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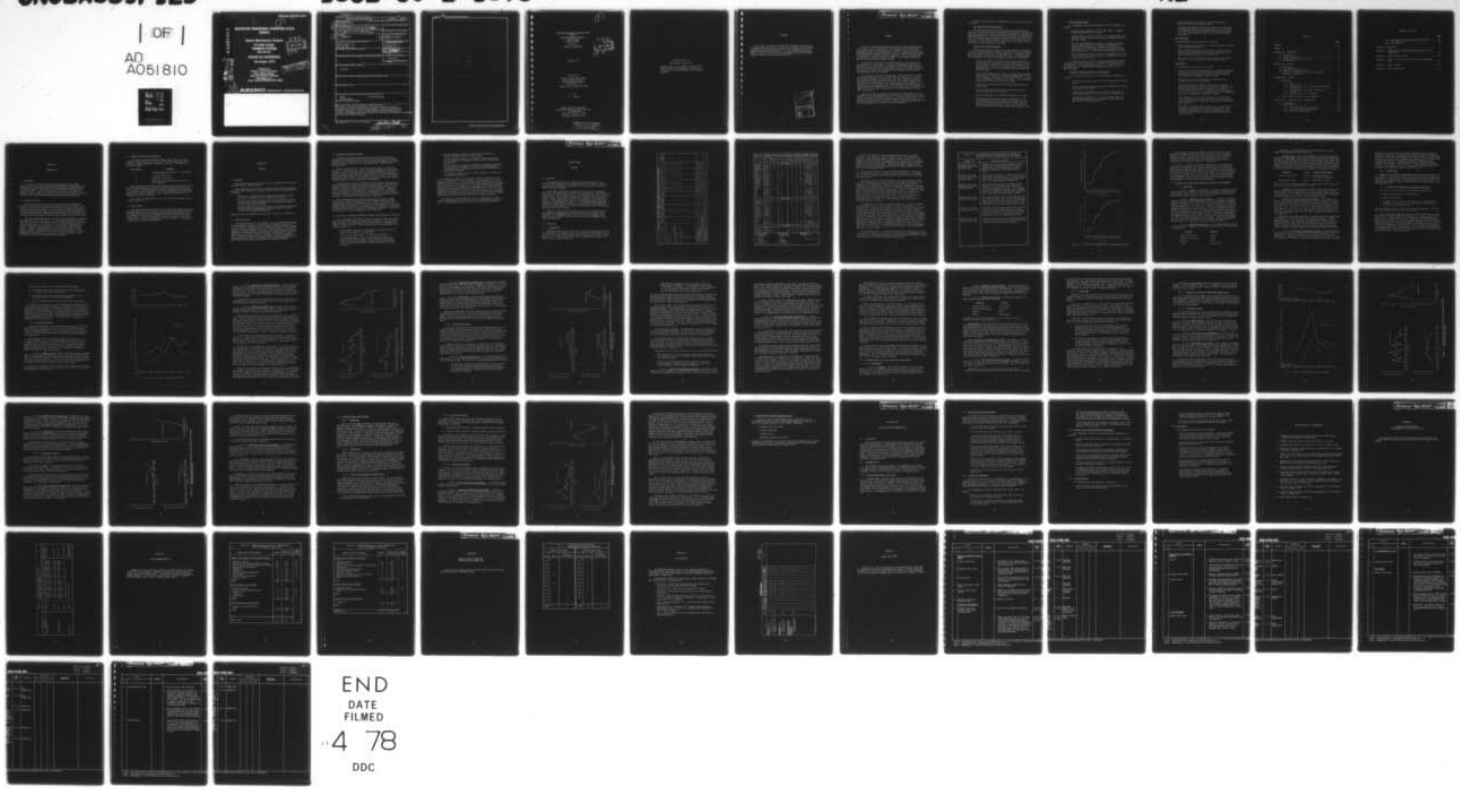

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DESTROYER ENGINEERED OPERATING CYCLE (DDEOC)

System Maintenance Analysis

FF-1052 CLASS FIREMAIN SYSTEM

SMA 203-521

REVIEW OF EXPERIENCE

November 1977

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Prepared for
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Ship Logistic Division
Naval Sea Systems Command
Washington, D. C.
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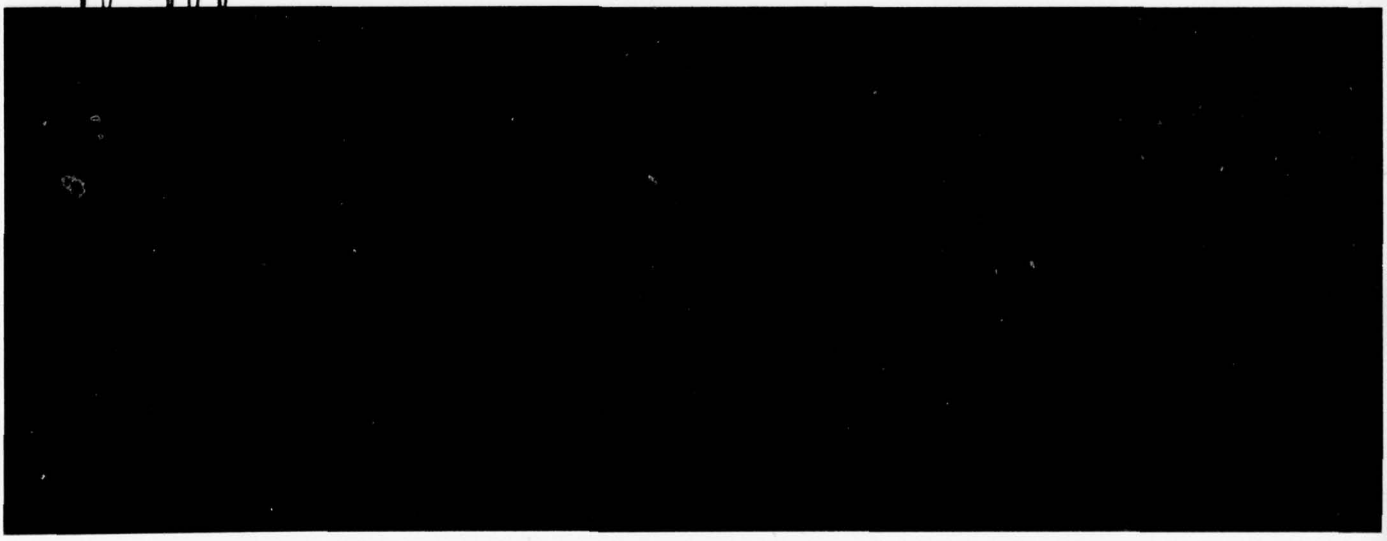

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This report, the Review of Experience, documents the historical maintenance experience for the FF-1052 Class Firemain System, presents an analysis of the problems encounetered, and recommends actions to improve system material condition. It has been developed for NAVSEA 934X, the sponsor of the Destroyer Engineered Operating Cycle (DDEOC) Program.

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by

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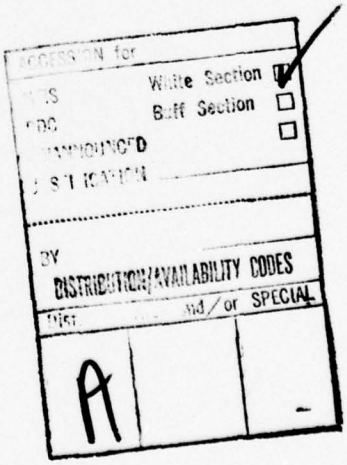
FOREWORD

This report, the Review of Experience, documents the historical maintenance experience for the FF-1052 Class Firemain System, presents an analysis of the problems encountered, and recommends actions to improve system material condition. It has been developed for NAVSEA 934X, the sponsor of the Destroyer Engineered Operating Cycle (DDEOC) Program, under Navy Contract N00024-78-C-4062.



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SUMMARY

The goal of the Destroyer Engineered Operating Cycle (DDEOC) 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 Maintenance Analyses (SMAs) are being conducted for selected systems and subsystems of designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the FF-1052 Class Firemain System.

The principal component of the Firemain System, the fire pump, has been subjected to major changes in design and maintenance support over most of the life of the class. Conversion of the conventional packing in both the Buffalo Forge and Fairbanks Morse vertical fire pumps to mechanical seals has recently been completed while upgrading to more erosion-resistant materials is in progress.

As the result of the various engineering change efforts, the configuration and performance of the FF-1052 Class fire pumps has not stabilized, making assessment of improvement difficult. Analysis of pump-end and motor-end bearing requisitions indicates that possible improvements in bearing life and mechanical reliability may have been achieved. Future performance will be affected by the implementation of the DDEOC maintenance strategy as recommended herein, and the installation of ShipAlts that affect the firemain load: a brine pump and auxiliary machinery cooling water supply pump.

This report does not address the feasibility, desirability, or cost effectiveness of the proposed ship alteration for the installation of horizontal fire pumps on FF-1052 Class ships. The report does, however, recommend close evaluation of the material condition and performance of the latest generation of vertical pumps in order to provide a quantitative base for decision-making with regard to the ship alteration.

The following actions are recommended as a result of the Firemain System ROE:

Fire Pump Maintenance Monitoring

The DDEOC Technical Group should monitor the performance and condition of the FF-1052 Class fire pumps using MDS data, site team inputs, and on-board fire pump operating-time information, as derived from Engineering Smooth Log. This monitoring should result in a determination of optimum planned maintenance intervals based on fire pump operating time. The monitoring should also result in an assessment of the performance of the upgraded vertical pumps for use in re-evaluating the decision to install horizontal fire pumps.

Baseline Overhaul Requirements

The Baseline Overhaul concept in the DDEOC program is designed to ensure that ships entering an extended cycle are in a state of material condition readiness that gives a high probability of operating without major restorative maintenance throughout the cycle. In keeping with this philosophy, the following maintenance actions are recommended:

- Overhaul the Buffalo Forge pumps to the specifications of TRS 0521-086-605, applicable to APLs 016150911 and 016150865. Install Alloy 20 components as supply assets permit and turn in bronze pump casings for refurbishment in accordance with NAVSEA policy. The overhauling agency should reinstall and align the pump.

- Overhaul the Fairbanks Morse Pumps to manufacturer performance specifications as detailed in Technical Manuals 0947-091-4011 (APL 016210239) or 0947-LP-229-7010 (APL 016210325). Install Alloy 20 components as supply assets permit. The overhauling agency should reinstall and align the pumps.

- Overhaul the Reliance Motors to the specifications of TRS 0521-086-606.

- The fire pump motor controllers and swing check valves should receive Class "B" overhauls.

- Resilient mountings and flexible piping should be renewed.

- The piping and miscellaneous valves associated with the Firemain System should be repaired in accordance with the ship's CSMP and the findings of the pre-overhaul test and inspection stipulated in MRCs 45 G66E N and T 92 B83V R on MIP A-604/2-B5, which covers PMS for the Firemain System.

Intracycle Maintenance

The recommended intracycle maintenance for the fire pumps is as follows:

- Realign all fire pumps at each SRA (IMA, SIMA, or shipyard with assistance from ship's force).
- Inspect pumps and replace bearings on all pumps and motors at each SRA, if such actions have not been performed since the last SRA or BOH.
- Use fire pump maintenance histories to verify or alter the initial planned maintenance intervals recommended in this report, and to determine the necessity of restorative maintenance at SRA for pumps and motors that have received major maintenance in the preceding interavailability period.
- Perform pump and motor PMS currently prescribed on MIPs E-28/205-55, E-28/231-46, and EL-4/28-17, as amended by the recommendations of this report.

The remaining components of the Firemain System should receive intracycle maintenance as currently specified by the PMS specific to the component. This recommendation applies to controllers and miscellaneous valves. General Firemain System PMS is specified on MIP A-604/2-B5.

Reliability and Maintainability Improvements

The recommended reliability and maintainability changes are as follows:

- Provide FF-1052 Class ships with a bearing heater or hydraulic press.
- Develop a Technical Repair Standard for Fairbanks Morse Pumps, APL 016210239 and 016210325.
- Investigate the possible role of gear-type couplings in reducing pump and motor bearing failure due to misalignment.
- Eliminate the discrepancy in the type of grease specified by TRS 0521-086-606, the fire pump technical manuals, and MRC C4 2KYS N on MIP EL-4/28-17.

- Develop a method for injecting a pre-measured amount of grease when lubricating motor bearings.

- Eliminate fire pump technical manual references to the use of a standard-fit bearing as an alternative to a loose-fit bearing on Reliance Motor APL 174752249. Ensure that the motor is on the proper Equipment Guide List to receive semiannual lubrication.

ILS Improvement

The recommended ILS improvements are as follows:

- Check to ensure that ships have the latest pump APLs consistent with the pump configuration.

- Revise Buffalo Forge Pump, APL 016150865, to show the proper number of impeller wearing rings, two per component, and to include onboard allowance for one spare rotor.

- Take steps to ensure that monel wearing rings are not issued for use on Alloy 20 impellers on Buffalo Forge Pumps.

PMS Changes

The recommended PMS changes are as follows:

- Revise MRC C4 2KYS N on MIP EL-4/28-17 to include a cautionary note on the dangers of over-lubrication, and referring the person doing the maintenance to the work center supervisor for direction on the amount of grease to add.

- Assign MIPs to Buffalo Forge Pump, APL 016150865, and Fairbanks Morse Pump, APL 016210325.

- Add instruction for recording as-opened and as-repaired wearing ring clearance, impeller diameter, and internal conditions on the 4790-2K to pump inspection MRCs, currently C3 D55T N and A6 K824 N. The periodicity should be changed to R-1. The note on when to accomplish should read "Accomplish when pump is overhauled or opened for repair".

- Add a management note to MIPs E-28/205-55 and E-28/231-A6 stating that the work center responsible for the pump maintenance should verify the semiannual lubrication of the driving motor bearings.

- Revise MRC T C3 D55Q N on MIP E-28/205-55 to conform to the procedure of NAVSHIPS 0947-068-1010, paragraph 4-7. This eliminates the requirement to have the Buffalo Forge Pump operating during the entire lubrication procedure and thus increases safety.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In support of the Destroyer Engineered Operating Cycle (DDEOC) Program, sponsored by NAVSEA 934X, System Maintenance Analyses (SMAs) are being conducted on selected systems and subsystems of program-designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the FF-1052 Class Firemain System, which was selected for analysis because components of this system are on the FF-1052 Class Maintenance Critical Equipment List.

1.2 PURPOSE AND SCOPE

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance of a ship system. The ROE report serves as a vehicle for assessing the significance and consequences of identified problems. It also presents specific recommendations and a system maintenance policy that will prevent or reduce the impact of maintenance problems while improving material condition and maintaining or increasing system availability throughout an extended ship operating cycle.

The analysis documented herein is specifically applicable to the Firemain System of the FF-1052 Class. Only those system components that had been installed or were aboard ship as of the fourth quarter of Fiscal Year 1976 were considered. The analysis used all available documented data sources from which system maintenance problems could be identified and studied. These included Maintenance Data System (MDS) data, Casualty Reports (CASREPs), Planned Maintenance System (PMS) requirements data, system alteration documentation, and system technical manuals. Sources of undocumented data employed in this analysis included discussions with ship's force and other cognizant technical personnel.

1.3 SYSTEM FUNCTION AND CONFIGURATION

The Firemain System distributes seawater under pressure to the fireplugs located throughout the ship. The system utilizes four motor-driven fire pumps, each rated at 900 gpm at 125 psig. The pumps are located as follows:

Fire Pump No.	Location
1	Auxiliary machinery room No. 1, lower level
2	Fireroom, lower level
3	Engineroom, lower level
4	Pump room, auxiliary machinery room, No. 2 first platform

The Firemain System also provides seawater to the Flushing System, the Auxiliary Machinery Cooling System, and the Distilling Plant brine eductors. Steaming instructions require that two fire pumps be operable as a precondition to getting underway. The Firemain System also provides emergency backup saltwater supply to various components including the main condenser and diesel generators.

The Firemain configuration on each ship of the FF-1052 Class is identified in Appendix A.

1.4 REPORT FORMAT

The remaining chapters of this report describe the analysis approach utilized (Chapter Two), briefly define significant system maintenance problems encountered and discuss potential problem solutions (Chapter Three), and summarize conclusions and recommendations derived from the analysis (Chapter Four). Specific analyses and evaluations supporting the results of this effort are included as appendixes to this report. A selected list of references precedes the appendixes.

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach to the performance of the ROE for the FF-1052 Class Firemain System.

The analysis was initiated at the component level at which Allowance Parts Lists (APL) numbers are assigned. Major steps of the analysis were as follows:

- Compilation of documented and undocumented maintenance history data from the sources listed in Chapter One, Section 1.2
- Analysis of the data to identify and define maintenance problems that will have significant impact on the maintenance program of the two systems during the DDEOC
- Detailed problem analysis and definition of alternative solutions for the purpose of recommending a specific course of action relative to the maintenance program.

These activities are described sequentially in Sections 2.2 through 2.4.

2.2 DATA COMPILATION

The analysis began with the compilation of a comprehensive data base on the maintenance history of the systems. The data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a system overhaul experience summary, and a system ShipAlt summary. A library of appropriate technical manuals, bulletins, and related documents was also assembled. The MDS data bank was compiled by examination of all MDS data reported for the FF-1052 Class from 1 January 1970 through 31 October 1976. CASREP information covering the period 1 July 1973 through 30 June 1976 was reviewed. Overhaul information was obtained from authorized Ship Alteration and Repair Plans (SARPs) for the FF-1052 Class.

2.3 MAINTENANCE PROBLEM DEFINITION

Potential maintenance problems associated with the system and its components were identified by a screening process employing data obtained from the above-described sources as well as from ship surveys, discussions with Navy technical personnel, and, when appropriate, NAVSEA special-interest items.

MDS data constituted the initial and primary source of information used in the screening process. This data base includes all part and labor records, as well as narrative material, describing maintenance actions reported against system components. Maintenance actions are represented by Job Control Numbers (JCNs). The purpose of the first step in the screening process was to identify the maintenance actions that had been reported against components of the system under investigation.

Computer-assisted analysis was next employed to quantify the man-hour and part-expenditure burdens incurred for each component. Individual components or component classes which had contributed significantly to the system's maintenance burden were selected for the analysis. Components were also selected for this purpose if they had generated a significant number of CASREPs or if other sources of information (e.g., ship surveys or overhaul experience) disclosed significant concern regarding maintenance problems or the maintenance programs for the components.

Detailed analysis of the selected components was directed toward defining each maintenance problem in terms of several specific factors. These were the effect of the problem on the component and system, the interval between occurrences of the problem, the redundancy of the affected component within the system, the criticality of the component to the system, the resources required to perform the maintenance necessary to correct the problem, and the expected component or system downtime.

2.4 ANALYSIS OF COMPONENT MAINTENANCE PROBLEMS AND DEFINITION OF SOLUTIONS

Once the component maintenance problems and their causes were identified, solutions were sought by examining each problem in relation to the extent to which it is recognized and its susceptibility to established types of corrective action. These analysis criteria are expressed in the following questions:

- Is the problem known to the Navy technical community and has a solution been proposed or established?
- Will a design change reduce or eliminate the problem?
- Is the problem PMS-related? Can the problem be reduced or eliminated by changes to PMS? (These changes might include adding or deleting requirements, changing requirement periodicity, or developing material condition assessment tests and procedures.)

- Can the problem be reduced or eliminated by improving the system's Integrated Logistic Support (ILS)?
- Can the problem be reduced or elimianted by improving ship's force, intermediate maintenance activity (IMA), or depot-level capabilities?
- Can the problem be reduced or eliminated by periodically performing restorative maintenance? Should this be accomplished at a Selected Restricted Availability (SRA) by ship's force, IMA, or depot-level facilities?
- Is the run-to-failure concept a viable maintenance strategy for the associated equipment?

An affirmative answer to any question resulted in analysis of the effects of the solution and in an estimate, when possible, of the cost to implement the solution. A negative answer prompted the analyst to go to the next question. After all the questions were answered, the alternative near-term and long-term solutions were evaluated and the most acceptable alternatives defined and documented as recommendations. "Near-term" recommended solutions are those that should be, and are likely to be, accomplished before completion of the initial FF-1052 Class Baseline Overhauls. "Long-term" recommended solutions are those not likely to be accomplished until some or all of the FF-1052 Class BOHs have been completed.

The historical overhaul experience for all installations of each selected component was then correlated with the recommended problem solutions. BOH recommendations for each selected component were defined.

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CHAPTER THREE

RESULTS

3.1 OVERVIEW

This chapter presents the results of analyses performed on the FF-1052 Class Firemain System, documenting the actions taken to identify and define the maintenance requirements of the system and to develop a DDEOC maintenance strategy.

The analysis described in Chapter Two resulted in the selection of three major system components for detailed investigation: the Buffalo Forge Pump (in FF-1052 through -1077), the Fairbanks Morse Pump (in FF-1078 through -1097), and the 100 horsepower Reliance Motor used as the driver for both pumps. MDS summary data for these components are presented in Table 3-1. Replacement parts reported in maintenance actions for these equipments are identified in Table 3-2. The CASREP analysis summarized in Appendix B corroborated the results of the MDS component screening and aided in the identification of repetitive maintenance actions and problems associated with the fire pumps.

Naval engineering and maintenance personnel were consulted during this analysis. Organizations providing input were USS THOMAS C. HART (FF-1092); USS SHENANDOAH (AD-26); Fleet Maintenance Assistance Group (FMAG), Norfolk; NAVSEC Code 6153; NAVSEA Code 045F; NAVSECMECHDIV; and SPCC, Mechanicsburg.

3.2 FIRE PUMPS

3.2.1 Introduction

Throughout this report the term "fire pumps" will be used to refer to the component of the Firemain System that consists of a pump end or liquid end, the motor that drives the pump, and the coupling that joins the pump and motor. The terms "Buffalo Forge Pump", "Fairbanks Morse Pump", or "pump" refer to the pump end only.

Table 3-1. MDS DATA SUMMARY OF SELECTED FIRE MAIN SYSTEM COMPONENTS

APL	Nomenclature	Applicable Ships	Components per Ship	Total Component Population	Total Ship Operating Time (Ship-Years)	Ships Reported	JCNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Parts Cost (Dollars)	Average Man-Hours/ Component Operating Year
016150582	Buffalo Forge Pump						1,647	19,961	15,554	35,515	403,718	
016150911							221	2,992	3,652	6,644	44,573	
Various	Coupling						40	39	21	60	2,302	
	Total	26	4	104	132	26	1,908	22,942	19,227	42,219	450,593	80
016210239	Fairbanks Morse Pump						919	14,957	8,512	23,469	241,046	
Various	Coupling						31	68	18	88	1,695	
	Total	20	4	80	68	20	950	15,025	8,530	23,557	242,741	86
174752249	Reliance Motor	46	4	184	200	44	589	12,884	6,049	18,933	27,527	24
TOTALS FOR SELECTED APLs						Totals	3,447	50,851	33,806	84,709	720,861	
TOTALS FOR ALL SYSTEM APLS							5,600	63,158	44,387	107,545	853,370	
PERCENT OF SYSTEM TOTAL REPRESENTED BY SELECTED APLS							62	81	76	79	84	

*The term "Ship Operating Years" refers to the time since commissioning of a ship less the time spent in overhaul, fitting out, and post-shakedown availability.

Table 3-2. REPORTED PARTS DATA FOR FIREMAIN SYSTEM COMPONENTS ANALYZED

Part Identification				MDS Data			
Nomenclature	NIIN	Qty. per Component	APLs Supported On*	Number of Ships Reporting	Number Requisitioned	Average per Unit Cost	JCNs
BUFFALO FORGE PUMP							
Ball Bearing	109 1382	**	**	12	127	13.06 (pr)	53
Ball Bearing	156 8051	2 pr	A	20	245	19.95 (pr)	71
Ball Bearing	156 8052	2 pr	B, C	26	556	16.63 (pr)	232
Ball Bearing	183 7489	**		6	22	21.42 (pr)	7
Mechanical Seal	480 3894	2	B, C	24	181	204.93 (ea)	72
Impeller Wearing Ring	785 3261	2	A, B, C	25	412	24.34 (ea)	160
Casing Wearing Ring	849 2379	2	A, B, C	26	426	63.75 (ea)	161
Deflector	810 2350	1	A	13	42	29.52 (ea)	24
Bearings Sleeve	752 8078	2	A	25	318	39.15 (ea)	125
Shaft Sleeve	463 2507	2	B, C	17	71	79.95 (ea)	31
Shaft Sleeve	463 2508	2	B, C	17	78	80.11 (ea)	28
Spacer Sleeve	892 2166	1	A, B, C	25	212	34.17 (ea)	114
Bushing, Thrust	021 1831	2	A	20	179	28.08 (ea)	80
Lantern Ring	785 4019	2 pr	A	19	163	16.34 (ea)	57
Rotor Assembly	851 7877	1	A	17	30	2646.96 (ea)	27
Impeller	778 3778	**		1	1	1142.00 (ea)	1
Key Washer	186 0967	1	A	13	26	2.73 (ea)	23
Key, Mach.	534 4194	2	A	9	65	0.74 (ea)	15
Nut, Plain RD	185 6389	2	A	16	74	5.29 (PG)	23
Couplings:							
Gasket	270 8470	0.2 SY	D, F	7	12	1.29 (SY)	8
Seal	298 0384	1	F	4	10	2.71 (ea)	6
Grid	920 0148	1	E	3	5	33.62 (ea)	3
Seal	958 2710	2	E	1	1	2.60 (ea)	1
Grid	940 8387	1	D	17	50	32.44 (ea)	44
Packing	968 9597	1	F	5	8	1.00 (ea)	6
Gasket	968 9598	1	F	4	7	1.70 (ea)	5
Seal	973 8695	2	D	17	107	2.45 (ea)	42
FAIRBANKS MORSE PUMP							
Ball Bearing	555 5207	2	A, B	19	335	2.91 (ea)	137
Ball Bearing	144 8657	**		14	106	1.84 (ea)	46
Mechanical Seal	185 0770	2	A, B	16	120	240.93 (ea)	52
Impeller Wearing Ring	128 0516	2	A	16	117	189.32 (ea)	58
Casing Wearing Ring	126 8429	2	A	18	97	121.26 (ea)	42
Shaft Sleeve	126 8427	**		14	74	78.60 (ea)	31
Shaft Sleeve	180 5590	2	A, B	9	17	760.59 (ea)	13
Bushing	126 8430	**		8	25	11.23 (ea)	11
Rotor Assembly	435 2716	1	A	10	17	2956.47 (LD)	14
Impeller	435 2720	1	A	3	3	1890.00 (ea)	3
Key Washer	186 0962	1	A	10	27	1.58 (PG)	19
Keyway Washer	186 0966	1	A	6	20	3.41 (PG)	14
Bearing Lock Nut	185 6464	2	A	7	43	0.79 (ea)	11
Nut, Pln. RD	185 6484	2	A	8	23	8.79 (PG)	19
Lower Bearing Spring	007 2917	2	B	9	31	1.32 (ea)	11
Couplings:							
Ring	058 1978	2	D, F	6	44	3.00 (ea)	10
Seal	058 2077	2	D, F	8	64	1.28 (ea)	17
Coupling	096 6007	1	D	8	20	31.06 (ea)	13
Seal	819 2336	2	E	7	18	1.65 (ea)	10
RELIANCE MOTOR							
Ball Bearing	155 6230	**		33	301	9.21	103
Ball Bearing	155 6302	**		24	201	8.68	67
Ball Bearing	156 8161	**		9	33	11.34	15
Ball Bearing	158 8273	**		11	32	15.96	16
Ball Bearing	833 9787	2	A	28	203	9.38	70

* BUFFALO FORGE PUMPS

A = 016150582, B = 016150911, C = 016150865 } (6/30/77)†

Couplings

D = 782350238, E = 782350246, F = 782650035 } (3/1/76)

FAIRBANKS MORSE PUMPS

A = 016210239 (3/1/76)
B = 016210325 (12/1/76)

Couplings

D = 780200045, E = 780200049, F = 780200062 } (3/1/76)

RELIANCE MOTOR

A = 174752429 (3/1/76)

†Date of APL Edition

** Although reported replaced, was not supported by the appropriate APL.

The FF-1052 Class has four vertically-mounted 900 gpm fire pumps installed. Fire pumps were added as generic items to the continuing Detection Action Response Techniques (DART) Program in March 1971. Consequently, the FF-1052 Class fire pumps have been the subject of extensive analysis by the Navy engineering and maintenance community for the greater portion of the life of the Class. Table 3-3 presents a summary of the major fire pump reliability and maintainability problems identified by the Navy early in the DART Program.

These problems led to two major hardware improvements: conversion from conventional packing to mechanical seals in the vertical fire pumps, and a series of changes in the materials used in wearing rings, impellers, and pump casings.

Conversion from conventional packing to John Crane mechanical seals in the fire pumps was initiated in July 1972 as ShipAlt DE-1052-134. Difficulties in procurement of conversion kits and training of personnel responsible for installation, as well as operational commitments, extended the conversion program through late 1976. Most ships did not have all four pumps converted during the same availability. Figure 3-1 documents a chronology of the conversion program, taken from DART program records; each ship's placement on the curve is determined by the date by which the fourth pump was fitted with mechanical seals. Following conversion to mechanical seals on Buffalo Forge Pumps, the old APL 016150582 was superseded by APL 016150911. The Fairbanks Morse Pump continued to be supported under APL 016210239.

The second major hardware improvement effort was initiated in response to accelerated erosion of wearing rings, impellers, and casings. New materials were introduced, most notably the Alloy 20 steel casings procured to replace the original bronze casings on both types of pump. Alloy 20 Buffalo Forge casings and new Buffalo Forge Pumps which incorporated all of the upgraded parts were first issued in 1974, supported by APL 016150865. No MDS data or CASREPs were reported against this APL in the period examined. Table C-1 in Appendix C lists the issues of Buffalo Forge Alloy 20 casings and pump ends as of this date. Issuance of Fairbanks Morse Alloy 20 casings began in 1975, and an Alloy 20 replacement pump was issued in 1977. Fairbanks Morse Pumps with Alloy 20 casings are supported by APL 016210325. No MDS data or CASREPs were reported against this APL in the period examined. Table C-1 lists the issues of Fairbanks Morse stainless steel casings and pump ends as of this date.

The implementation of the above-mentioned changes complicates the use of past data in making projections of future maintenance requirements. Trends in maintenance were therefore analyzed, and are discussed in detail in following sections for each pump type and the driving motor.

Table 3-3. MAJOR RELIABILITY AND MAINTAINABILITY PROBLEMS IN FIRE PUMP AND MOTOR AS IDENTIFIED IN DART PROGRAM

Component(s)	Problem Description
Buffalo Forge Pump Fairbanks Morse Pump Reliance Motor	Original conventional packing required cooling leakage which a) resulted in pump end lower bearing failure, and b) produced a saltwater spray that clogged the pump motor cooling screen.
Buffalo Forge Pump Fairbanks Morse Pump Reliance Motor	Pump-to-motor alignment is critical and has frequently been done improperly. This has resulted in excessive vibration, coupling failure, bent shafts, and reduced pump and bearing life.
Buffalo Forge Pump Fairbanks Morse Pump Reliance Motor	Pump end bearings have been a) damaged during installation, b) installed with an improper orientation (Buffalo Forge Pump), and c) inadequately and improperly greased. Motor bearings have been a) installed with improper orientation, and b) improperly and inadequately greased.
Buffalo Forge Pump Fairbanks Morse Pump	The original Buffalo Forge casing wearing rings were made of bronze, the original Fairbanks Morse impeller rings were made of gun metal, and the casing wearing rings were made of bronze. These materials eroded rapidly in salt water service.
Buffalo Forge Pump Fairbanks Morse Pump	The original bronze pump casings showed accelerated deterioration, especially in the casing wearing ring regions of the Buffalo Forge Pump, and at the junction of the casing and suction passage O-ring of the Fairbanks Morse Pump.
Buffalo Forge Pump Fairbanks Morse Pump	Running the pumps below the minimum-allowed pressure of 110 psi has led to cavitation and accelerated deterioration of pump internals.

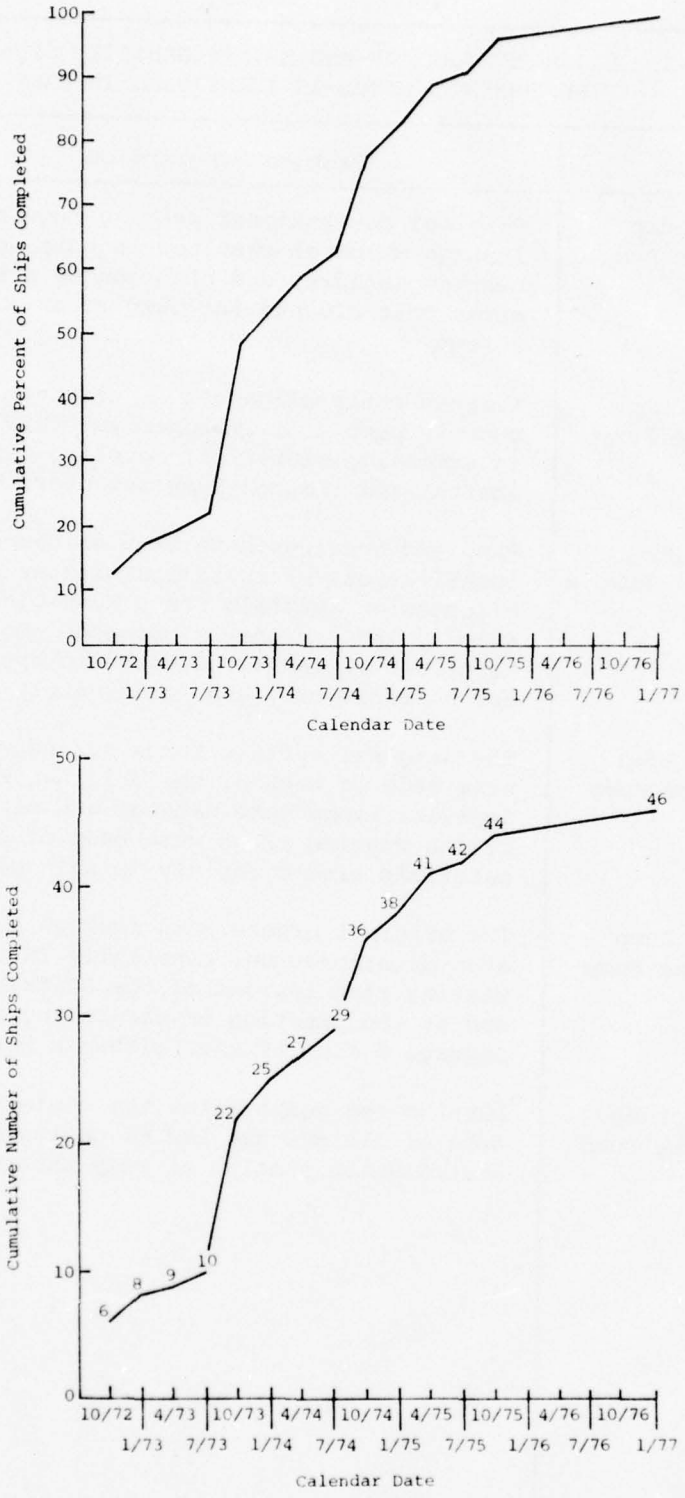


Figure 3-1. FF-1052 CLASS MECHANICAL SEAL CONVERSION CHRONOLOGY

The performance of the fire pumps will be affected by the implementation of ShipAlt FF-1052-372, installation of a brine overboard discharge pump; and ShipAlt FF-1052-378, installation of an auxiliary machinery seawater cooling pump. These alterations will result in a reduction in firemain load; they are scheduled for installation across the Class during the period FY 77 through FY 83.

Planning is currently underway for ShipAlt FF-1052-374, which replaces the vertical fire pumps with horizontal types. The alteration may become less important as a result of the decreased load on the fire pumps resulting from the other alterations cited above and the mechanical and material upgrading of the vertical fire pumps. The latest generation of vertical fire pumps should be monitored. This would provide data on the performance of new materials in 900 gpm service and provide quantitative benchmarks that the horizontal fire pumps should exceed to make implementation of ShipAlt FF-1052-374 desireable.

3.2.2 Buffalo Forge Pump, APLs 016150582, 016150911, and 016150865

3.2.2.1 Background

3.2.2.1.1 General. The Buffalo Forge Pump installed on FF-1052 through FF-1077 is a single-stage, vertical, split-case centrifugal pump with a double suction impeller. The rotating assembly is supported by ball bearings located on each end of the shaft.

3.2.2.1.2 Mechanical Seal Conversion. In response to bearing corrosion and motor cooling problems associated with excessive saltwater leakage, conversion of the pumps from conventional packing to mechanical seals was initiated in July 1972. APL 016150911 was to apply to the pump following completion of the conversion. However, examination of MDS and CASREP data showed that repair personnel continued to report both maintenance and casualties against the original APL 016150582 after conversion. This was established by checking the recorded APL on those transactions which specifically mentioned mechanical seals. Discussions with NAVSEC and NAVSEA personnel revealed that accurate conversion dates for particular pumps or particular ships were not available. Thus the intended distinction between APL 016150582 and APL 016150911 was not preserved, and MDS data for the two APLs were summed and analyzed together.

3.2.2.1.3 Material Alterations. As originally designed to MIL-P-1739, the major components of the Buffalo Forge Pump were of the following materials:

Component	Material
Casing wearing ring	Bronze
Impeller wearing ring	Monel
Impeller	Monel
Casing	Valve bronze

In response to accelerated erosion of these materials, various changes were implemented as described below.

Wearing Rings — Early in the deployment of FF-1052 Class ships with Buffalo Forge Pumps, monel casing wearing rings were manufactured by the Navy as replacements for the bronze casing wearing rings. Later, when the pump impeller material was changed to Alloy 20 steel (ACI-CN-7M), the impeller wearing ring material was changed to Alloy 20. Throughout these changes, the wearing ring part numbers (NIINs) — 785-3261 for the impeller wearing ring and 849-2379 for the casing wearing ring — remained constant. A discussion with SPCC, Mechanicsburg yielded the following as current:

Component	NIIN	Material Specification
Impeller wearing ring	785-3261	QQ-N-288 "A" (Monel) or ACI-CN-7M (Alloy 20)
Casing wearing ring	849-2379	QQ-N-288 "B" (Monel)

With respect to the impeller wearing ring, the current supply policy is to use up the monel stock and then use the steel.

Impeller — As stated above, the Buffalo Forge Pump impeller was changed to Alloy 20, designated NIIN 100-2767. An exact date for the implementation of this change could not be determined; however, the change was made sometime prior to 1974. No requisitions for Alloy 20 impellers have been reported in the MDS data for the period examined.

Buffalo Forge Alloy 20 Casings and Pumps - The original valve bronze casings showed accelerated erosion and were refurbished by a private contractor for reuse. In addition, procurement of Alloy 20 casings from Puget Sound Naval Shipyard (PSNY) for Buffalo Forge Pumps was initiated in 1973. Issues of the Alloy 20 casings began in October 1975 and have totaled 13 (see Table C-1). Also in 1973, procurement of new pumps with Alloy 20 casings, impellers, and impeller wearing rings began. The first new pumps were issued in August 1974; 19 have been issued to date (see Table C-1).

The Buffalo Forge Pumps with Alloy 20 casings were to be supported by APL 016150865. The MDS and CASREP data examined contained no reports against this APL. Since the pumps are mechanically identical to APL 016150911 (Buffalo Forge Pump with mechanical seals), and since MDS and CASREP data do not record the detailed information necessary to track casing condition, no attempt was made to segregate data for pumps with Alloy 20 casings from data reported against APLs 016150582 and 016150911.

3.2.2.1.4 MDS Reported Maintenance Burden. The dollar and man-hour totals in Table 3-1 do not reflect the burden applicable to private contractors or shipyards performing pump overhauls, and are therefore conservative. Examination of the raw data also showed that while the flexible couplings used between the pump and the motor do have their own APLs

assigned, the vast majority of coupling maintenance has been reported against the pump APLs. The small burden reported against coupling APLs 782350238, 782350246, and 782650035 was therefore added to the pump burden. The first two APLs are Falk Steelflex grid couplings, which are described in the latest revision of the Buffalo Forge Pump Technical Manual, NAVSHIPS 0947-068-1010. Coupling APL 782350238 is specified on APLs 016150911 and 016150865. APL 782650035 is a Poole Foundry internal-gear coupling. This coupling is specified on pump APL 016150582; both this coupling and the pump APL should no longer be in use.

3.2.2.2 CASREP Data

CASREP data for Buffalo Forge Pumps reported during the period 1 July 1973 through 30 June 1976 are broken down by type of failure in Table B-1 of Appendix B. The types of failure correspond to the basic problem areas addressed in the DART Program. Problems identifiable as associated with pump bearings, mechanical seals, and misalignment accounted for 86 of 145 reported casualties.

3.2.2.3 Ship's Force Corrective Maintenance Capabilities

Pump repairs can be classified in the following categories:

a. Bearing and mechanical seal replacements

b. Wearing ring renewal

c. "Overhaul", which consists as necessary of 1) replacement of bearings, seals, impeller, and shaft sleeves, and 2) repairs to bearing housings and casing.

All of the above require, as a minimum, complete disassembly of the pump and realignment of the pump to the driving motor.

Ship's force can theoretically replace bearings and mechanical seals. Discussions with NAVSEC, SIMA, and IMA personnel, however, indicated that ship's force personnel generally lack familiarity with mechanical seal installation. Problems have also been experienced in replacing bearings, partly as the result of poor repair procedure documentation and the lack of onboard equipment such as a bearing heater or hydraulic press. Revisions to technical manuals and PMS procedures, and the issuance of maintenance notes, were implemented to improve skills in seal and bearing installation. A recommendation to supply FF-1052/1078 Class ships with a hydraulic press was made by NAVSEC, but not implemented.

Wearing ring clearance can be restored by three methods:

a. The impeller rings can be skim-cut and a new casing wearing ring cut to the proper inner diameter.

b. The casing rings can be skim-cut and the impeller rings replaced and cut to the proper outer diameter.

c. Both the impeller and casing wearing rings can be replaced.

Discussions with ship's force and IMA personnel revealed that ship's force usually seeks outside assistance in cutting wearing rings, while performing pump disassembly and reassembly themselves. Ship's force can replace the rotating assembly if necessary by use of the allowed onboard spare rotor. However, IMA, SIMA, or shipyard facilities are needed to balance rotors or repair casings. DART documentation and NAVSEC engineers also cited problems in obtaining proper pump-to-motor alignment, a job usually performed by ship's force. Training efforts in the area of alignment have been instituted.

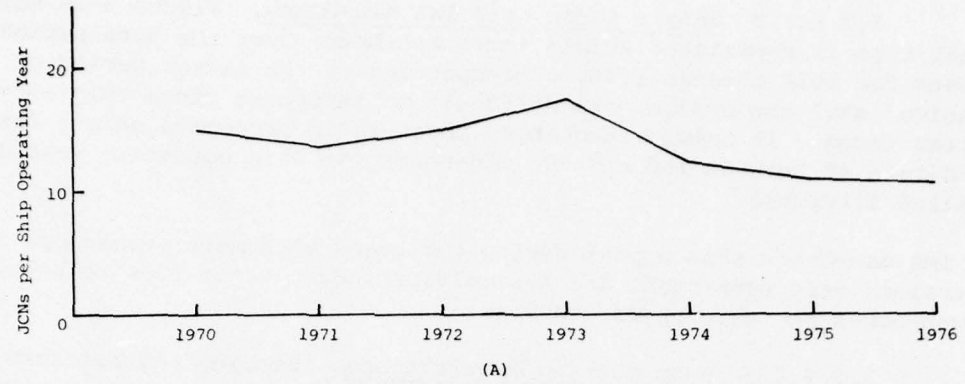
3.2.2.4 Maintenance Trends

Selected MDS maintenance data reported against pump APLs 016150582 and 016150911 were analyzed as a function of calendar time to examine trends in overall pump maintenance as mechanical-seal conversion and material upgrading progressed. MDS data categories used were number of JCNs, ship's force and IMA man-hours, and pump bearing and mechanical seal requisitions.

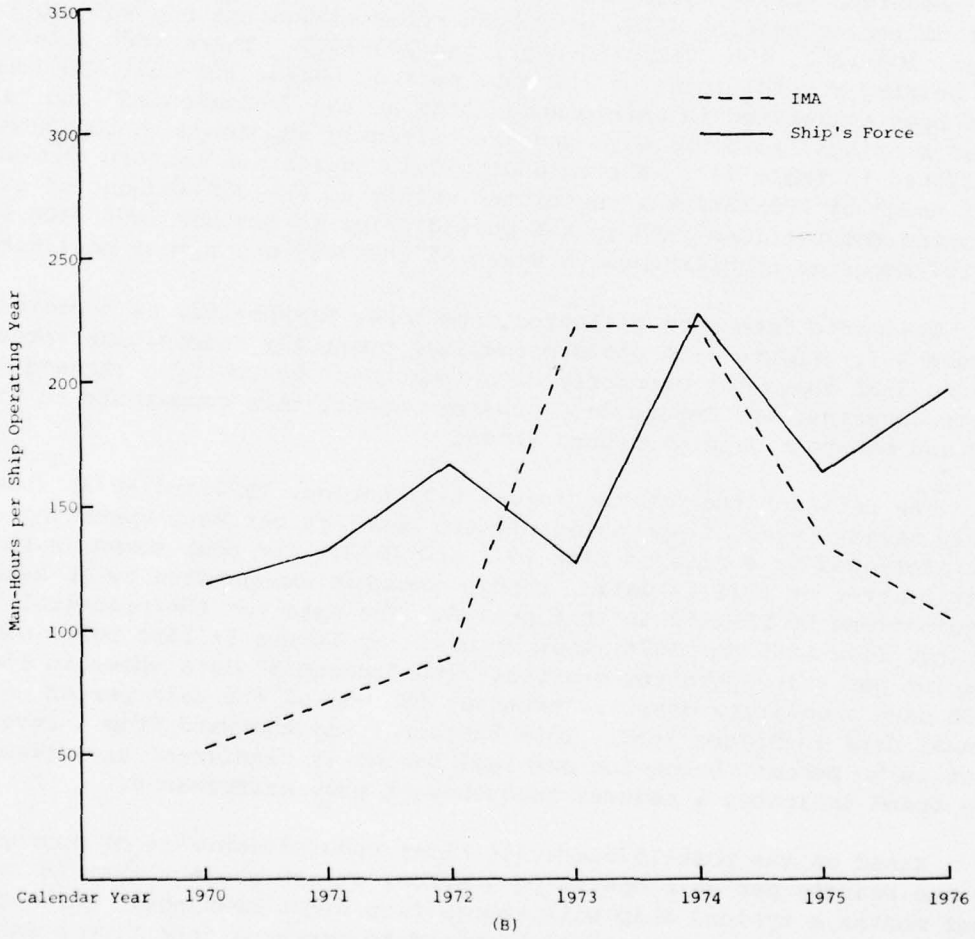
The trending process involved normalization of the data, i.e., dividing the quantities of the above-mentioned categories reported in a calendar year or quarter by the total number of FF-1052 Class ship operating years or ship operating quarters for that calendar period. These normalized data were then plotted and interpreted in light of information gathered from sources such as interviews with NAVSEA and NAVSEC, and DART Fire Pump documentation.

3.2.2.4.1 Number of JCNs. Figure 3-2A shows a plot by calendar year of JCNs per ship operating year submitted against the Buffalo Forge Pump. This parameter is a rough measure of repair activity for the pump over the data period examined. It should be noted that the data point for 1976, is based on data for the first 6 months of 1976 and annualized to the number of ship operating years in that 6-month period.

The plot itself shows a gradual decline in the number of job actions being reported. The peak in 1973 corresponds to the activity associated with mechanical seal conversion.



(A)



(B)

Figure 3-2. NORMALIZED MDS DATA FOR BUFFALO FORGE PUMPS BY CALENDAR YEAR

3.2.2.4.2 Ship's Force and IMA Man-Hours. Figure 3-2B shows a gradual rise in normalized ship's force man-hours over the data period. The data for 1974 through 1976, corresponding to the latter period of mechanical seal conversion, are difficult to interpret since they show no clear trend. It seems reasonable, however, to project a ship's force expenditure of between 150 and 200 man-hours per ship operating year on installed firepumps.

IMA man-hours show a peak during the years when most mechanical seal conversions were performed, and a significant drop since 1974 to below 100 man-hours per ship operating year.

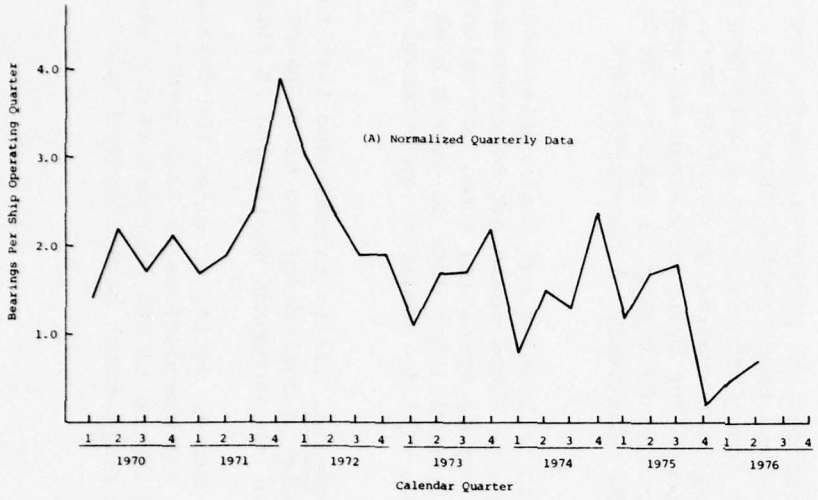
3.2.2.4.3 Pump Bearing Requisitions. Bearing requisitions are a good overall indicator of pump repair, since any repair that involves opening the pump and working on the shaft requires replacement of the bearings, whether or not they are the failed component.

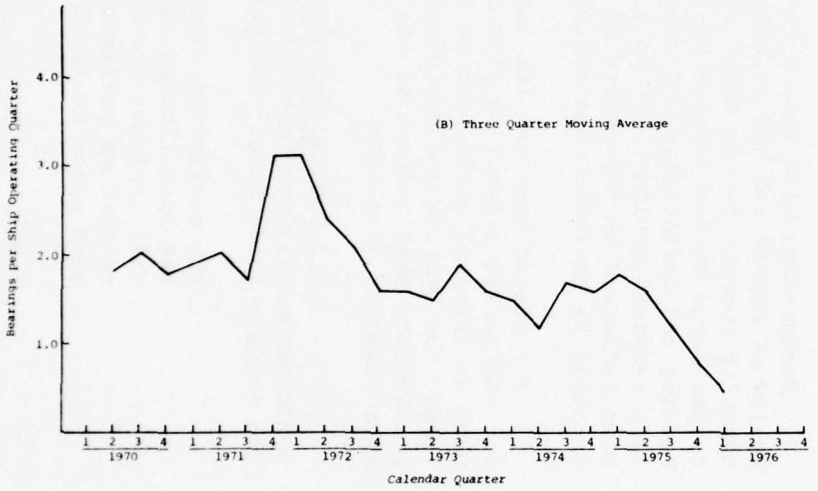
Reported parts requisitions for the fire pumps are shown in Table 3-2. Four different bearing NIINs have been reported against the Buffalo Forge Pump: 109-1382, 156-8051, 156-8052, and 183-7489. There were a total of 950 bearing requisitions for the data period. NIINs 156-8051 and 156-8052 have been designated in maintenance notes as the "recommended" and "alternate" bearings, respectively, and are currently supported on the APLs as listed in Table 3-2. The chronological requisition pattern showed that usage of 109-1382 was restricted mainly to FF-1062 (53 out of 127 reported requisitions) and to the period prior to October 1973 (106 out of 127 reported requisitions). Usage of 183-7489 was almost negligible.

The parts data were evaluated from three viewpoints, as depicted in Figure 3-3. Figure 3-3A shows normalized quarterly requisition rates; Figure 3-3B shows the quarterly data "smoothed" by use of a three-quarter moving average; and Figure 3-3C presents annual data comparable to the JCN and man-hour data discussed above.

The data for the pre-mechanical seal period, 1970 and 1971, show an early steady level of approximately two bearings per ship operating quarter, followed by a rise in late 1971 and 1972. The peak shown in the last quarter of 1971 is valid, though somewhat exaggerated by 26 bearing requisitions by FF-1053 in that period. The data for the post-seal period, late 1975 and 1976, show requisition levels falling below one bearing per ship operating quarter. The "smoothed" data shown in Figure 3-3B show a definite downward trend at the end of the data period, as do annual data in Figure 3-3C. This further trend downward from a level that is 50 percent below the pre-seal period is considered significant. The trend indicates a reduced frequency of pump maintenance.

Based on the post-1975 average Fleet requisition rate of approximately one bearing per ship operating quarter, we can project that in twenty-four months a typical ship will requisition eight bearings. This corresponds to the number of bearings required to overhaul four fire pumps, indicating that the average maintenance interval for fire pumps that have been upgraded by mechanical seal installations is approximately 24 months.





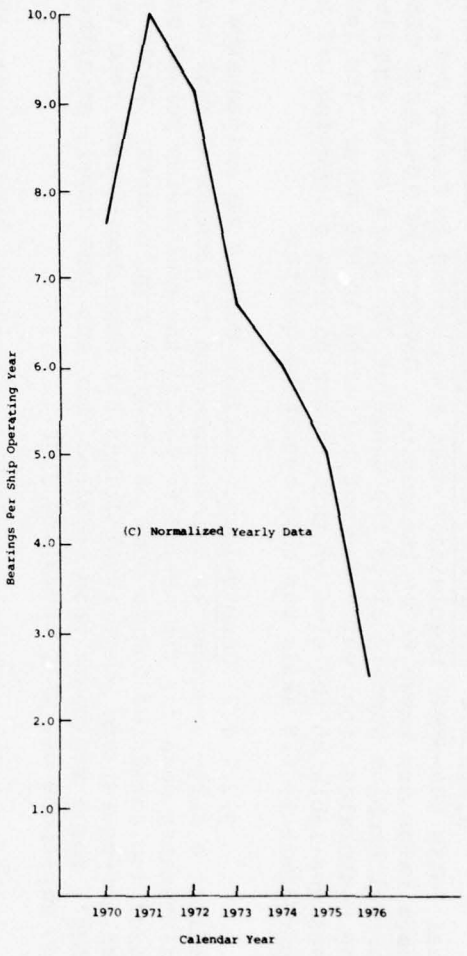


Figure 3-3. BUFFALO FORGE FIRE PUMP BEARING REQUISITION HISTORY FOR FF-1052 CLASS SHIPS

3.2.2.4.4 Mechanical Seal Requisitions. Normalized mechanical seal (NIIN 480-3894) requisition data are plotted in Figure 3-4. The early usage rates are known to be inaccurate. NAVSEC's FF-1052/1078 Class Historical Problem Summary cited the usage of 208 spare seals supplied with the conversion kits, which was not reflected in MDS data. The latest data available at the time of this report do show a leveling off at approximately 0.8 seals per ship operating quarter.

3.2.2.4.5 Conclusions. Buffalo Forge Pump maintenance data reflect a large increase in maintenance due to mechanical seal conversion. Maintenance data for the period following the conversion period give a mixed indication of future pump maintenance requirements. While JCNs, IMA man-hours, and parts requisitions all show down-trends from 1974, ship's force man-hours have remained near the peak level, at approximately 200 man-hours per ship operating year.

Pump bearing and mechanical seal requisition data indicate that bearing problems have decreased. Future trends in mechanical reliability should be monitored in view of the pending installation of horizontal pumps, since the material upgrading of the vertical pumps (which is in process) may make them materially equivalent to the proposed horizontal pumps.

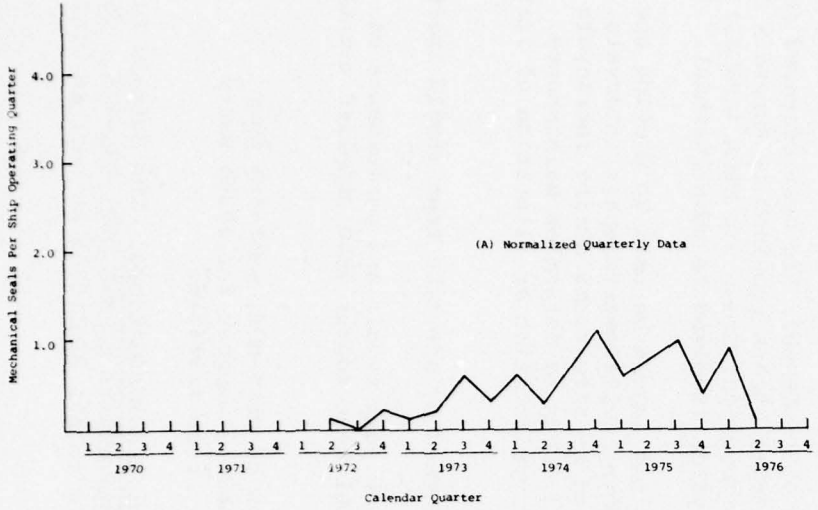
3.2.2.5 Maintenance Strategy

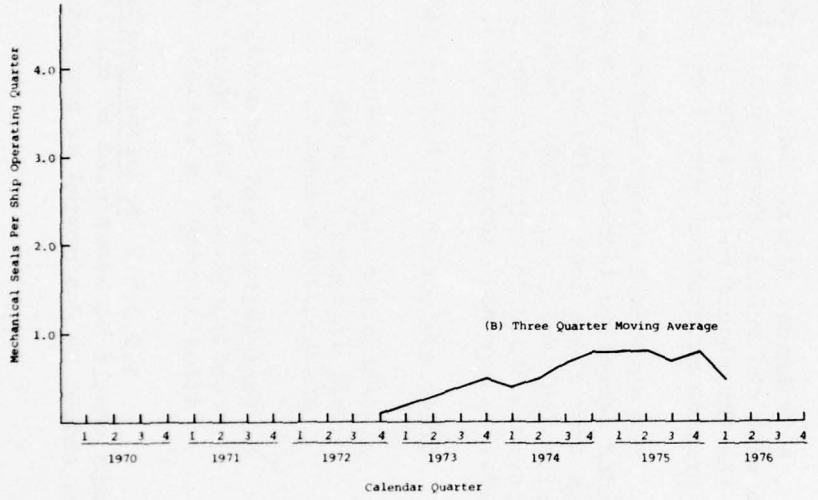
Discussions with ship's force personnel and NAVSEC engineers, and a review of CASREP and MDS narratives, showed that FF-1052 Class ships normally operate two or three of their four fire pumps while underway, due to the large burden imposed by the auxiliary systems on the fire main. Pending the installation of separate pumps for brine discharge and auxiliary seawater cooling, the loss of even one fire pump is serious, as has been reflected in the number of CASREPs submitted. A run-to-failure strategy is therefore not acceptable.

A specific interval for inspection or bearing and seal replacement for the latest generation of Buffalo Forge Pumps could not be determined. Such an interval would best be based on pump operating time, not calendar time. The bearing and mechanical seal requisition data do show a high probability that corrective maintenance will be needed at an interval of approximately 24 months.

3.2.2.5.1 Maintenance Monitoring. It is recommended that the DDEOC Technical Group assume a lead role in monitoring the maintenance of the Buffalo Forge Pump. The purpose of the proposed monitoring is twofold:

- The monitoring should be used to verify or alter the initial SRA hard time maintenance recommendations of this report. This includes providing guidance to SRA planners on the need to perform maintenance on pumps which have received major work prior to the SRA.





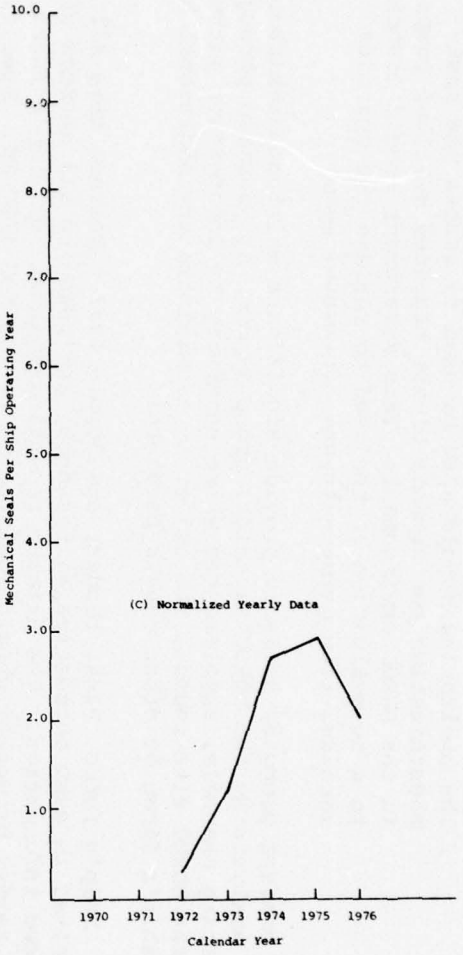


Figure 3-4. BUFFALO FORGE FIRE PUMP MECHANICAL SEAL REQUISITION HISTORY FOR FF-1052 CLASS SHIPS

. The monitoring should also be used to assess the post-modernization performance of the upgraded vertical pumps in the DDEOC environment. This assessment should contribute to a re-evaluation of the need to replace the upgraded vertical fire pumps with new horizontal pumps.

The concept proposed seeks to provide significant maintenance-history data for analysis by the DDEOC Technical group as much as possible through existing channels, supplemented where necessary by information gathered by the DDEOC site teams. The object is to minimize any additional burden on ship's force or other repair personnel.

Ship's force, SIMA, tender, and depot-level personnel have all been involved in pump corrective maintenance, and thus are all sources of needed information. The primary reporting channel for ship's force, SIMA, and tender personnel should continue to be the MDS 4790-2K. Specific reporting requirements for pump internal condition data should be incorporated in the pump inspection MRC, currently C3 D55T N on MIP E-28/205-55. The party performing the inspection should record on the 4790-2K the as-opened and as-repaired wearing ring clearance, impeller diameter, and data on material condition such as the number, length, depth, and location of defects, pits, or cracks. This data will aid in planning maintenance for the vertical pumps and in assessing the performance of Alloy 20 components in FF-1052 Class service.

A Technical Repair Standard, TRS 0521-086-605, has been prepared for use with the Buffalo Forge Pump. The data sheets provided in Appendix C of the TRS should be forwarded to the Technical Group via *PERA (CRUDES)* to provide maintenance data from shipyards involved in pump overhaul.

The shipboard smooth engineering log should be used to provide the needed operating time base for monitoring replacement/repair intervals. Data from these logs should be gathered by site teams during intracycle visits and used by the DDEOC Technical Group to determine maintenance intervals based on operating time for verification or alteration of initial hard time overhaul recommendations.

Other monitoring activities performed by the site team should include:

a. Debriefing ship's force on fire pump repair and performance at all intracycle visits, to supplement repair data supplied through MDS and TRS channels.

b. Verification and documentation of post-BOH, post-SRA pump configurations, and proper onboard support for cases where Alloy 20 pumps or casings have been installed.

3.2.2.5.2 Baseline Overhaul Recommendations. The Buffalo Forge Pumps should be overhauled to the requirements of TRS 0521-086-605. The TRS should be designated as applicable to APL 016150865 as well as 016150?11.

The overhaul should be performed by SIMA, IMA, or shipyard personnel to ensure total overhaul capability and responsibility within one organization. (Ship's force does not have the capability to balance the rotating assembly or, in general, the machining expertise required for cutting wearing rings or making repairs to shafts and casings.) The overhauling agency should also be responsible for reinstallation of the pump and its alignment with the motor and piping flanges. This alignment is particularly critical in preventing premature failure of the pump.

The pumps should be materially upgraded by piece-part installation of Alloy 20 impellers and casings, or installation of Alloy 20 pumps. It is noted that, based on current procurement plans and BOH dates, Alloy 20 casings or pumps may not be available through the supply system for all ships entering BOH. This possibility should be investigated well in advance of scheduled overhauls to identify ships for which bronze casings will have to be reused. Bronze casings and pump ends that are replaced should be turned in for refurbishment in accordance with present NAVSEA 045F policy.

3.2.2.5.3 Intracycle Maintenance Requirements. Corrective maintenance may have to be performed between DDEOC scheduled availabilities. This maintenance will most likely involve bearing or mechanical seal replacement, and initially the need for such maintenance will be determined by ship's force routine inspections. When the pump is opened upon indication of a problem, the internal condition should be recorded as described in Section 3.2.2.5.1.

It is recommended initially that pumps which have not received corrective maintenance in the interavailability period be opened and inspected and have the bearings renewed at the SRA. Also, all pumps should have the motor-to-pump and pump-to-piping flange realignment performed. These actions should serve to reduce in-service failures during the following interavailability period. The work should be performed by tender, SIMA, or shipyard personnel, with ship's force assistance for training purposes.

Maintenance histories maintained by the DDEOC Technical Group should provide internal-condition and bearing-replacement data as a function of pump operating time. These data should be used to determine the need for SRA maintenance on pumps opened in the preceding interavailability period and to develop preemptive maintenance intervals.

PMS requirements for the Buffalo Forge Pump are currently listed on MIP E-28/205-55, which is applicable to APL 016150911. No MIP has been assigned to APL 016150865. MRC C3 D55T N provides for opening and inspection of the pump "when the mechanical seal leaks or during overhaul once a cycle". As part of the maintenance strategy outlined, this MRC should be revised to include the recording of internal condition data. It is also recommended that the periodicity be changed to R-1, and the note on when to accomplish be changed to read "Accomplish when pump is overhauled or opened for repair."

The continued reporting of pump maintenance against APL 016150582 after mechanical seal conversion, and the absence of data for APL 016150865, indicate that APL changes are not reaching the personnel performing the maintenance. To ensure accurate reporting in the future and proper onboard support, a check should be made to see if ships have the proper APLs for the pumps installed, and that ship's force maintenance personnel are informed of changes in their APL configuration.

A review of APL 016150865 revealed that it does not provide support for an onboard spare rotor, and that both the quantity per component and support for the impeller wearing ring are incorrect.

MRC C3 D55T N contains a note that states, "...Ensure obsolete gun metal type wearing rings are replaced with monel type, regardless of wear limit." A check with SPCC, Mechanicsburg through NAVSEA 045F revealed that 1) the impeller stocked as NIIN 100-2767 and listed on APL 016150911 is Alloy 20 and 2) the impeller wearing rings stocked as NIIN 785-3261 is Alloy 20, or monel (QQN-288"B"). SPCC indicated that the monel wearing rings would continue in use until depleted, when Alloy 20 would be issued.

The circumstances outlined indicate the possibility of placing dissimilar metals in close contact on the pump, a situation that could accelerate wear via galvanic corrosion. Steps should be taken to ensure that pumps operating with Alloy 20 impellers do not use monel impeller wearing rings.

MRC T C3 D55Q N on MIP E-28/205-55 provides the procedure for lubrication and sound testing of the pump bearings. As currently written, this MRC specifies under "Preliminary" that the person performing the bearing lubrication should "Ensure pump is in operation." This implies that the pump is operating while vent fittings are removed and new lubricant is added. At least one ship has reported that this presents a safety hazard. Discussions with NAVSEC personnel disclosed that operation of the pump is necessary only to vent the bearing housings following the injection of new lubricant.

Buffalo Forge Pump Technical Manual 0947-068-1010, paragraph 4-7, provides a procedure for bearing lubrication. This procedure states that the pump should be tagged out of service while new lubricant is added; operated for 15 minutes to vent excess lubricant; and then secured to reinstall vent plugs. This procedure eliminates the safety hazard associated with lubrication, and it is recommended that MRC T C3 D55Q N be revised to conform with the Technical Manual procedure.

3.2.3 Fairbanks Morse Pump, APLs 016210239 and 016210325

3.2.3.1 Background

3.2.3.1.1 General. Hulls FF-1078 through FF-1097 have pumps manufactured by the Fairbanks Morse Pump Division of Colt Industries. The pump is of a vertical single-stage split casing centrifugal design. The Fairbanks Morse Pump uses upper and lower suction passages that are not integral to the pump casing.

3.2.3.1.2 Mechanical Seal Conversion. Like the Buffalo Forge Pump, the Fairbanks Morse type underwent conversion from conventional packing to mechanical seals between mid-1972 and late 1976. The spare rotors, which incorporate pump suction passages, were machined to accommodate mechanical seals. The converted pumps were supported by the revised APL 016210239.

3.2.3.1.3 Material Alterations. As originally designed, the pump component materials were as follows:

Component	Material
Casing wearing ring	Valve bronze
Impeller wearing ring	Gun metal
Impeller	Monel
Casing	Valve bronze

In response to accelerated erosion of these components, changes in material were made as discussed below.

Wearing Rings — Early in the operation of FF-1078 Class ships, the Navy manufactured monel wearing rings for pumps already delivered, with the understanding that the manufacturer would supply monel rings for the pumps still to be delivered and replacement parts stock. Discussions with SPCC, Mechanicsburg indicated that the latter action was not fully implemented, with the result that until recently non-monel wearing rings remained in the supply system. This was confirmed in discussions with ship's force personnel.

Casing and Alloy 20 Fairbanks Morse Pumps — Procurement of Alloy 20 casings as replacements for valve bronze casings was instituted in April 1974. The earliest issue of a replacement casing was July 1975, with 30 total issues to date (see Table C-1). Discussions with SPCC indicated that pumps with Alloy 20 casings continued using monel impellers. Replacement pumps with Alloy 20 casings and Alloy 20 impellers were also procured; the only issue to date was in March 1977. Discussions with NAVSEA 045F and SPCC indicated that pumps with Alloy 20 casings and Alloy 20 replacement pumps are supported by APL 016210325. Impeller wearing rings are not used with the Alloy 20 impeller.

3.2.3.1.4 MDS Reported Maintenance Burden. The dollar and manhour totals in Table 3-1 do not reflect the burden applicable to private contractors or shipyards performing pump overhauls. The totals shown are therefore conservative.

Examination of the data revealed that while the flexible couplings used between the pump and motor do have their own APLs assigned,

the vast majority of coupling maintenance has been reported against pump APL 016210239. The small burden reported against coupling APLs 780200045, 780200049, and 780200062 was therefore added to the pump burden. All three couplings are Sier-Bath internal gear type. Coupling APL 780200045 is currently listed on pump APL 016210239 as an associated item; and coupling APL 780200062 is currently listed on pump APL 016210325.

3.2.3.2 CASREP Data

CASREP data for the Fairbanks Morse Pumps for the period 1 July 1973 through 30 June 1976 are broken down by type of failure in Table B-2. The types of failures correspond to the basic problems addressed in the DART Program.

Comparison of CASREP data for the Fairbanks Morse Pump and the Buffalo Forge Pump points up disparities in two areas. Over roughly the same number of operating years, the Buffalo Forge Pump experienced 77 failures definitely attributable to bearing or mechanical seal failures, while the Fairbanks Morse Pump experienced only 20. On the other hand, the Fairbanks Morse Pump experienced 14 instances of coupling failure, while the Buffalo Forge Pump experienced only 3.

Differences in pump bearing design and mechanical seal installation may account for a higher rate of mechanical failure of the Buffalo Forge Pump. The major differences between the two pumps are:

a. The suction passages of the Fairbanks Morse Pump are not an integral part of the casing, and support the nonrotating portion of the mechanical seals. In the Buffalo Forge design, the suction passages are an integral part of the casing, and the nonrotating portion of the mechanical seals is secured to the casing.

b. The Buffalo Forge Pump has a double thrust bearing assembly on each end, installed with the thrust faces abutting. This design introduces the possibility of improper orientation. The Fairbanks Morse Pump has only one bearing at each end, and orientation makes no difference.

Even given these design differences, the disparity in the number of coupling failures suggests that the incidence of bearing failure may also be a function of the type of external coupling used with the pump. A grid-type coupling is used with the Buffalo Forge Pump, and an enclosed gear coupling with the Fairbanks Morse version. At least part of the bearing and mechanical seal problems on these pumps is the result of misalignment, causing bearing and seal failures rather than grid coupling failures. On the other hand, misalignment of the Fairbanks Morse pump and driving motor would more often lead to coupling failure, thus protecting the pump bearings and the pump mechanical seals. This may account in part for the lower incidence of such failures on the Fairbanks Morse Pumps.

A ShipAlt is being prepared that would extend the use of grid-type coupling to Fairbanks Morse Pumps. It is recommended that the possible protective role of the gear type coupling be further investigated before any such action is taken.

3.2.3.3 Ships Force Corrective Maintenance Capabilities

As for the Buffalo Forge Pumps, ship's force does not have a total maintenance capability for the Fairbanks Morse Pumps, and difficulties have been encountered in performing those corrective maintenance actions (bearing replacement, mechanical seal replacement, pump alignment) theoretically within ship's force capability. Section 3.2.2.3 provides a more detailed discussion of this situation.

3.2.3.4 Maintenance Trends

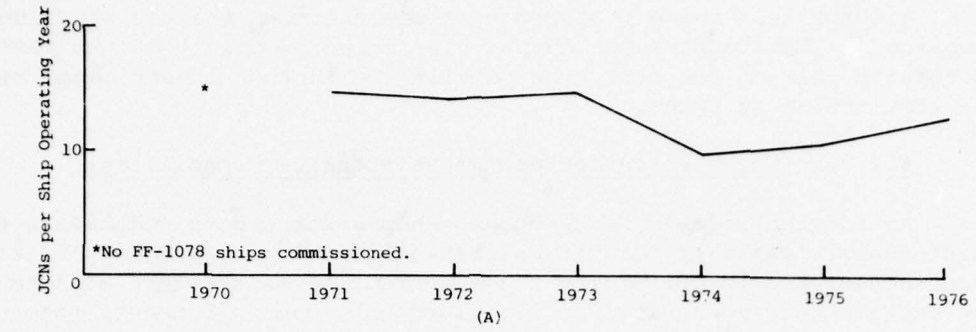
MDS data reported against Fairbanks Morse Pump APL 016210239 were analyzed in the same manner as previously discussed for Buffalo Forge Pump data; see Section 3.2.2.4. MDS data by calendar period were normalized and then plotted to examine overall trends.

3.2.3.4.1 Number of JCNs. Figure 3-5A shows the pattern for JCNs reported against the Fairbanks Morse Pump APL over the data period. The most recent data show a decrease from the 1973 peak level of approximately 15 JCNs per ship operating year to approximately 12 JCNs per year. The latest data do show a slight rise, corresponding perhaps to the recent rise in mechanical seal requisitions discussed below (Section 3.2.3.4.4).

3.2.3.4.2 Ship's Force and IMA Man-Hours. In Figure 3-5B, post-1973 data for ship's force and IMA man-hours show declines from peak levels of 370 and 175 man-hours, respectively, in that year. Ship's force man-hours appear to have stabilized at around 150 man-hours per ship operating year and IMA man-hours to less than 100.

3.2.3.4.3 Pump Bearing Requisitions. Two bearing stock numbers have been reported against the Fairbanks Morse Pump: 144-8657 and 555-5207 which are the "alternate" and "recommended" bearings, respectively. The data of Figure 3-6 show a decline of about 50 percent from peak requisition levels of approximately two bearings per ship operating quarter. The corresponding decline using yearly data is from slightly less than nine to approximately four bearings per ship operating year. The data for 1976 indicate that the decline is leveling off.

As with the Buffalo Forge Pump, a requisition rate for Fairbanks Morse Pump bearings of one bearing per ship operating quarter indicates an average pump maintenance interval of twenty-four months. This again is based on the latest data available, chosen to reflect the requirements of pumps converted to mechanical seals.



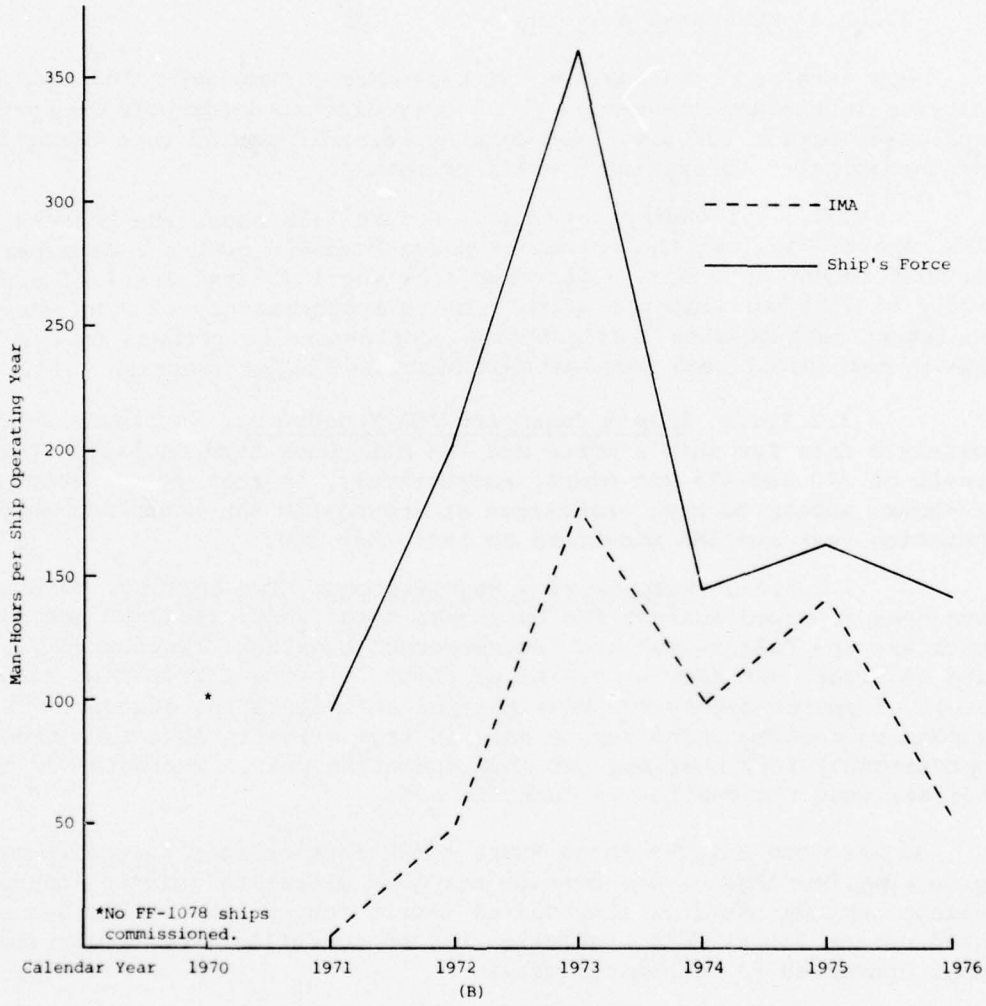


Figure 3-5. NORMALIZED MDS DATA FOR FAIRBANKS MORSE PUMPS BY CALENDAR YEAR

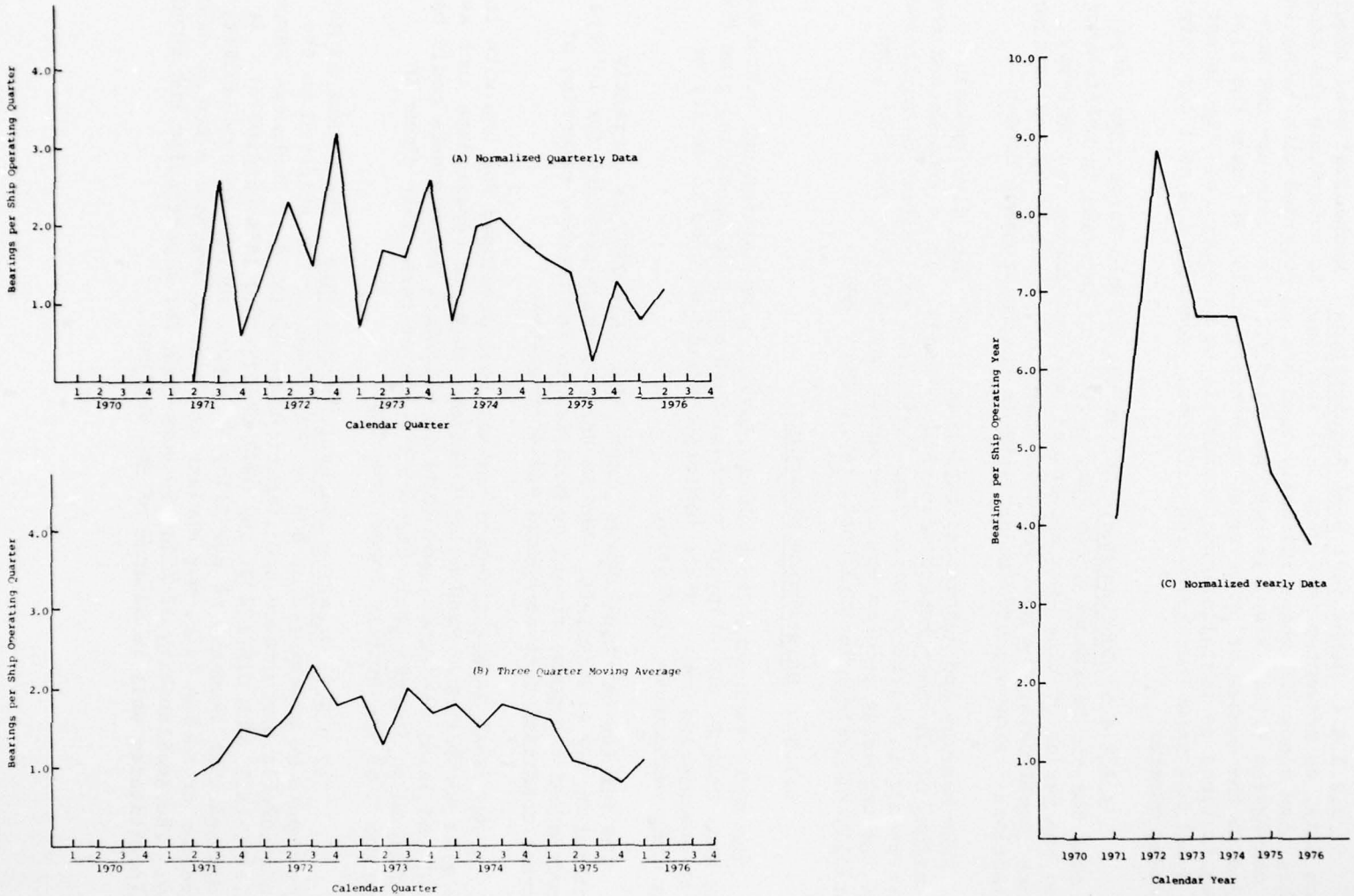


Figure 3-6. FAIRBANKS MORSE FIRE PUMP BEARING REQUISITION HISTORY FOR FF-1052 CLASS SHIPS

3.2.3.4.4 Mechanical Seal Requisitions. Mechanical seal requisition data, as presented in Figure 3-7, are known to understate the usage of this item since the ships initially used spares provided with mechanical seal conversion kits. Also, it must be noted that the data are not normalized to the number of pumps using mechanical seals, and thus the rise in requisitions as installations progress is to be expected. The latest data available show increasing requisitions, exceeding one seal per ship operating quarter.

3.2.3.4.5 Conclusions. As for the Buffalo Forge Pump, available data for the Fairbanks Morse Pump reflect an increase in maintenance during the period of time when mechanical seal conversion was underway. In more recent data, the most reliable indicators - man-hours and bearing requisitions - show significant declines in the maintenance burden.

Pump bearing and mechanical-seal requisition data give opposing indications of the most recent maintenance trends. It is recommended that future trends in Fairbanks Morse Pump mechanical reliability be monitored, since the upgrading program now in progress may make the vertical pumps materially equivalent to horizontal replacement pumps.

3.2.3.5 Maintenance Strategy

The DDEOC Technical Group should develop pump maintenance histories using MDS, CASREP, and shipyard overhaul data and pump operating time from smooth engineering logs. These histories should be used to verify or alter pump maintenance intervals.

PMS for the Fairbanks Morse pumps, APL 016210239, is currently specified on MIP E-28/231-46. MRC A6 K824 N, which provides for internal inspection of the pump, should be modified to incorporate reporting of internal condition data as-opened and as-repaired.

A Technical Repair Standard has not been developed for use with the Fairbanks Morse Pump. Pending such action, shipyard repair data such as radial and axial clearances and coupling alignment measurements could be provided on an interim basis through the use of forms like those in Apppendix C of the Buffalo Forge Pump TRS.

3.2.3.5.1 Baseline Overhaul Requirements. The Fairbanks Morse Pumps should be overhauled at BOH by IMA, SIMA, or the shipyard to the manufacturer's performance specifications as detailed in Technical Manual 0947-091-4011 (APL 016210239) and 0947-LP-229-7010 (APL 016210325). It is recognized that issuance of new Alloy 20 pumps, subject to availability and direction of NAVSEA 045F, may obviate the need to overhaul a bronze casing pump. The availability of Alloy 20 pump-ends for a particular BOH should be investigated well in advance of the overhaul.

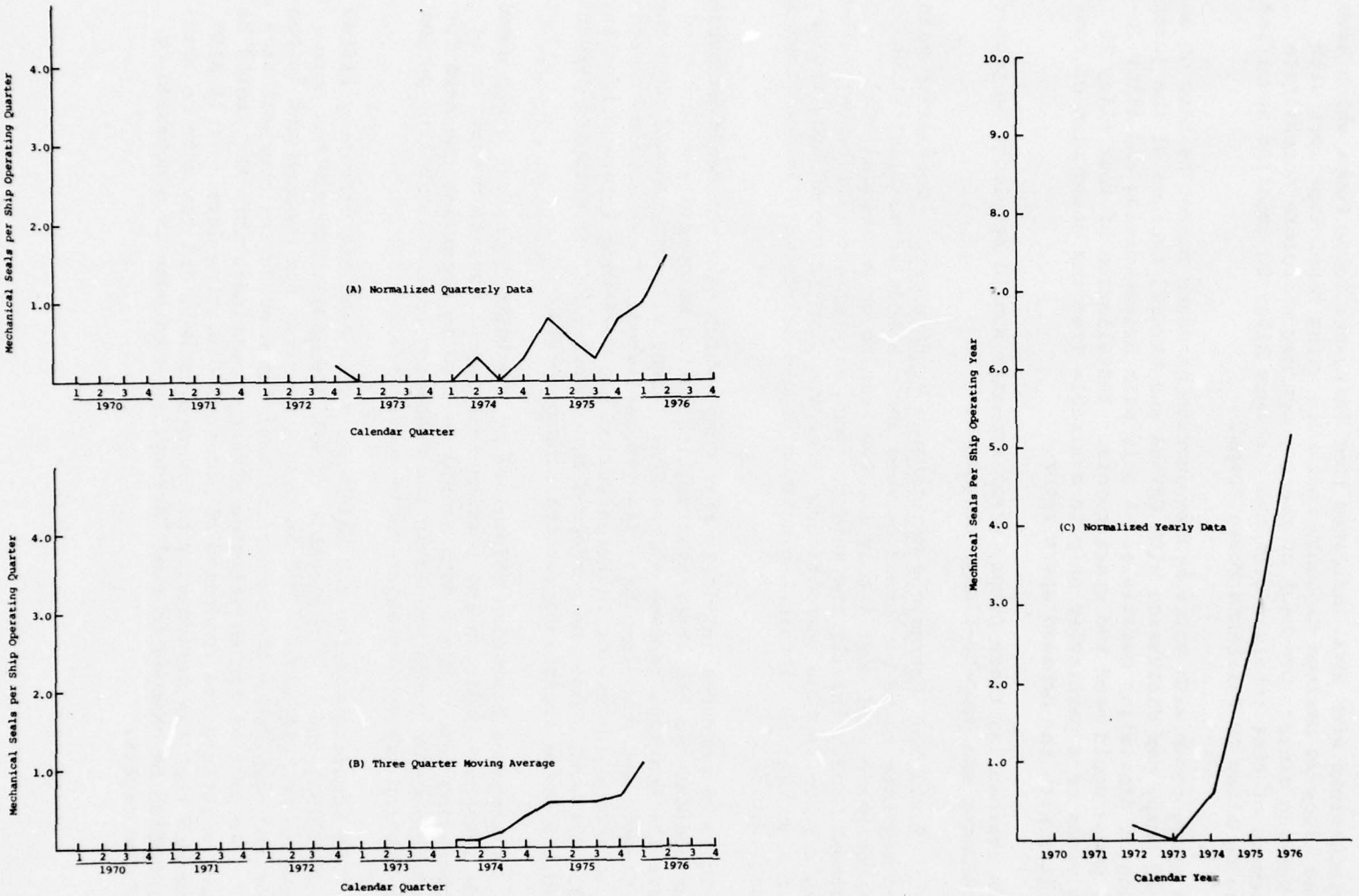


Figure 3-7. FAIRBANKS MORSE FIRE PUMP MECHANICAL SEAL REQUISITION HISTORY FOR FF-1052 CLASS SHIPS

Discussions with SPCC indicated that Fairbanks Morse Pumps which have received Alloy 20 casings probably continued using monel impellers with monel wearing rings. Overhaul of these pumps may therefore necessitate replacement of that impeller with the ringless Alloy 20 impeller specified for use on Alloy 20 Fairbanks Morse Pumps.

A spare rotor with valve bronze suction passages cannot be used on an Alloy 20 pump, per discussion with NAVSEA and NAVSEC, because of the juxtaposition of dissimilar materials. A ship with bronze-casing and Alloy 20-casing pumps would need two spare rotors. Installation of four Alloy 20 casing pumps on a particular ship is desirable from the standpoint of compatability with the onboard spare rotor.

In overhauling these pumps, great emphasis should be placed on proper pump-to-motor and pump-to-flange alignment.

3.2.3.5.2 Intracycle Maintenance Requirements. Corrective maintenance may have to be performed between DDEOC scheduled availabilities. This maintenance will most likely involve bearing or mechanical seal replacement, and initially the need for such maintenance will be determined by ship's force routine inspections. When the pump is opened upon indication of a problem the internal condition should be recorded as described in Section 3.2.2.5.1.

It is recommended initially that pumps which have not received corrective maintenance in the inter-availability period be opened and inspected and have the bearings renewed at the SRA. Also, all pumps should have the motor-to-pump and pump-to-piping flanges realigned. These actions should serve to reduce in-service failures during the following interavailability period. The work should be performed by tender, SIMA, or shipyard personnel, with ship's force assistance for training purposes.

Maintenance histories maintained by the DDEOC Technical Group should provide internal-condition and bearing-replacement data as a function of pump operating time. These data should be used to determine the need for SRA maintenance on pumps opened in the preceding interavailability period and to develop preemptive maintenance intervals.

PMS requirements for the Fairbanks Morse Pump are currently listed on MIP E 28/231-A6 which is applicable to APL 016150911. No MIP has been assigned to APL 016210239. MRC A6 K82A N provides for opening and inspection of the pump "when the mechanical seal leaks or during overhaul once a cycle". As part of the maintenance strategy outlined, this MRC should be revised to include the recording of internal condition data. It is also recommended that the periodicity be changed to R-1, and the note on when to accomplish be changed to read "Accomplish when pump is overhauled or opened for repair."

3.2.4 Reliance Motor, APL 174752249

3.2.4.1 Background

Each of the fire pumps installed in FF-1052 Class ships uses a Reliance Electric and Engineering Company 100-horsepower squirrel cage induction motor, APL 174752249. The motor is totally enclosed and employs a screened fan at the top to move air along vertical cooling fins on the motor cover. The motor has identical ball bearings at the upper and lower ends of the armature. In response to frequent motor bearing failure, a bearing of loose internal fit was specified as the replacement for the standard-fit type originally installed. In analysis of motor winding failures, NAVSEC engineers involved in the DART Program cited overheating as a contributing factor. The overheating was attributed to cooling screen blockage by salt spray from conventionally packed pumps. Installation of mechanical seals which allow near-zero leakage when properly installed was instituted to alleviate this and other problems.

3.2.4.2 CASREP Data

Motor CASREP data as a function of pump type are summarized in Tables B-1 and B-2. The data show the dominance of bearing failures, accounting for 50 of 83 total motor CASREPs. Winding failure accounted for 23 of the 83 failures. It is interesting to note that for a nearly equivalent number of ship operating years, during the CASREP data period the number of winding failures resulting in CASREPs for each pump type is in approximate parity - 13 for the motors used with Buffalo Forge Pumps and 10 for the motors used with Fairbanks Morse Pumps. Contrarily, motor bearing failures with the Buffalo Forge Pump are nearly double those for the motors with the Fairbanks Morse Pumps, 33 versus 17. This again suggests some interaction between the coupling type and bearing failure.

3.2.4.3 Ship's Force Maintenance Capabilities

Motor bearings can be replaced by ship's force. This job, however, necessitates disconnecting the motor from the pump and lifting it by chainfall. Realignment to the pump following repair is of course necessary. DART documentation does cite instances of improper installation of bearings (forcing rather than heating or pressing on the shaft, and improper orientation). NAVSEC has recommended that FF-1052/1078 Class ships be provided with hydraulic presses, and maintenance notes have been issued outlining proper installation of bearings. Ship's force personnel stated that bearings were usually heated in the galley oven prior to installation.

Motor winding and rotor balancing require the assistance of IMA, SIMA, or shipyard facilities and personnel.

3.2.4.4 Maintenance Trends

Motor bearing requisition data were analyzed to determine present maintenance levels and to examine trends. The "recommended" and "alternate" motor bearings, per fire pump maintenance notes and fire pump technical manuals, have been:

a. Recommended (NIIN 833-9787) — Single shielded, loose internal fit

b. Alternate (NIIN 155-6230) — Single shielded, standard internal fit

NIIN 833-9787 is supported on the current motor APL. Analysis of MDS parts requisition data revealed that five bearing stock numbers have been charged against the motors. NIIN 155-6302 has been used the most extensively, followed by 833-9787 and an unsupported bearing NIIN 155-6302, both with approximately the same usage. All have been used concurrently.

Figure 3-8 shows pump bearing requisition data as a function of calendar time. For most of the period, the trend of bearing usage had been downward, reaching levels in 1975 significantly below one bearing per ship operating quarter. A reversal of the trend occurred toward the end of 1975, but the indicated bearing usage is still significantly below the peak levels experienced in 1971-72. An initial estimate of future average sage would be one bearing per ship operating quarter or eight bearings per 24-month period. This indicates that, on the average, motor bearings need replacement at approximately 24 months.

3.2.4.5 Maintenance Strategy

The most serious factor limiting motor performance is bearing failure. Although ship's force can accomplish bearing replacement given the proper equipment, the criticality of the fire pumps and the possibility of extensive damage to the pump and coupling resulting from motor bearing failure, makes planned replacement desirable. The fire pump maintenance histories should provide the basis for determining bearing life. It may also be possible to determine an operating-time dependence for winding failure.

3.2.4.5.1 Baseline Overhaul Requirements. The pump motor should receive Class "B" overhaul at BOH to the specifications of Technical Repair Standard 0521-086-606.

3.2.4.5.2 Intracycle Maintenance Requirements. Intracycle maintenance should initially consist of performing the PMS actions listed on MIP EL-4/28-17, and of bearing renewal upon indication of an impending failure. It is recommended that, initially, motors which have not experienced bearing failure between successive availabilities have the bearings replaced at the SRAs by IMA, SIMA, or shipyard personnel with ship's force assistance. The DDEOC Technical Group should verify or alter replacement intervals based on operating time considerations.

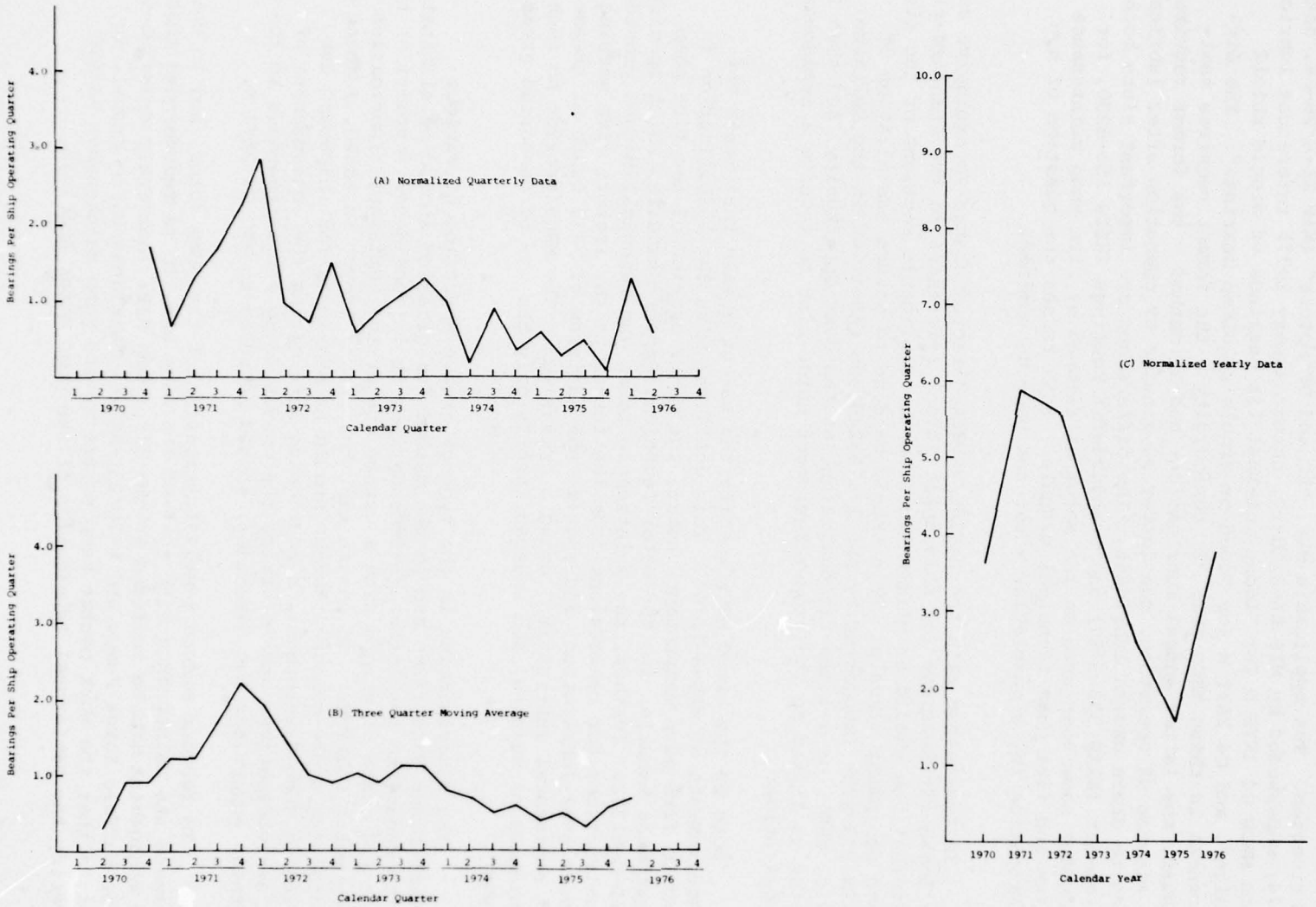


Figure 3-8. RELIANCE MOTOR BEARING REQUISITION HISTORY FF-1052 FOR FF-1052 CLASS SHIPS

Review of PMS procedures for motors, which are common to all motor types, revealed some possible difficulties with regard to proper motor-end lubrication. The applicable MIP, "AC and DC Motors" (MIP EL-4/28-C4, dated 1974; superseded by MIP EL-4/28-17, dated January 1977) references lubrication MRCs C4 2KYS N for "loose internal fit bearings of single shield design", and C4 2KYT N for "open or single shielded bearings". The differences in these MRCs are: 1) periodicity - the former requires semiannual, the latter annual lubrication; and 2) method - the former requires 15 minutes of operation, the latter 30 minutes of operation after lubrication to drain excess lubricant. The differences are important since both loose-fit (NIIN 833-9787) and standard-fit bearings (NIIN 155-6230, for example) have been used on the motor as allowed by fire pump maintenance notes and fire pump technical manuals. This raises the question of how lubrication for a particular motor has been determined.

In consonance with the NAVSEC/NAVSEA-directed change to exclusive use of loose-fit bearings for this application, references to the standard-fit alternatives should be eliminated from the applicable sections of the fire pump equipment manuals. This should be done to ensure installation of NIIN 833-9787 (supported by APL 174752249 and specified in the Reliance Motor TRS), or a loose-fit equivalent at the next opportunity, and that the motor is listed on the proper Equipment Guide List to receive a semiannual lubrication.

Both of the cited MRCs specify the use of grease that meets the requirements of MIL-G-18709. This conflicts with the specification in NAVSEC fire pump maintenance notes, the motor section of the fire pump equipment manuals, and the motor *Technical Repair Standard*, which specify MIL-G-81322. Further, the maintenance notes and Technical Manual provide instructions for conversions from the former to the latter; give warning about over-lubrication; and specify the addition of "1/2 ounce of grease at semiannual lubrication" using a grease gun. The MRCs provide no such guidance or warning, and instead specify only the use of "assorted grease cups".

The discrepancies in the type of grease specified by various maintenance directives and in the method for greasing should be eliminated. With regard to the latter recommendation, it is considered impractical to add 1/2 ounce of grease with a grease gun at the semiannual lubrication of the motor bearings. To ensure that the proper amount is added, a means of injecting a pre-measured amount should be developed for shipboard use. Pending such development, a cautioning note citing the consequences of over-lubrication, and referring the person doing the maintenance to the work center supervisor for direction, should be added to MRC C4 2KYS N.

To further ensure timely lubrication of the pump rotor, and to coordinate its maintenance with that of the pump end, it is recommended that a management note be included in the fire pump MIPs (currently E-28/205-55 for Buffalo Forge Pumps and E-28/231-A6 for Fairbanks Morse Pumps), to state that the work center responsible for the pump maintenance should verify the semiannual lubrication of the pump motor bearings.

3.3 Miscellaneous Firemain System Components

Several firemain system components were responsible for only an insignificant portion of the total system maintenance burden and so were not discussed in detail in this report. They were:

- Firepump Motor Controllers
- Resilient Mountings
- Flexible Piping
- Miscellaneous Valves and Piping

Although not discussed in the report, these system components will require maintenance during BOH. Appropriate recommendations are included under Baseline Overhaul Requirements in Chapter Four.

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CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The FF-1052 Class fire pumps (pump and driving motor) will require intracycle maintenance as a consequence of the recorded rates of pump and motor bearing failure, pump mechanical seal failure, and pump internal erosion. The incidence of pump internal erosion in the extended operating cycle will depend on the extent to which material upgrading is accomplished, and the in-service effectiveness of stainless steel alloy parts. The eventual performance of the vertical pump will be dependent upon the implementation of the recommendations of this report, and the reduction in firemain load resulting from installation of ShipAlts FF-1052-372 and FF-1052-378.

4.2 RECOMMENDATIONS

The following subsections detail the recommendations developed as a result of the Firemain System ROE. In addition, Appendix D provides a tabular summary of recommended PMS changes. Appendix E lists all recommendations along with the agency responsible for implementation.

4.2.1 Fire Pump Maintenance Monitoring

The DDEOC Technical Group should monitor the performance and condition of the FF-1052 Class fire pumps using MDS data, site team inputs, and fire pump operating-time information derived from the smooth engineering logs as discussed in Sections 3.2.2.5, 3.2.3.5, and 3.2.4.5. This monitoring should be used to verify or alter the initial planned maintenance intervals recommended in this report. The monitoring should also result in an assessment of the performance of the upgraded vertical pumps for use in re-evaluating the installation of horizontal fire pumps.

4.2.2 Baseline Overhaul Requirements

The Baseline Overhaul concept in the DDEOC program is designed to ensure that ships entering an extended cycle are in a state of material condition readiness that gives a high probability of operating without major restorative maintenance throughout the cycle. In keeping with this philosophy, the following maintenance actions are recommended:

- The fire pump motor controllers and swing check valves should receive Class "B" overhauls.
- Resilient mountings and flexible piping should be renewed.
- The piping and miscellaneous valves associated with the Firemain System should be repaired in accordance with the ship's CSMP and the findings of the pre-overhaul test and inspection stipulated in MRCs 45 G66E N and T 92 B83V R on MIP A-604/2-B5, which covers PMS for the Firemain System.
- Overhaul the Buffalo Forge pumps to the specification of TRS 0521-086-605, applicable to APLs 016150911 and 016150865. Install Alloy 20 components as supply assets permit. Turn in bronze pump casings for refurbishment in accordance with NAVSEA policy. The overhauling agency should reinstall and align the pump.
- Overhaul the Fairbanks Morse Pumps to manufacturer performance specifications as detailed in Technical Manuals 0947-091-4011 (APL 016210239) or 0947-LP-229-7010 (APL 016210325). Install Alloy 20 components as supply assets permit. The overhauling agency should reinstall and align the pumps.
- Overhaul the Reliance Motors to the specifications of TRS 0521-086-606.

4.2.3 Intracycle Maintenance

Intracycle maintenance for the fire pumps is discussed below. The remaining components of the Firemain System should receive intracycle maintenance as currently specified by the PMS specific to the component. This recommendation applies to controllers and miscellaneous valves. General Firemain System PMS is specified on MIP A-604/2-B5.

The recommended intracycle maintenance for the fire pumps is as follows:

- Realign all fire pumps at each SRA (IMA, SIMA, or shipyard with assistance from ship's force).
- Inspect pumps and replace bearings on all pumps and motors at each SRA, if such actions have not been performed since the last SRA or BOH.

- Use fire pump maintenance histories to verify or alter the initial planned maintenance intervals recommended in this report and to determine the necessity of restorative maintenance at SRA for pumps and motors that have received major maintenance in the preceding interavailability period.

- Perform pump and motor PMS currently prescribed on MIPs E-28/205-55, E-28/231-46, and EL-4/28-17, as amended by the recommendations of this report.

4.2.4 Reliability and Maintainability Improvements

The recommended reliability and maintainability changes are as follows:

- Provide FF-1052 Class ships with a bearing heater or hydraulic press.

- Develop a Technical Repair Standard for Fairbanks Morse Pumps, APLs 016210239 and 016210325.

- Investigate the possible role of gear-type couplings in reducing pump and motor bearing failure due to misalignment.

- Eliminate the discrepancy in the type of grease specified by fire pump motor TRS 0521-086-606, the fire pump technical manuals, and MRC C4 2KYS N on MIP EL-4/28-17.

- Develop a method for injecting a pre-measured amount of grease when lubricating motor bearings.

- Eliminate fire pump technical manual references to the use of a standard-fit bearing as an alternative to a loose-fit bearing on Reliance Motor APL 174752249. Ensure that the motor is on the proper Equipment Guide List to receive semiannual lubrication.

4.2.5 ILS Improvements

The recommended ILS improvements are as follows:

- Check to ensure that ships have the latest pump APLs consistent with the pump configuration.

- Revise Buffalo Forge Pump APL 016150865 to show the proper number of impeller wearing rings, two per component, and to include onboard allowance for one spare rotor.

- Take steps to ensure that monel wearing rings are not issued for use on Alloy 20 impellers on Buffalo Forge Pumps.

4.2.6 PMS Changes

The recommended PMS changes are as follows:

- Revise MRC C4 2KYS N on MIP EL-4/28-17 to include a cautionary note on the dangers of over-lubrication, and referring the person doing the maintenance to the work center supervisor for direction on the amount of grease to add.

- Assign MIPs to Buffalo Forge Pump APL 016150865 and Fairbanks Morse Pump APL 016210325.

- Add instructions for recording as-opened and as-repaired wearing ring clearance, impeller diameter, and internal conditions on the 4790-2K to pump inspection MRCs, currently C3 D55T N and A6 K824 N. The periodicity should be changed to R-1. The note on when to accomplish should read "Accomplish when pump is overhauled or opened for repair".

- Add a management note to MIPs E-28/205-55 and E-28/231-A6 stating that the work center responsible for the pump maintenance should verify the semiannual lubrication of the driving motor bearings.

- Revise MRC T C3 D55Q N on MIP E-28/205-55 to conform to the procedure of NAVSHIPS 0947-068-1010, paragraph 4-7. This eliminates the requirement to have the Buffalo Forge Pump operating during the entire lubrication procedure and thus increases safety.

SELECTED SOURCES OF INFORMATION

1. Generation IV MDS part and maintenance data for FF-1052 Class, 1 January 1970 through 31 October 1976.

2. CASREPs for FF-1052 Class, 1 July 1973 through 30 June 1976.

3. NAVSHIPS 0947-068-1010, *Fire Pump, Type 5 x 6 SLV,* 15 March 1974.

4. NAVSEA 0947-091-4011, *Vertical Splitcase, Centrifugal 5" Fig. 5844DX Fire Pump,* 3 February 1975.

5. NAVSEC, *Historical Summary of Fire Pump Problems On Board DE-1052/1078 Class Ships,* enclosure to NAVSEC letter 6153D1/AAN 9503 ESR 6070038 Ser. 535.

6. NAVSEC *DE-1052/1078 Class Fire Pump Maintenance Notes,* enclosure to NAVSEC letter 6153D1/AAN 9503 ESR 6070038 Ser. 535.

7. Detection Action Response Technique (DART) Fire Pump Improvement Program progress reports, October 1971 through March 1977.

8. Maintenance Index Pages E-28/205-55, May 1975; E-28/231-46, October 1976; EL-4/28-17, January 1977; A-604/2-B5, November 1975; and MRCs listed thereon.

9. Allowance Parts Lists (APLs) 016150582, 016150865, and 016150911, all dated 30 June 1977; 016210325, dated 1 December 1976; and 016210239 and 174752249, dated 1 March 1976.

10. Technical Repair Standard 0521-086-605 (applicable to APL 016150911), dated 18 September 1975.

11. Technical Repair Standard 0521-086-606 (applicable to APL 174652249), dated 11 November 1975.

12. MIL-P-17639D (SHIPS), 13 March 1972.

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APPENDIX A

FIREMAIN SYSTEM COMPONENT CONFIGURATIONS IN FF-1052 CLASS SHIPS

This appendix identifies the configuration, for each ship of the FF-1052 Class, of the major Firemain System components analyzed in this report.

Table A-1. APL DEFINITION FOR MAJOR INSTALLED FIREMAIN SYSTEM COMPONENTS

Nomenclature	APL	Applicable Ship's Hull (Number Installed)	Tech. Manual
Buffalo Forge Pump	016150911	FF-1052(4), 1053(4), 1054(4), 1055(4), 1056(4), 1057(3) 1058(1), 1059(3), 1061(2), 1063(4), 1064(4), 1065(2) 1066(4), 1067(4), 1068(2), 1069(4), 1070(4), 1072(4) 1073(1), 1075(2), 1076(4), 1077(4)	0947-068-1010
	016150865	FF-1057(1), 1058(3), 1059(1), 1060(4), 1061(2), 1062(4) 1065(2), 1068(2), 1071(4), 1073(3), 1074(4), 1075(2)	0947-068-1010
Fairbanks Morse Pump	016210239	FF-1079(2), 1080(2), 1082(2), 1085(1), 1086(4), 1088(2) 1089(4), 1090(4), 1091(4), 1092(4), 1093(4), 1094(4) 1095(4), 1096(4), 1097(3)	0947-091-4011
	016210325	FF-1078(4), 1079(2), 1080(1), 1081(4), 1082(2), 1083(4), 1084(4), 1085(3), 1087(4), 1088(2), 1097(1)	0947-LP-229-7010
Reliance Motor	174752249	FF-1052 through 1097(4)	Same as for associated pump end.

APPENDIX B

CASREP SUMMARY ANALYSIS

CASREPs for the FF-1052 Class, covering the period 1 July 1973 through 30 June 1976, were analyzed to determine the types of critical failures experienced by the Firemain System. The number of failures attributable to system components as a function of pump end type are shown in Tables B-1 (FF-1052 through -1077) and B-2 (FF-1078 through -1097).

Table B-1. FIREMAIN CASREPs FOR FF-1052 THROUGH FF-1077, 1 JULY 1973 THROUGH 30 JUNE 1976

CASREP Factors by Equipment	Number	Percent of Grand Total	Number Of Ships
Buffalo Forge Pump, APLs 016150582/016150911			
Bearing(s) Failed	35	17.2	20
Bearing(s) and Mechanical Seals(s) Failed	26	12.8	15
Casing and/or Rotating Assembly Deteriorated	26	12.8	16
Mechanical Seals(s) Failed	16	7.9	12
General Wear	9	4.4	6
"Unknown"	7	3.4	6
Internal Misalignment/Binding	6	2.9	5
Shaft Broken	4	2.0	4
Motor-to-Pump Misalignment	3	1.5	3
Coupling Failed	3	1.5	3
Other	10	5.0	-
TOTAL	145	71.4	
Reliance Motor, APL 174752249			
Bearing(s) Failed	33	16.2	15
Windings Shorted/Burned/Grounded	13	6.4	13
General Wear	2	1.0	1
"Unknown"	2	1.0	2
Shaft Broken	1	0.5	1
Other	3	1.5	-
TOTAL	54	26.6	
Motor Controller, APL 151207595			
Thermal Overload Relay Failed	3	1.5	3
Other	1	0.5	-
TOTAL	4	2.0	
GRAND TOTAL	203	100.0	

Table B-2. FIREMAIN CASREPs FOR FF-1078 THROUGH 1097, 1 JULY 1973 THROUGH 30 JUNE 1976

CASREP Factors by Equipment	Number	Percent of Grand Total	Number Of Ships
Fairbanks-Morse Pump, APL 016210239			
Bearing(s) Failed	15	15.0	8
Coupling Failed	14	14.0	8
Casing and/or Rotating Assembly Deteriorated	13	13.0	7
General Wear	8	8.0	5
Internal Misalignment/Binding	7	7.0	4
Mechanical Seal(s) Failed	3	3.0	3
Pump Lost Suction	3	3.0	2
Bearing(s) and Mechanical Seal(s) Failed	2	2.0	2
Motor-to-Pump Misalignment	2	2.0	1
Other	3	3.0	-
TOTAL	70	70.0	
Reliance Motor, APL 174752249			
Bearing(s) Failed	17	17.0	10
Windings Shorted/Burned/Grounded	10	10.0	6
Other	2	2.0	-
TOTAL	29	29.0	
Motor Controller, APL 151207595			
"Defective"	1	1.0	1
TOTAL	1	1.0	
GRAND TOTAL	100	100.0	

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APPENDIX C

ISSUES TO DATE OF FIRE PUMP
CASINGS AND REPLACEMENT ENDS

Table C-1 lists issues to date of FF-1052 Class fire pump Alloy 20 casings and Alloy 20 replacement pumps.

Table C-1. FIRE PUMP CASING AND PUMP END INSTALLATIONS ON FF-1052 CLASS SHIPS

Buffalo Forge Pumps			Fairbanks Morse Pumps		
Ship	Casing	Pump End APL 016150865	Ship	Casing	Pump End APL 016210325
1057		1	1078	4	
1058	3		1079	2	
1059		1	1080	1	
1060	4		1081	4	
1061	2		1082	2	
1062		4	1083	4	
1065	2		1084	4	
1068	2		1085	3	
1071		4	1087	4	
1073		3	1088	2	
1074		4	1097		1
1075		2			
TOTAL	13	19	TOTAL	30	1

APPENDIX D

MRC EVALUATION

The DDEOC MRC Evaluation table in this appendix specifies the Maintenance Index Pages (MIPs) and the associated Maintenance Requirement Cards (MRCs) that should be modified or deleted to implement the recommendations in Chapter Four.

Supplementary information concerning the column headings of the DEEOC MRC Evaluation form is provided below:

- MRC Title - Title of MRC, applicable MIP page numbers, and description of maintenance specified by MRC
- Responsibility - Organizations responsible for change
- Man-Hours - Personnel time burden allotted to complete maintenance action
- Frequency - When the MRC maintenance action is to be performed, i.e., D = Daily, W = Weekly, M = Monthly, Q = Quarterly, C = Once every cycle, R = As Required
- Type - Perform maintenance (P), or survey material condition of component (S)
- Who Performs Test - Organizations responsible for performing maintenance action or test — i.e., tender, DDEOC site team, or ship's force personnel
- Data - Indicate whether data are recorded during performance of maintenance action

SHIP CLASS: FF-1052
SMA NO: 203-521
SYSTEM: FIREMAIN

DDEOC MRC EVALUATION

MRC TITLE	MRC NUMBER	RESPONSIBILITY		CURRENT STATUS			MAN HOURS		FREQUENCY		TYPE*	SHIP PERFORMED TEST			SHIP PERFORMANCE	DATA	REMARKS
		CNAVEVLA	DDEOC	OLD MRC NO CHANGE	OLD MRC REVISION	NEW	PRE DDEOC (MH)	POST DDEOC (MH)	PRE DDEOC	POST DDEOC	P-PERF S-SURV	FEDMEA	DDEOC	SHIP	1-ID POST S-AT SEA	YES NO	
ELECTRIC DRIVE FIRE PUMP - MIP E-28/205-55																	
1. Inspect pump internal parts	C3 D55T N				X		14.2	14.2	C-1R	R-1	P,S	X		X	I	Yes	
2. Add management note to MIP	-																
3. Lubricate and sound test roller/ ball bearings.	T C3 D55Q N				X		0.5	0.5	M-9	M-9	P,S			X	I,S	No	
ELECTRIC DRIVEN FIRE PUMP - MIP E-28/231A-6																	
1. Inspect pump internal parts	A6 K82A N				X		30.0	30.0	C-1R	R-1	P,S	X		X	I	Yes	
2. Add management note to MIP	-																
DEVELOP MIP FOR APL 016210325	-																
DEVELOP MIP FOR APL 016150865																	
AC AND DC MOTORS - MIP EL-4/28/17																	
1. Lubricate units installed with loose internal fit bearings of single shield design.	C4 2KYS N				X		0.3	0.3	S-1	S-1	P			X	I,S	No	

*P PERFORM MAINTENANCE S SURVEY INSPECTION

APPENDIX E

DDEOC ACTION TABLE

DDEOC action items are presented in the following table. The table is formatted to provide the implementation status of changes through completion of the Class Maintenance Plan, and to serve as a ready reference to specific paragraphs in Chapter Three that address the subject in detail.

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DDEOC ACTION

1 ACTION ITEM * a. NO.	b. TITLE	2 DDEOC EVALUATION **	3 ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)	5
	BASELINE OVERHAUL REQUIREMENTS				
1.	Buffalo Forge Pump		1. The Buffalo Forge pumps should be overhauled to the specifications of TRS 0521-086-605.	3.2.2.5	I S
2.	Fairbanks Morse Pumps		1. The Fairbanks Morse Pump should be overhauled to the specifications of Technical Manuals 0947-091-4011 or 0947-LP-229-7010.	3.2.3.5	I S
3.	Reliance Motor		1. The Reliance Motors should be overhauled to the specifications of TRS 0521-086-606.	3.2.4.5	I S
4.	Motor Controllers, Check Valves		1. These components should receive "Class B" overhauls.	3.3	I S
5.	Piping, miscellaneous valves		1. Repair in accordance with ship's CSMP and findings of POT&I based on MRCs 45 G66E N and T 92 B83V R on MIP A-604/2-B5.	3.3	S I S
6.	Resilient mounts and flexible piping		1. Renew at overhaul.	3.3	S
	INTRACYCLE MAINTENANCE				
1.	Buffalo Forge Pump Fairbanks Morse Pump Reliance Motor		1. Align all fire pumps at each SRA.	3.2.2.5 3.2.5.1	I S S A
			2. DDEOC Technical Group use fire pump maintenance histories to verify or alter initial planned maintenance intervals for intracycle maintenance. Initially, inspect pumps and replace bearings on all pumps and motors at each SRA if such actions have not been performed in the previous inter-availability period.	3.2.2.5 3.2.3.5 3.2.4.5	D G

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUA

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: FF-1052
SMA NO: 203-521
SYSTEM: Firemain

DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
e of	3.2.2.5	IMA,SIMA, Shipyard					
be of or	3.2.3.5	IMA,SIMA, Shipyard					
er- TRS	3.2.4.5	IMA,SIMA, Shipyard					
	3.3	IMA,SIMA Shipyard					
CSMP RCs	3.3	Ships Force, IMA,SIMA, Shipyard					
	3.3	Shipyard					
.	3.2.2.5 3.2.5.1	IMA,SIMA Shipyard with Ship's Force Assistance					
ump or e ance. lace at t nter-	3.2.2.5 3.2.3.5 3.2.4.5	DDEOC Technical Group					

UIRED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

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1 ACTION ITEM * a. NO.	b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)
	RELIABILITY AND MAINTAINABILITY			
1.	General		1. Provide FF-1052/1078 Class ships with bearing heater or hydraulic press.	3.2.2. 3.2.4.
			2. Investigate the possible role of gear-type couplings in preventing pump and motor bearing failure due to misalignment.	3.2.3.
2.	Fairbanks Morse Pump		1. Develop a Technical Repair Standard for APLs 016210239 and 016210325.	3.2.3.
3.	Reliance Motor		1. Eliminate the discrepancy in the type of grease specified by TRS 0521-086-606, fire pump technical manuals, and MRC C4 2KYS N on MIP EL-4/28-17.	3.2.4.
			2. Develop a method for injecting a pre-measured amount of grease in lubricating motor bearings.	3.2.4.
			3. Eliminate fire pump technical manual references to the use of a standard fit bearing as an alternative to a loose fit bearing on Reliance Motor APL 174752249. Ensure that motor is on the proper Equipment Guide List (EGL) to receive semi-annual lubrication.	3.2.4.
	ILS IMPROVEMENTS			
1.	Buffalo Forge Pump		1. Conduct check to ensure that ships have latest pump APLs consistent with configuration.	3.2.2.
			2. Revise APL 016150865 to show proper number of impeller wearing rings, 2 per component, and to include allowance for one spare rotor.	3.2.2.

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTI

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

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2

SHIP CLASS: FF-1052
SMA NO: 203-521
SYSTEM: Firemain

DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
lps with ress.	3.2.2.3 3.2.4.2	NAVSEA 934					
of gear- pump to	3.2.3.2	NAVSEC					
ndard 325.	3.2.3.5	PERA (CRUDES)					
the type 21-086- ls, and 17.	3.2.4.5	NAVSEC PERA (CRUDES) NAVSEA 934					
g a pre- lubricat-	3.2.4.5	NAVSEC					
manual ndard to a Motor otor is List lubrica-	3.2.4.5	NAVSEA 045F NAVSEC					
ships ent with	3.2.2.5	SPCC NAVSEA 045F					
proper ngs, 2	3.2.2.5	SPCC NAVSEA 045F					

EQUIRED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

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1 ACTION ITEM * a. NO.	1 ACTION ITEM * b. TITLE	2 DDEOC EVALUATION **	3 ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)
	ILS IMPROVEMENTS (Cont.)			
			3. Take steps to ensure that monel wearing rings are not issued for use on Alloy 20 impellers.	3.2.2.5
2.	Fairbanks Morse Pump		1. Conduct check to ensure that ships have latest pump APLs consistent with configuration.	3.2.3.1
	PMS CHANGES			
1.	Buffalo Forge Pumps		1. Assign an MIP to APL 016150865.	3.2.2.5
			2. Add instructions for recording as-opened and as-repaired wearing ring clearance, impeller diameter, and internal condition on the 4790-2K to MRC C3 D55T N. Change the periodicity of the MRC to R-1, and revise the note on when to accomplish to read "Accomplish when pump is overhauled or opened for repair".	3.2.2.5
			3. Add a management note to MIP E-28/205-55 which states that the work center responsible for the pump maintenance should verify the semi-annual lubrication of the driving motor bearings.	3.2.4.5
			4. Revise MRC T C3 D55Q N on MIP E-28/205-55 to conform to the procedure of NAVSHIPS 0947-068-1010, paragraph 4-7.	3.2.4.5

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTIN

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: FF-1052

SMA NO: 203-521

SYSTEM: Firemain

DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
wear- e on	3.2.2.5	SPCC NAVSEA 045F					
ips t	3.2.3.1	SPCC NAVSEA 045F					
	3.2.2.5	NAVSEA 934					
as- ring nd 2K to dicity he note uled	3.2.2.5	NAVSEA 934					
28/205- enter nance ubri- rings.	3.2.4.5	NAVSEA 934					
-28/ ure graph	3.2.4.5	NAVSEA 934					

UIRED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

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1. ACTION ITEM * a. NO.	1. ACTION ITEM * b. TITLE	2. DDEOC EVALUATION **	3. ACTION ITEM DESCRIPTION	4. REPORT REFERENCE (PARA.)
2.	Fairbanks Morse Pump		1. Assign an MIP to APL 016210325.	3.2.3
			2. Add instructions for recording as-opened and as-repaired wearing ring clearance, impeller diameter, and internal condition on the 4790-2K to MRC A6 K824N. Change the periodicity of the MRC to R-1, and revise the note on when to accomplish to read "Accomplish when pump is overhauled or opened for repair".	3.2.3
			3. Add a management note to MIP E-28/231-46 which states that the work center responsible for the pump maintenance should verify the semi-annual lubrication of the driving motor bearings.	3.2.4
3.	Reliance Motor		1. Revise MRC C4 2KYS N on MIP EL-4/28-17 to include a continuing note on the dangers of over lubrication and refering the person doing the maintenance to the work center supervisor for direction on the amount of grease to add.	3.2.4

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONT

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: FF-1052

SMA NO: 203-521

SYSTEM: Firemain

DDEOC ACTION TABLE

	4. REPORT REFERENCE (PARA.)	5. RESPONSIBILITY †	6. SCHEDULING DATES a. REQD.	b. START	c. COMP.	7. REMARKS, FUNDING IMPLICATIONS, ETC.	8. ACTUAL ACTION TAKEN
	3.2.3.5	NAVSEA 934					
- ing l t to ity note ed	3.2.3.5	NAVSEA 934					
/231- ter nce ri- ngs.	3.2.4.5	NAVSEA 934					
28- n nd nte- or ease	3.2.4.5	NAVSEA 934					

RED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.