043	Boat and missile crane 115,000 lbs.	2 components listed on the APL. No commonality.
572080001 vs. 572080012 vs. 572080016 vs. 572080022	Bridge and travelling missile crane, 65,000 lbs.; Gantry crane, 7,000 lbs.; cargo and sail crane, 10,000 lbs.; boat crane 30,000 lbs.	572080001 has 33 components listed on APL, 572080012 has 10 components listed on APL, 572080016 has 31 components listed on APL, 572080022 has 26 components listed on APL. Only commonality is one flexible shaft coupling, which is listed on both 572080016 and 572080022.
572240005	Cargo and sail crane, 10,000 lbs.	No component breakout provided on APL.
572350002	Bridge crane	No component breakout provided on APL.
572450003	Repair and boat crane 60,000 lbs.	No component breakout provided on APL.
572570006	Pedestal crane, 50,000 lbs.	No component breakout provided on APL.
950004770	Crane, wheel mounted Model 40SC	No APL available.
950424770	Crane group	No APL available.

APPENDIX D

INSTALLATION REDUNDANCY OF CRANES

Table D-1 summarizes the installation redundancy of topside boat, airplane, missile, repair, and traveling and bridge cranes for the AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships. It shows the number of installed cranes, number required to perform the lifting mission, and percentage of redundancy calculated.

Table D-1. INSTALLATION REDUNDANCY OF CRANES						
Ship Class	Boat, Airplane, Missile, and Repair Cranes			Bridge and Traveling Cranes (Cargo, Paravane, and Stores)		
	Number Installed	Number Required	Percentage of Redundancy*	Number Installed	Number Required	Percentage of Redundancy*
AD-14	2	1	100	2	1	100
AD-37	2	1	100	2	1	100
AR-5	2	1	100	--	--	--
AS-11	2	1	100	2	1	100
AS-19	2	1	100	3	1	200
AS-31	2	1	100	4	2	100
AS-33	2	1	100	2	1	100
AS-36	1**	1	0	2	1	100
AS-39	1**	1	0	2	1	100
*Calculated by: $\frac{(\text{Number Installed} - \text{Number Required})}{\text{Number Required}} \times 100$ **AS-36 and AS-39 Class submarine tenders also have a wheel-mounted crane, 950004770, and a crane group, 950424770, for which no data were available.						

APPENDIX E

CASREP SUMMARY

Table E-1 lists the major crane system failures reported in CASREPs. It includes a brief description of the failure, the number of CASREPs reporting that failure, and the total supply and maintenance downtime incurred as a result of the failure.

Table E-1. CASREP SUMMARY FOR AD, AR, AS CLASS SHIPS														
Failure Mode	Number of Failures by Ship Class								Number of CASREPs	Downtime (In Hours)			Percentage of CASREPs	Number of Ships
	AD-14	AD-37	AR-5	AS-11	AS-19	AS-31	AS-33	AS-36	AS-39	Supply	Maintenance	Total		
Hydraulic System Failure	4	--	3	2	2	--	--	--	3	2,448	34,690	37,138	13	8
Brake System Failure	2*	--	3	1	1	--	--	--	1	0	3,984	3,984	7	8
Electrical System Failure	8**	7	4	--	3	--	2	4	--	2,751	8,922	11,673	26	14
Motor and Pump Failures	4*	--	2	3	--	--	--	2	--	5,374	7,257	12,631	10	8
Gear, Reducer, Wire Drum, Shaft, or Bearing Failures	2	3*	1	4	--	--	2	1	--	2,206	7,153	9,359	12	8
Structural Failure	2	--	--	2	1	1	3	--	1	3,546	7,890	11,436	9	9
Corrosion or Moisture Failure	4	1	--	1	1	--	1	--	--	0	3,284	3,284	7	6
Other	4	--	2	1	--	4	1	3	2*	1,948	20,713	22,661	16	11
Total	30	11	15	14	8	5	9	10	7	18,273	93,893	112,166	100	--
Percentage of CASREPs Reported	28	10	14	13	7	5	8	9	6	--	--	--	100	--

*1 CASREP remaining open.

**2 CASREPs remaining open.

Note: No CASREP data reported on AD-19 or AS-41.

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 AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ships for the period 1 January 1975 through 31 July 1981.
2. CASREPs for the classes under study for the period 1 January 1978 through 31 July 1981.
3. COMNAVSURFLANT and COMNAVSURFPAC Type Commander's Coordinated Shipboard Allowance Lists (COSALs), dated 1 June 1981 and 1 July 1981, respectively.
4. COMNAVSUBLANT and COMNAVSUBPAC Type Commander's Coordinated Shipboard Allowance Lists (COSALs), dated 19 September 1981 and 24 June 1981, respectively.
5. Allowance parts lists (APLs) for selected components of the AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ship boat, airplane, repair, missile, and traveling and bridge cranes as identified in Appendix B, Table B-1.
6. Maintenance index pages (MIPs) and maintenance requirement cards (MRCs) for the AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ship boat, airplane, repair, missile, and traveling and bridge cranes.
7. Shipalt briefs and SAMIS shipalt information for AD-14, AD-37, AR-5, AS-11, AS-19, AS-31, AS-33, AS-36, and AS-39 Class ship boat, airplane, repair, missile, and traveling and bridge cranes.
8. Common configuration class lists (CCCLs):
 - AD-14, dated 6/25/80
 - AD-37, dated 10/27/81
 - AR-5, dated 10/25/81

9. Ship alteration and repair packages (SARPs):

- AD-14, dated 4/12/78
- AD-15, dated 6/28/76
- AD-15, dated 6/3/81
- AD-17, dated 5/2/77
- AD-18, dated 3/9/79
- AD-19, dated 4/3/80
- AD-37, dated 10/10/78
- AD-37, dated 4/26/79
- AD-38, dated 5/15/75
- AD-38, dated 10/1/79
- AR-5, dated 1/12/81
- AR-6, dated 9/25/78
- AR-7, dated 10/11/78
- AR-7, dated 8/31/79
- AR-8, dated 7/28/77
- AS-12, dated 10/17/79
- AS-19, dated 11/21/78
- AS-32, dated 5/5/81
- AS-33, dated 11/15/76
- AS-37, dated 5/12/77

10. Repair Profiles

- AD-14, dated 10/25/81
- AD-37, dated 10/25/81
- AR-5, dated 10/25/81

11. NAVSHIPS Supplement Technical Manual 0317-LP-001-0010, *Operation and Maintenance Instructions for Boat and Airplane Handling Crane* (applicable to AD-17).

12. NAVSHIPS Technical Manual 317-0020, *Instruction Book for Paravane and Stores Crane* (applicable to AD-14, AD-15, AD-17 and AD-18).

13. NAVSHIPS Technical Manual 317-0028, *Instruction Manual for Paravane and Stores Crane* (applicable to AS-11, AS-12, AS-18 and AS-19).

14. NAVSHIPS Technical Manual 317-0060, *Instructions for Installation, Operation and Maintenance U.S. Navy Type Cranes AR-6 and AR-7.*
15. NAVSHIPS Technical Manual 317-0021, *Operation and Care of Boat and Airplane Crane* (applicable to AS-11 and AS-12).
16. NAVSHIPS Technical Manual 317-0032, *Instructions for Care and Operation of Boat and Airplane Crane Machinery* (applicable to AD-19, AR-8, and AS-19).
17. NAVSHIPS Technical Manual 0920-013-6000, *Missile Handling Crane Type AT* (applicable to AS-19).
18. NAVSHIPS Technical Manual 320-1096, *Travelling Crane Model KX2D-3.5/36* (applicable to AS-33 and AS-34).
19. NAVSHIPS Technical Manual 0920-064-4010, *Travelling Cargo and Sail Service Cranes Model KE2D 5/55* (applicable to AS-36 and AS-37).
20. NAVSHIPS Technical Manual 0920-064-7010, *Description, Operation and Maintenance of Electro-Hydraulic Type Repair and Boat Crane KX3D-15/120* (applicable to AS-36).
21. NAVSHIPS Technical Manual S9583-AA-MMO-010/30 ton, *30-Ton Repair and Boat Crane* (applicable to AS-39 and AS-40).
22. NAVSHIPS Technical Manual 0378-043-4100, *Operating and Maintenance Instructions for the 47.5 Ton Capacity Boat and Missile Crane* (applicable to AS-34 and AS-37).
23. NAVSHIPS Technical Manual 0920-024-1010, *Technical Service Manual for 30-Ton Boat and Repair Crane* (applicable to AD-37 and AD-38).
24. NAVSHIPS Technical Manual 0920-023-8010, *Service Manual for 7000/12,000 Pound Travelling Crane* (applicable to AD-37 and AD-38).
25. NAVSHIPS Technical Manual 0920-051-2010, *Operation and Maintenance Instructions for 47.5 Ton Capacity Boat and Missile Crane* (applicable to AS-31 and AS-32).
26. NAVSHIPS Technical Manual 320-0917, *Instruction and Parts Manual for Cargo and Torpedo Cranes* (applicable to AS-31 and AS-32).
27. OPNAVINST 4790.4, *Material Maintenance Management (3-M) Manual, Volumes I, II and III*, June 1973.
28. OPNAVINST C3501.2E, *Naval Warfare Mission Areas*, 19 October 1977.
29. Ship Work Authorization Boundaries for Surface Ships, March 1981.

30. Ship Information Books (SIBs):

- AS-37, Volume I: *Hull and Mechanical*, with change 3, dated 1 December 1978.
- AS-31, Volume I: *Hull and Mechanical*, dated October 1967.
- AS-33, Volume I: *Hull and Hull Mechanical Systems*, with change 2, dated January 1978.
- AS-12, Volume I: *General Information*, with change 2, dated 1975.
- AS-37, Volume I: *Hull and Mechanical*, with change 1, dated 15 February 1980.

31. Results of ARINC Research Corporation visits to AS-36 (USS L. Y. SPEAR) on 20 January 1982; and to AD-18 (USS SIERRA) on 21 January 1982.

32. Grafton, C.M., *Cranes, Aircraft Elevators and Powered Closures* Branch, NAVSEA 5143, 12 and 14 January 1982.