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MAR 73 E J LUTZ, D J HOFFMAN N00024-72-C-5388
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FINAL REPORT

ESTABLISHMENT OF RELIABILITY AND MAINTAINABILITY DATA BANK FOR SHIPBOARD MACHINERY

Volume I

March 1973

Prepared for
NAVAL SHIP SYSTEMS COMMAND
WASHINGTON, D. C.
under Contract N00024-72-C-5388

ARINC RESEARCH CORPORATION

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This report presents the procedures and techniques established by ARINC Research and used to analyze corrective-maintenance data on ship-board equipments and to develop reliability and maintainability indices. These indices, along with the basic equipment identification and source data, are conveniently displayed on format sheets, which are compiled in Volume II in Component Identification Number (CID) sequence and by Generic Groups.

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ABSTRACT

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SUMMARY

ARINC Research Corporation established procedures and techniques for use in analyzing corrective-maintenance data on shipboard equipments and in developing reliability and maintainability indices. The procedures and techniques are presented and explained in Volume I. The data sheets, with equipment identification, source data, and reliability and maintainability (R&M) indices, are presented in Volume II in CID (component identification) sequence and by generic groupings, i.e., equipments of similar type and rating.

The data bank developed by this study provides a quantitative baseline of reliability and maintainability information for a wide range of shipboard equipments that can be used in preparing equipment specifications and evaluating studies containing R&M predictions of new equipment designs.

Equipments analyzed in this report are significantly different from those addressed in previous studies, which have usually been concerned with main propulsion equipment. This study was directed toward the auxiliary and deck equipments, with a limited number of aviation-oriented equipments included, e.g., aviation-fuel-oil service pumps. The principal difference lies in the dual uses of many of these equipments, as well as the ambiguity of the Equipment Identification Codes (EIC) in describing the equipment for which a code is intended, both causing a problem in data reporting. These coding errors necessitate much more manual screening, sorting, and recording of the data than required for data from an item of main propulsion equipment, for which a code is more easily found in the EIC manual.

The type of equipment studied in this report differed also in the accessibility of the operating time of the equipments. For the most part, no logs are kept on auxiliary-type equipments, and such values as percent of underway steaming hours had to be estimated in order to determine operating time. These estimates, or equipment-use factors, are at best very rough, and it is recommended that a systematic program be established in the Navy to develop use factors for equipments on which logs are not currently maintained.

The maintenance factors used to convert maintenance man-hours to active maintenance time have similar deficiencies. These factors must be developed systematically so that they can be used with greater confidence in predicting maintenance manning requirements.

As the Generation III MDCS programs become operational, there will be a greater need for better equipment-use factors, maintenance factors, and programs such as the Source Data Automation Program for the production of more accurate R&M indices.

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CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

In the past 20 years, techniques for measuring, predicting, and controlling reliability and maintainability have advanced significantly; however, most of the research has been concerned primarily with electronic systems. The capability for assuring the reliability and maintainability of mechanical systems is not nearly so advanced.

Under contract to the Navy, ARINC Research Corporation has been active for more than six years in developing, improving, and applying techniques for reliability and maintainability assessment of Navy mechanical systems.

One of the major benefits to the Navy from these efforts -- and one that applies directly to the Shipboard Machinery Reliability and Maintainability Data Bank Program -- was the development, testing, and application of a computerized logic program* capable of accurately analyzing pre-1970 Maintenance Data Collection Subsystem (MDCS) data to identify discrete maintenance events concerning individual equipments. The logic program identifies, sorts, and counts corrective-maintenance events, forced-shutdown failures, and support-maintenance events as the reported data apply to a specific type of equipment. It also screens the MDCS data for erroneous or inapplicable data.

In addition, ARINC Research has compatible, computer-programmed ship-steaming-hour data for the Fleet for the period July 1965 through 30 June 1969, and more than one million equipment-MDCS maintenance reports on computer tapes for the ships and equipments considered during the studies mentioned above.

These available computer programs and data tapes -- together with a thorough understanding of the work flow and analysis requirements associated with obtaining operational reliability and maintainability indices on shipboard mechanical equipments -- permitted a sound technical approach to be used for the timely development of a mechanical-equipment data bank. Figure 1-1 is a flow chart of the major steps involved in the effort.

**ARINC Research Publication 933-01-2-1079, November 1970.*

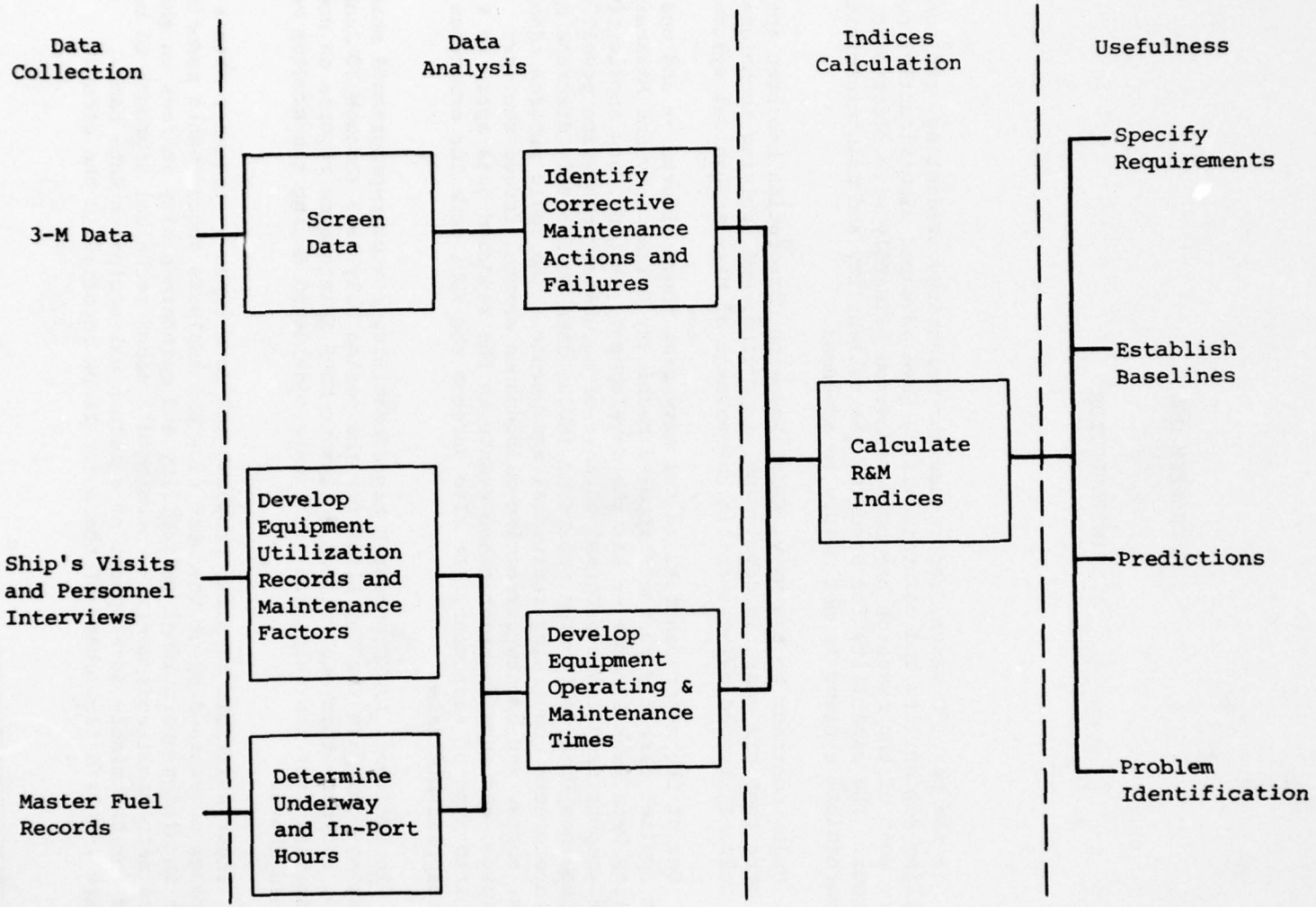

Figure 1-1. DEVELOPMENT OF MACHINERY R&M DATA

Work performed for the Navy by ARINC Research Corporation had shown that Fleet maintenance data could be used to develop reliability and maintainability Figure of Merit (FOM) indices for shipboard mechanical equipments. These data, supplemented by operating-time data obtained from ship's records, can be used to derive meaningful indices, provided the data are logically analyzed in relation to each specific type of equipment. This report describes the program conducted by ARINC Research, utilizing the techniques, skills, and logic now available, to compile a reliability and maintainability data bank for selected shipboard equipments.

This effort was directed toward accomplishing the following:

- Improve the decision-making capability of engineering and maintenance management in the selection of equipments for new ships now in the planning stage.
- Improve judgments on the requirements and resources needed to support existing operational equipment
- Provide substantiated documentation for obtaining and allocating funds
- Aid in identifying proper corrective actions for improving Fleet readiness
- Provide quantitative *baselines* for the preparation of equipment specifications

This volume describes the data collection and analysis procedures and the logic used to compute the reliability and maintainability indices. The following chapters will present detailed information on:

- Data-bank format entries - Chapter Two
- Selection of equipments for this study - Chapter Three
- Data-collection efforts - Chapter Four
- Discussion of the data-analysis logic and computation of indices - Chapter Five
- Discussion of previous ARINC Research studies for inclusion in the data bank - Chapter Six
- Description of the process for generic grouping and selection of equipments - Chapter Seven
- Conclusions and recommendations - Chapter Eight

The appendixes contain information on the 3-M subsystem MDCS codes for "Action Taken" and "How Malfunction" (Appendix A); a description of the process for analyzing data rejected by the computer program for determining maintenance events (Appendix B); and the instructions and logic flow charts for the Maintenance-Event Identification and Classification Program (Appendix C).

CHAPTER TWO

DATA-BANK PRESENTATION FORMAT

2.1 SELECTION OF FORMAT

The Shipboard Machinery Reliability and Maintainability Data Bank Presentation Format was selected for its adaptability to presenting mechanical-equipment data, ease of updating, and capability to be microfilmed for storage purposes. It is shown in Figure 2-1.

2.2 DESCRIPTION OF FORMAT

This section describes the data-bank format. It gives a detailed explanation of the type of information to be provided and the definition of the Figures of Merit (FOM). The procedures for computing the FOMs are described in Chapter Five, Section 5.5.

2.2.1 Equipment Identification

Equipment identifiers are as follows:

Noun Name. The service-application descriptor assigned to the equipment as taken from the Equipment Identification Code (EIC) directory.

General Description. The equipment's pertinent design specifications, as taken from the Ship Part Control Center (SPCC) Deck E Card Index "A" entry.

CID/APL Number(s). The Component Identification (CID) Number/ Allowance Part List (APL) Number assigned to the specific equipment. In the case of a system comprising many CID/APLs, the primary equipment/system CID will be listed. The generic grouping will have all the CIDs comprising the group identified.

Federal Stock Number The Federal Stock Number assigned to the CID/APL Number(s).

Equipment Identification Code. The seven-digit Equipment Identification Code (EIC), as taken from the EIC Directory, used to code the equipment in reporting maintenance data. Both the Generation I and Generation III MDCS EICs are shown where possible.

SHIPBOARD MACHINERY
RELIABILITY AND MAINTAINABILITY DATA BANK

Equipment Identification

Noun Name: _____

General Description: _____

CID/APL Number(s): _____ Federal Stock Number: _____

Equipment Identification Code: _____

Technical Manual: _____

Manufacturer: _____

Basic Data

Ship Population: _____ Equip. Population/Ship: _____

Equip. Population in Data Base: _____ Data Assessment Period: _____

Utilization Factors: _____

Total Equip. Operating Time (hours): _____

Total Number of: Failures (CM_f): _____ Corrective Maintenance Events (CM): _____

Total CM_f Repair Man-Hours: _____ Total CM Repair Man-Hours: _____

Maintenance Factors: _____

Reliability Indices

Mean Time Between Failure
(Forced Shutdown Corrective Maintenance)

$MTBCM_f$: _____

90% Confidence Interval

Upper Limit: _____

Lower Limit: _____

Mean Time Between Corrective Maintenance

MTBCM: _____

90% Confidence Interval

Upper Limit: _____

Lower Limit: _____

Maintainability Indices

Corrective Maintenance — (Forced Shutdown Failure Events Only)

$MTTR_f$: _____

$MCMM_f$: _____

Max. Observed MH: _____

$\overline{MCMM}_f$: _____

Variance: _____

Corrective Maintenance — (All Events)

$MTTR_{cm}$: _____

$MCMM_{cm}$: _____

Max. Observed MH: _____

$\overline{MCMM}_{cm}$: _____

Variance: _____

Indicated Distribution(s): Exponential _____ Normal _____ Log Normal _____

*REMARKS: _____

_____

_____

Figure 2-1. SAMPLE DATA-BANK FORMAT

Manufacturer. The manufacturer of the equipment as identified in the CID/APL number.

2.2.2 Basic Data

The following are the basic data elements used in the development of the R&M indices:

Ship Population. The specific hull designations and numbers of the ships on which the equipment is located as identified by the SPCC Deck "E" card for the appropriate CID/APL number and service-application noun name.

Equipment Population/Ship. The number of units on each ship as listed in the ship COSAL and the SPCC Deck "E" card for the appropriate CID/APL number and service application.

Total Equipment Population in Data Base. The total number of equipments in the ship population that comprises the data base for each CID.

Data-Assessment Period. The period of time comprising the data period: beginning month/year - ending month/year - number of months.

Utilization Factors (K_u). Required for equipments that do not have individually reported operating time. The factor is the ratio of the equipment's operating time to some other known time base such as ship steaming hours, clock hours, or calendar hours. The Application Code preceding the utilization factor indicates what time base is being used.

Application Code	Time-Related Base
S	Steaming Hours
H	Calendar/Clock Hours

Total Equipment Operation Time. The total time all equipments selected within the design category operate. The method of computing this time is shown in Chapter Five, Section 5.4.

Total Number of Failures (CM_f). The occurrence of any unsatisfactory operation of an equipment that results in the equipment's forced shutdown or failure to start up. The total number of failures for a design application is derived by summing the individual failures of the equipments on the ships being used to develop the FOM.

Total Number of Corrective-Maintenance Events (CM). Any unscheduled maintenance performed on an equipment. The total number of corrective-maintenance events is derived by summing the individual corrective-maintenance events, including failures, on the equipments that comprise the population sample being used to develop the FOM.

Total CM_f Repair Man-Hours. The total number of man-hours required to repair failures -- obtained by summing the maintenance man-hours from all corrective-maintenance events resulting only from the equipment failures.

Total CM Repair Man-Hours. The sum of the maintenance man-hours from all corrective-maintenance events, including those events resulting from equipment failure.

Maintenance Factor. A ratio of men to maintenance events that has been derived from Fleet survey and data analysis for some equipments; used to convert equipment maintenance man-hours to active maintenance time. In this study, where no specific maintenance factor exists, 0.67 is used.

2.2.3 Reliability Indices

Reliability indices are as follows:

Mean Time Between Failures (Forced Shutdown Corrective Maintenance) $MTBCM_f$. The average equipment operating time between corrective-maintenanee events resulting from forced equipment shutdowns, i.e., failures. The 90-percent confidence interval will be based on the assumption that the time between failures follows an exponential distribution.

Mean Time Between Corrective Maintenance - MTBCM. The average equipment operating time between all unscheduled corrective-maintenance events. The 90-percent confidence interval will be used on the assumption that the time between corrective maintenance follows an exponential distribution.

2.2.4 Maintainability Indices

Maintainability indices are as follows:

Mean Time to Repair (Failures) Forced-Shutdown Corrective Maintenance - $MTTR_f$. Mean time to repair an equipment malfunction that resulted in a forced equipment shutdown. The index is a measure of the hours of active maintenance required to repair an equipment failure; it does not include logistics or administrative time.

Median Corrective-Maintenance Man-Hours (CM_f) - $MCMM_f$. The median number of man-hours required to perform corrective maintenance resulting from forced-shutdown failures only. This index is selected to aid in providing a better indicator of the distribution of maintenance man-hours. The literature indicates that maintenance man-hour distributions are most often log-normal; therefore, the median is often a more applicable measure of the central tendency.

Maximum Observed Man-Hours (CM_f). The highest reported value of the corrective-maintenance man-hours resulting from forced-shutdown failure.

Mean Corrective-Maintenance Man-Hours (CM_f) - $\overline{MCMM_f}$. The average man-hours to perform all corrective maintenance resulting from forced-shutdown failure.

Variance (CM_f). The variance of the forced-shutdown corrective-maintenance event man-hours -- included to indicate the concentration of the individual values about the mean value.

Mean Time to Repair (Corrective Maintenance) - $MTTR_{cm}$. Mean time to repair these equipments for all corrective-maintenance events. Same definition as $MTTR_f$, but includes all unscheduled corrective maintenance as well as maintenance resulting from equipment failures.

Median Corrective-Maintenance Man-Hours (CM) - $MCMM_{CM}$. The median number of man-hours required to perform all maintenance. This index is provided for the same reasons as $MCMM_f$ above.

Maximum Observed Man-Hours (CM). The highest reported value of all corrective-maintenance-event man-hours.

Mean Corrective-Maintenance Man-Hours - $\overline{MCMM_{cm}}$. The average man-hours to perform all corrective maintenance.

Variance (CM). The variance of the corrective-maintenance-event man-hours for all corrective-maintenance events -- included for the reason stated above for CM_f.

Indicated Distribution of Maintenance Man-Hours. The probable distribution of maintenance man-hour times as reported for this type of equipment. A check in the space by one of the distributions indicates that the analysis procedure described in Chapter Five, Section 5.5.2 has shown the observed distribution to be

closest to this theoretical distribution and within the critical value for the test. The absence of checks in any of the spaces indicates that insufficient information was available to make a distribution analysis, i.e., less than 50 corrective-maintenance events.

CHAPTER THREE

SELECTION OF EQUIPMENTS

3.1 SELECTION CRITERIA

The following criteria were established by NAVSEC in the contract requirements as a guide for selecting new equipments to be included in the initial shipboard-machinery R&M Data Bank:

- Equipment will be less than twelve years old.
- There will be at least four of each of the selected equipments (two ships - two equipments each) in use in an operational environment.
- Maintenance Data Collection Subsystem (MDCS) and ships' utilization data have been previously collected or can be made available by NAVSEC on the equipments of interest.
- A minimum of 250 component identification (CID) numbers will be selected over and above those for which R&M indices are available and adequate.

In meetings with NAVSHIPS, NAVSEC, and ARINC Research personnel, a joint decision was made to accomplish the following:

- Identification of the ship mechanical systems of immediate interest
- Identification of the types of equipments used in the system of immediate interest and the ship types and classes using these equipments
- Identification of the specific equipment EICs (MDCS Equipment Identification Codes) within each equipment type to be used as a baseline from which to gather further information on particular equipment designs. These equipments and systems are listed in Table 3-1.

Table 3-1. INITIAL EQUIPMENT-SELECTION LIST FOR R&M DATA BANK

Equipment/System	EIC	Selection Action
Diesel Engines, Propulsion	1A00	Accepted
Pump, Fuel Oil Service	1F01	Accepted
Purifier, Fuel Oil DeLaval	1F28	Accepted
Purifier, Fuel Oil Sharples	1F30	Accepted
Purifier, Lube Oil DeLaval	1G43	Accepted
Purifier, Lube Oil Sharples	1G44	Accepted
Transmission Systems	1K00	Accepted
Engine Diesel Fire Pump	3A02	Rejected
Air Conditioning Systems	AA00	Accepted
Compressor, Air HP Recip.	AB18	Accepted
Compressor, Air LP & IP Recip.	AC01	Accepted
Distilling Plants	AE00	Accepted
Pump, Recip. Steam Dr. Fire	AFD1	Rejected
Pump, Fresh Water	AH17	Accepted
Purifier, Fuel Oil DeLaval	AFG3	Accepted
Purifier, Fuel Oil Sharples	AJG4	Accepted
Refrigeration Systems	AM00	Accepted
CO_2 Removal Systems	AU01	Rejected
O_2 Generating Plant	AU02	Rejected
O_2N_2 System	AU03	Rejected
Pump, CTFGL Aircraft Fuel/Defuel	AX04	Accepted
Pump, Priming Aircraft Fuel/Defuel	AX05	Accepted
Elevator, Electro Mech., Weapon/Cargo	GWEB	Accepted
Elevator	GWBC	Tentative
Elevator Ammo	GWGA	Rejected
Crane Loader ASROC	JFCA	Rejected
Winches and Hoisting Equip.	K100	Accepted
Winch, Bathythermograph	K101	Accepted

(continued)

Table 3-1. (continued)

Equipment/System	EIC	Selection Action
Winch, Fanfare Streaming	K102	Accepted
Winch, Fuel at Sea	K112	Accepted
Winch, Topping, Electric	K113	Accepted
Winch, Elect. Hyd.	K115	Accepted
Winch, Main Deck Ramp	K123	Accepted
Hoisting Equipment, Bow Ramp	K130	Rejected
Winches, Boat	KC00	Accepted
Windlass, Anchor	KG00	Accepted
Windlass, Vert. SC	KG01	Accepted
Windlass, Vert. SC	KG02	Accepted
Windlass, Horiz. DG	KG03	Accepted
Shaft Vert.	KG04	Accepted
Shaft Horiz.	KG05	Accepted
Windlass	KG06	Accepted
Winches, Snaking & Warping	KK00	Accepted
Crane, Boat and Airplane	KP00	Rejected
Elevator, Cargo	KT06	Accepted
Elevator, Stores	KT07	Accepted
Winches, RAS	KU00	Accepted
Winches, Cargo	KV00	Accepted
400 Hertz M/G Sets	QD00	Accepted
Boiler - CE DLG 29, 30, 31	ZA00	Accepted
Purifier, Disc Type, Lube Oil	ZU05	Accepted
Purifier, L.O. Sharples	ZU14	Accepted
Purifier, L.O. DeLaval	ZU16	Accepted
Controllable Pitch Propllers	1H10 *1M00	Accepted

**Coast Guard, Hamilton Class Cutter, Gas Turbines*

3.2 EQUIPMENT-SELECTION PROCEDURE

A list of 218 ships representing 22 different types, shown in Table 3-2, was developed from the active roster; it included those ships for which normal steaming hours and normal maintenance actions were reported during the data period 1 July 1967 through 30 June 1969. Ships overhauled during the data period were not included in the list. With the exception of some of the AFs, AOs, ATFs, LSTs, MSCs, and MSOs, the ships selected had a commissioning date more recent than 1956. Listed ships older than this were included to provide the broadest possible group of designs for comparison within a given equipment type.

The ship COSALs (Coordinated Shipboard Allowance Lists) of at least one ship of each class of the selected ship types were manually screened for the equipment CID/APL numbers of the equipment categories shown in Table 3-1. Approximately 40 COSAL screenings were conducted.

With the CID/APL numbers of the equipment of interest, it was then possible to examine the Ship Parts Control Center (SPCC) Deck "E", which is a listing by CID/APL number of every HM&E item in the Navy. This list indicates on what ships a particular CID is located, the application of the equipment on the ship, and the quantity used in each application. The CIDs of interest were located in the Deck "E", and the information on population and application was manually extracted. The COSALs and the Deck E are located at the NAVSEC Technical Library, Prince Georges Center, Hyattsville, Maryland, and at MSO, the Maintenance Support Office, at Mechanicsville, Pennsylvania.

From the information obtained by the COSAL and Deck E screenings, a more complete equipment EIC list was developed. It is shown in Table 3-3. This list of 114 third-level EICs, along with the initial list of 218 ships, provided the information needed for requesting the MDCS data from the Naval Ship Systems Command.

3.3 EQUIPMENTS SELECTED

Final equipment selection was made after the processing of the MDCS data showed that it was possible to identify data with the particular equipment CID of interest. Only where the data were identifiable with the equipment could the final selection be made for the data bank.

To accomplish this, it was necessary in many cases to screen the data manually for errors such as obvious miscodings (e.g., two or three EICs are used to report data from the same piece of equipment because of the overlapping of the noun names of the equipments and EICs); and reporting of data under different EICs because the equipment performs several functions (e.g., the fuel-oil purifier, which purifies both fuel for the Emergency Diesel and the aviation-fuel service tank). Where the ambiguity of either the EIC codes or equipment use caused the data to be reported in several places, these data were recorded under a single EIC before being processed for corrective-maintenance and failure-event determination.

Table 3-2. **SELECTED SHIPS**

Ship Type/ Hull No.	UIC	Ship Type/ Hull No.	UIC	Ship Type/ Hull No.	UIC
AE 21	08821	ATF 100	07100	DD 951	04667
AE 22	08822	ATF 101	07101	DDG 2	04668
AE 23	08391	ATF 103	07103	DDG 5	04671
AE 25	08301	ATF 105	07105	DDG 6	04672
AF 52	01591	ATF 107	07107	DDG 7	04673
AF 61	02401	ATF 114	07114	DDG 8	04674
AFS 1	05831	ATF 156	07156	DDG 9	04675
AFS 2	74025	ATF 159	07159	DDG 11	04677
AFS 3	05834	ATF 161	07161	DDG 12	04678
AO 97	04847	ATF 162	07162	DDG 13	04679
AO 100	04850	ATF 163	07163	DDG 14	04680
AO 105	04805	CVA 61	03361	DDG 15	04681
AO 106	04806	CVA 62	03362	DDG 16	04682
AO 107	04807	CVA 63	03363	DDG 17	04683
AO 108	04808	CVA 64	03364	DDG 18	04684
AO 109	04809	CVA 66	03366	DDG 19	04685
AO 143	05903	DD 875	52175	DDG 20	04686
AO 145	05905	DD 876	52176	DDG 21	04687
AO 146	05906	DD 877	52177	DDG 24	04691
AO 147	05907	DD 878	52178	DDG 31	52196
AO 148	05908	DD 880	52180	DE 1021	54021
AS 31	04689	DD 881	52181	DE 1022	54022
AS 32	04696	DD 882	52182	DE 1027	54027
AS 33	04697	DD 883	52183	DE 1028	54028
AS 34	04720	DD 884	52184	DE 1029	54029
ATF 67	07067	DD 885	52185	DE 1033	54031
ATF 72	07072	DD 886	52186	DE 1034	54034
ATF 75	07075	DD 888	52188	DE 1045	54041
ATF 76	07076	DD 889	52189	DEG 1	04692
ATF 84	07084	DD 937	52197	DEG 2	04693
ATF 85	07085	DD 940	52199	DEG 4	04695
ATF 86	07086	DD 941	52200	DEG 5	04698
ATF 91	07091	DD 942	52201	DLG 8	52233
ATF 92	07092	DD 946	04662	DLG 9	52234
ATF 96	07096	DD 948	04664	DLG 10	52235
ATF 98	07098	DD 950	04666	DLG 11	52236

(continued)

Table 3-2. (continued)

Ship Type/ Hull No.	UIC	Ship Type/ Hull No.	UIC	Ship Type/ Hull No.	UIC
DLG 14	52685	LST 1123	58123	SSBN 598	05106
DLG 18	52689	LST 1126	58126	SSBN 599	05107
DLG 19	52690	LST 1141	58141	SSBN 600	05108
DLG 20	52691	LST 1146	58146	SSBN 601	05109
DLG 22	52693	LST 1150	58150	SSBN 602	05110
DLG 23	52698	LST 1156	58156	SSBN 608	05116
DLG 28	52703	LST 1157	58157	SSBN 609	05117
DLG 29	52704	LST 1159	58159	SSBN 628	05702
DLG 30	52705	LST 1161	58161	SSBN 629	05703
DLG 31	52706	LST 1162	58162	SSBN 630	05704
DLG 32	52707	LST 1163	58163	SSBN 631	05705
DLG 33	52708	LST 1166	58166	SSBN 632	05706
LPD 1	07170	LST 1167	58167	SSBN 633	05707
LPD 2	07171	LST 1168	58168	SSBN 634	05708
LPD 3	07172	LST 1169	58169	SSBN 635	05709
LPD 4	07175	LST 1170	58170	SSBN 636	05710
LPD 5	07176	LST 1173	58173	SSBN 640	05711
LPD 6	07177	LST 1174	58174	SSBN 641	05712
LPD 7	07178	LST 1175	58175	SSBN 642	05713
LPH 2	07350	LST 1176	58176	SSBN 643	05714
LPH 3	07351	MSC 198	16461	SSBN 644	05715
LPH 7	07352	MSC 199	16462	SSBN 645	05716
LSD 28	03128	MSC 205	16468	SSBN 654	05717
LSD 29	03129	MSC 206	16469	SSBN 655	05718
LSD 30	03130	MSC 207	16470	SSBN 656	05719
LSD 31	03131	MSC 208	16473	SSBN 657	05720
LSD 32	03132	MSC 209	16474	SSBN 658	05721
LSD 33	03133	MSC 289	16475	SSBN 659	05722
LSD 34	03134	MSC 290	16476	SSN 578	05597
LSD 35	03135	MSO 437	07967	SSN 579	05598
LST 1032	58032	MSO 438	07968	SSN 585	05606
LST 1073	58073	MSO 462	07992	SSN 588	05051
LST 1076	58076	MSO 466	07996	SSN 594	05057
LST 1077	58077	MSO 488	08146	SSN 604	05112
LST 1082	58082	MSO 490	08148	SSN 605	05113
LST 1084	58084	MSO 508	08156	SSN 606	05114
LST 1122	58122	MSO 521	08162		

Table 3-3. EXPANDED LIST OF SELECTED EQUIPMENT EICs PENDING AVAILABILITY OF MDCS DATA AND UTILIZATION FACTOR INFORMATION

EIC	Equipment/System
1A00	Diesel Engine Propulsion
1F28	Purifier, Fuel Oil, DeLaval
1F30	Purifier, Fuel Oil, Sharples
1G43	Purifier, Lube Oil, DeLaval
1G44	Purifier, Lube Oil, Sharples
1H10	Propellers (Variable Pitch Only)
1K00	Transmission Systems, Gears, Clutches, Couplings, etc.
A100	Diesel Engine, Auxiliary
AA01	Air Conditioning, R-12 Direct Expansion
AA03	Air Conditioning, R-12 Chilled Water
AA04	Air Conditioning Plant, Self Contained
AA05	Air Conditioning Plant, Lithium Bromide Absorption
AA06	Air Conditioning Plant, Air Cycle
AA07	R-11 Chilled Water Plant A.C. System
AB18	Compressor, HP Air RCIPG
AB43	Compressor, RCIPG, Air Mtdrn., A.C. Air Cooled
AC01	Compressor, LP and IP Air RCIPG
AC43	Compressor, Air, Ballast Blowing
AE01	Distilling Plant, LP Submerged Tube Type
AE02	Distilling Plant, LP Flash Type
AE03	Distilling Plant, Vapor Compression
AE07	Distilling Plant, H.R., Submerged Tube
AH17	Pump, Fresh Water Service
AH22	Pump, Priming, Fresh Water
AH31	Pump, Hot Fresh Water Circ.
AJ04	Pump, JP-5 Cargo, Motor Driven
AJ09	Purifier, JP-5 Disc Type
AJ27	Pump, JP-5 Aviation Service
AJ35	Pump, Priming HEAF/JP-5 Blending TRF and SER Transfer
AJ53	Pump, Main Aviation Gasoline
AJ64	Pump, Diesel F.O. Service
AJ82	Pump, JP-5 Service and Transfer
AJG3	Purifier, Fuel Oil, DeLaval
AJG4	Purifier, Fuel Oil, Sharples
AM01	Refrigeration System, R-11 to Brine
AM02	Refrigeration System R-12 Direct Expansion
AM03	R-12 Refrigeration System to Chilled Water
AX04	Pump CTFGL, Aircraft Fueling/Defueling, JP-5/AvnGas

(continued)

Table 3-3. (continued)

EIC	Equipment/System
AX05	Pump, Priming, Aircraft Fueling and Defueling Pump
AX10	Pump, Aircraft Fueling and Defueling
AX14	Pump, Aircraft Fueling and Defueling
AX15	Pump, Priming, Aircraft Fueling and Defueling
BH00	Stabilizer, Fin Type
K100	Winches and Hoisting Equipment
K101	Winch, Bathythermograph
K102	Winch, Fanfare Streaming
K106	Winch, Stern Anchor
K112	Winch, Fueling at Sea
K113	Winch, Topping, Electric
K115	Winch, Elec/Hyd.
K123	Winch, Main Deck Ramp
KC01	Winch, Boat, Electric
KG00	Windlass, Anchor
KG01	Windlass, Vert. Shaft, Electric
KG02	Windlass, Vert. Shaft, Elec/Hyd.
KG03	Windlass, Horizontal Shaft, Electric
KG04	Shaft, Vertical, Elec/Hyd.
KG06	Windlass, Anchor, Non-Magnetic
KH03-07	Towing Machine, Auto. Elec.
KK00	Winches, Snaking and Warping
KK01	Winch, Drone Snaking, Electric
KK02	Winch, Electric 15 HP
KK03	Capstan, Vertical, Electric Warping
KK06	Capstan, Vehicle Hydraulic
KT04	Conveyor, Vertical Stores, Tray Type
KT06	Elevator, Cargo
KT07	Elevator, Stores
KU00	Winches, RAS
KU01	Winch, RAS, Elec Hyd, Auto-Tensioning
KV00	Winches, Cargo
KV01	Winch, Cargo, Elec.
KV02	Winch, Cargo and Snaking, Elec/Hyd.
LE00	Minesweeping Machinery
QD00	400 Hertz M/G Sets
ZU05	Purifier, Disc. Type, Lube Oil
ZU14	Purifier, L.O. Sharples
ZU16	Purifier, L.O. DeLaval

Volume II is a compilation of all of the final equipment designs processed for R&M indices under this contract, as well as those equipments and R&M indices previously developed under separate contracts.

CHAPTER FOUR

DATA COLLECTION

4.1 DATA SOURCES

Data collection was accomplished in three steps:

1. Data were obtained for the selected Equipment Identification Codes (EIC) and the 230 selected ships from the Maintenance Data Collection Subsystem (MDCS).

2. Summaries of ship steaming records (master fuel tapes) for the data period were obtained for the selected ships.

3. Operational data, along with information on data-reporting techniques and maintenance criteria, were obtained during visits to selected ships and facilities. Most of this information, however, was obtained from previous ARINC Research reports and discussions with personnel from the Naval Ship Engineering Center (NAVSEC) since operational commitments permitted only a very limited number of ships to be visited.

4.1.1 MDCS Data

The MDCS data on the selected equipment types were obtained for the 230 ships for the period 1 July 1967 through 30 June 1969. These data, representing approximately 350,000 maintenance records, were forwarded on computer tapes from the Naval Ship Systems Command (NSSC) in EIC, ship, and MCN order. Labor-action data for selected ships were used in the development of equipment reliability and maintainability indices. In the engineering analysis of certain MDCS reports, part records were used to aid in classifying maintenance events as preventive or corrective.

4.1.2 Steaming Hours

Because of the large number of equipments and ships on which data were collected, it was not practical to assemble individual equipment operating logs to establish equipment operating time for the data period. In addition, very few logs of the available logs cover mechanical equipments other than the main propulsion plant. Therefore, equipment operating time was estimated on the basis of (1) ship's monthly steaming hours as reported

in the Fleet Master Fuel Records supplied by the Naval Ship Systems Command; (2) the equipment-use factors developed for previous studies, as well as from the limited visits within the scope of this contract; and (3) the new equipment-use factors generated by ARINC Research engineers in conjunction with appropriate personnel from the technical codes at NAVSHIPS and NAVSEC.

4.1.3 Ship Visits

MDCS data alone are insufficient for developing reliability indices because they do not include data on equipment operating time. The purpose of ship visits was to overcome this deficiency by providing data on the use of the selected equipments, as well as environmental and operational considerations that could affect equipment reliability. For this study, this information was obtained on a limited basis by interviewing ships' personnel and reviewing samples of the ships' logs. The six ships visited consisted of one oiler (AO), one ocean Fleet tug (ATF), one amphibious personnel landing ship docks (LPD), one amphibious assault helicopter carrier (LPH), one landing ship dock (LSD), and one refrigerated cargo ship (AF).

4.2 EQUIPMENT-USE FACTORS

In addition to visits with shipboard personnel, interviews were conducted with a number of officers and enlisted men at the North Severn Naval Station for information about their sea assignments. Their estimates of the operating time of equipments with which they were familiar are incorporated in the new utilization factors used in this report. A number of equipment-use factors had already been developed for previous ARINC Research studies; and where they are still valid, they are used in the calculation of operating times for new equipments. Table 4-1 shows the equipment-use factors used in this report and the source, i.e., previous ARINC Research studies, ship visits, or interviews with knowledgeable Naval personnel other than those currently stationed aboard ship. The majority of new equipment-use factors developed for this study were the result of the best estimates of Navy and civilian engineering personnel at NAVSHIPS and the Naval Ship Engineering Center, Hyattsville, Maryland.

Table 4-1. EQUIPMENT USE FACTORS

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Pumps						
AE - Ammunition Ship	AH17	2	0.50	0.50	0.10	4
AF - Stores Ship	AH17	2	0.50	0.0	0.05	4
AFS - Combat Stores Ship	AH17	2	0.50	0.50	0.50	4
	AH31	4	1.00	1.00	1.00	4
AO - Oiler (105 Class)	AH17	2	0.50	0.50	0.50	4
(143 Class)	AH17	4	0.50	0.37	0.25	4
	AH31	2	1.00	1.00	1.00	4
CVA - Carrier	AH17	4	0.50	0.50	0.50	4
	AH22	4	0.50	0.50	0.50	4
	AH31	32	1.00	1.00	1.00	4
	AJ27	8	0.04	0.005	0.001	4
	AX04	8	0.20	0.029	0.005	4
	AJB2	4	0.07	0.005	0.0	4
	AX05	2	0.10	0.002	0.0	4
DD - Destroyer	AH17	2	0.50	0.30	0.10	4
	AH22	2	0.50	0.30	0.10	4
	AH31	1 & 3	1.00	1.00	1.00	4
	AJ27	1	0.01	0.0	0.001	4
DDG - Destroyer Guided Missile	AH17	2	0.50	0.30	0.10	4
	AH22	2	0.50	0.30	0.10	4
	AH31	2	1.00	1.00	1.00	4
DE - Destroyer Escort	AH17	2	0.50	0.30	0.10	4
	AH31	2	1.00	1.00	1.00	4
	AJ27	1	0.01	0.0	0.001	4

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Pumps (continued)						
DEG - Destroyer Escort Guided Missile	AH17	2	0.50	0.30	0.10	4
	AH31	2	1.00	1.00	1.00	4
	AJ27	2	0.01	0.00	0.001	4
DLG - Destroyer Leader Guided Missile	AH17	2	0.50	0.30	0.10	4
	AH22	2	0.50	0.30	0.10	4
	AH31	4	1.00	1.00	1.00	4
LPD - Amphibious Personnel Ship Dock	AH17	2	0.50	0.50	0.50	4
	AH22	2	0.50	0.50	0.50	4
	AH31	8	0.70	0.50	0.50	4
	AJE6	2	0.40	0.10	0.10	4
	AX04	3	0.03	0.03	0.03	4
LPH - Helicopter Amphibious Assault Ship	AJ53	2	0.10	0.10	0.10	4
LSD - Landing Ship Dock	AH17	2	0.50	0.50	0.50	4
	AH31	4	0.65	0.65	0.65	4
LST - Landing Ship Tank	AH17	3	0.67	0.45	0.10	4
(1156 Class)	AH31	3	0.67	0.67	0.67	4
(1173 Class)	AH17	4	0.50	0.50	0.25	4
MSC - Minesweeper, Coastal	AH17	2	0.50	0.50	0.10	4
	AH31	1	1.00	1.00	1.00	4
MSO - Minesweeper, Ocean	AH17	2	0.50	0.50	0.10	4
	AH31	1	1.00	1.00	1.00	4
Pump and Driver						
AO - Oiler	ZH05 ZH07	2	1.0	0.1	0	1
	ZQ01 ZQ17	3	0.67	0.07	0	1

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3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Pump and Driver (continued)						
AO - Oiler	ZQ03 ZQ13	2	1.0	0.1	0	1
DD - (692 & 710 Class) Destroyer	ZH04 ZH05	2	0.05	0.5	0	1
	ZQ01 ZQ10	4	0.5	0.33	0	1
	ZQ02 ZQ12	4	0.05	0.33	0	1
	ZQ03 ZQ13	4	0.5	0.33	0	1
DD - (931 & 945 Class) Destroyer	ZH04 ZH05	2	0.25	0.5	0	1
	ZQ01 ZQ10	2	0.54	0.11	0	1
	ZQ01 ZQ17	2	0.4	0.4	0	1
	ZQ02 ZQ18	2	0.12	0.09	0	1
	ZQ02 ZQ18	2	0.8	0.44	0	1
	ZQ03	4	0.51	0.25	0	1
DDG - Destroyer, Guided Missile	ZH04 ZH05	2	0.1	0.52	0	1
	ZQ01 ZQ10	2	0.52	0.27	0	1
	ZQ01 ZQ17	2	0.52	0.27	0	1
	ZQ02 ZQ12	2	0.57	0.0	0	1
	ZQ02	2	0.62	0.63	0	1
	ZQ18	4	0.3	0.3	0	1
	ZQ03	4	0.46	0.32	0	1
	ZQ13	6	0.3	0.2	0	1

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4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Pump and Driver (continued)						
DE - (1006, 1021 & 1033 Class)	ZH04 ZH05	1	0.03	1.0	0	1
	ZQ01 ZQ17	2	0.75	0.5	0	1
	ZQ02 ZQ18	2	0.56	0.51	0	1
	ZQ03	2	0.56	0.51	0	1
DE - (1040 Class) Destroyer Escort	ZH04 ZH05	1	0.02	1.0	0	1
	ZQ01 ZQ17	2	0.55	0.5	0	1
	ZQ02 ZQ18	2	0.55	0.5	0	1
	ZQ03 ZQ13	2	0.55	0.5	0	1
DEG - Destroyer Escort, Guided Missile	ZH04 ZH05	1	0.01	1.0	0	1
	ZQ01 ZQ17	2	0.51	0.5	0	1
	ZQ02 ZQ18	2	0.51	0.50	0	1
	ZQ03 ZQ13	2	0.51	0.50	0	1
DLG - Destroyer Leader, Guided Missile	ZH04 ZH05	2	0.6	0.55	0	1
	ZQ01 ZQ17	4	0.67	0.33		1
	ZQ02	6	0.6	0.37	0	1
	ZQ18	4	0.4	0.24	0	1
	ZQ12	2	0.2	0.12		
	ZQ03 ZQ13	6	0.67	0.56	0	1

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Pump and Driver (continued)						
LPD - Amphibious Personnel, Transport Dock	ZH04 ZH05	2	0.06	0.2	0	1
	ZQ01 ZQ17	4	0.72	0.1	0	1
	ZQ02 ZQ18	4	0.72	0.1	0	1
	ZQ03 ZQ13	4	0.72	0.1	0	1
LSD - Landing Ship Dock	ZH04 ZH05	2	0.05	0.5	0	1
	ZQ01 ZQ17	4	0.52	0.25	0	1
	ZQ02 ZQ18	4	0.52	0.25	0	1
	ZQ03 ZQ13	4	0.52	0.25	0	1
SSBN - Submarine, Ballistic Missile, Nuclear	ZH07 ZH09	2	1.0	0.5	0	1
	ZQ01 ZQ17	4	0.5	0.25	0	1
	ZQ03 ZQ65	4	0.4	0.25	0	1
SSN - Submarine, Nuclear	ZH07 ZH09	2	0.78	0.78	0	1
	ZQ01 ZQ17	4	0.47	0.47	0	1
	ZQ03 ZQ65	4	0.34	0.34	0	1

Source Codes:

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2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment		
			Util. Factor (K_u)	Time Base	Source Code
Boiler 600 PSI					
DE - 1006 Class	ZA00	2	1.0	Boiler Operating Hours listed by serial number, i.e., 1A or 1B)	
	ZA01	2	1.0		2
	ZA02	2	1.0		2
	ZA03	2	1.0		2
	ZA04	2	1.0		2
	ZA05	2	1.0		2
	ZA06	5	0.45		2
	ZA08	4	1.00		2
	ZQ01	2	1.00	Ship Underway Operating Hours	2
	ZQ02	2	0.50	Sum of 1A and 1B Boiler Operating Hours	2
	ZQ03	2	0.52		2
	ZQ13	2	0.52		2
	ZT01	2	0.43	(1A Boiler Hours)	2
			0.54	(1B Boiler Hours)	
	ZT03	2	0.43	(1A Boiler Hours)	2
			0.54	(1B Boiler Hours)	

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Boiler 1200 PSI						
DLG - FW/B&W	ZA01 thru ZA05	4	0.5[illegible]	0.26	0	3
	ZA06	16/24	0.26	0.13	0	3
	ZA07	40/44	0.05	0.05	0	3
	ZA08	16	0.41	0.21	0	3
	ZA10	4	0.51	0.26	0	3
	ZA11	4	0.51	0.26	0	3
	ZA12	4	0.51	0.26	0	3
	ZT01	4	0.51	0.26	0	3
	ZT03	4	0.51	0.26	0	3
DLG - CE	ZA01 thru ZA05	4	0.51	0.26	0	4
	ZA06	12	0.36	0.18	0	3/4
	ZA07	6	0.02	.005	0	3/4
	ZA08	8	0.41	0.21	0	3/4
	ZA10 thru ZA12	4	0.51	0.26	0	3/4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Air Compressors, H.P., I.P., and L.P.						
AE - Ammunition Ship	AB18	2	0.02	0.0	0.0	4
	AC01	3	0.22	0.22	0.22	4
AFS - Combat Stores Ship	AB18	2	0.10	0.10	0.10	4
	AC01	2	0.32	0.32	0.32	4
AO - Oiler (105 Class and 143 Class)	AB18	1	0.02	0.05	0.0	4
(Hose Blow Down)	AC01	1	0.02	0.05	0.00	4
(Ship Service)	AC01	2	0.30	0.30	0.30	4
AS - Submarine Tender	AB18	6	0.25	0.25	0.25	4
ATF - Fleet Tug						
(Ship Service)	AC01	1	0.13	0.42	0.42	4
(Diesel Start)	AC01	2	0.01	0.01	0.01	4
CVA - Attack Aircraft Carrier						
(Ship Service)	AB18	3	0.05	0.005	0.005	4
($0_2 \times N_2$ Plant)	AB18	4	0.50	0.25	0.0	1
(Ship Service)	AC01	2	0.40	0.30	0.40	4
(Aviation Service)	AC01	3	0.22	0.22	0.22	4
(Combustion Control)	AC01	8	0.40	0.15	0.0	4
DD - Destroyer						
(DD692 Class)	AB18	1	0.02	0.0	0.0	4
	AC01	2	0.40	0.40	0.40	4
(DD931 Class)	AB18	1	0.06	0.02	0.01	1/4
	AC01	2	0.40	0.40	0.40	4
DDG - Destroyer Guided Missile	AB18	1	0.13	0.05	0.025	1/4
	AC01	3	0.53	0.25	0.40	4
DE - Destroyer Escort (1045 Class)	AB18	2	0.06	0.025	0.013	1/4
	AC01	2	0.30	0.30	0.30	4

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3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Air Compressors, H.P., I.P., and L.P. (continued)						
DEG - Destroyer Escort, Guided Missile	AB18	2	0.06	0.025	0.013	1/4
	AC01	2	0.45	0.25	0.30	4
DLG - Destroyer Leader, Guided Missile	AB18	2	0.19	0.025	0.01	1/4
	AC01	4	0.30	0.30	0.30	4
LPD - Amphibious Personnel Ship Dock	AB18	1	0.07	0.07	0.07	4
	AC01	2	0.40	0.20	0.20	4
	AC43	2	0.05	0.005	0.0	
LPH - Helicopter Amphibious Assault Ship	AB18	2	0.07	0.07	0.07	4
	AC01	3	0.30	0.10	0.10	4
LSD - Landing Ship Dock	AC01	2	0.40	0.45	0.45	4
LST - Landing Ship Tank						
(Diesel Start)	AC01	2	0.01	0.01	0.01	4
(Ship Service)	AC01	2	0.30	0.30	0.30	4
MSC - Minesweeper, Coastal						
(Ship Service)	AC01	2	0.13	0.42	0.42	1
(Diesel Start)	AC01	2	0.01	0.01	0.01	4
MSO - Minesweeper, Ocean						
(Ship Service)	AC01	2	0.13	0.42	0.42	1
(Diesel Start)	AC01	2	0.01	0.01	0.01	4
SSBN - Submarine, Nuclear, Ballistic Missile						
(Ship Service)	AB18	3	0.03	0.10	0.10	4
(Ballast Blow)	AC43	1	0.001	0.005	0.005	4
SSN - Submarine, Nuclear	AB18	2	0.03	0.10	0.10	4
	AC43	1	0.001	0.005	0.005	4

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Distilling Plants						
AE - Ammunition Ship	AE02	2	1.00	0.70	0.0	4
AFS - Combat Store Ships	AE02	2	1.00	0.70	0.0	4
AS - Tender, Submarine	AE02	2	0.70	1.00	0.0	4
ATF - Tug, Fleet Ocean (156 Class)	AE03	2	0.40	0.0	0.0	4
DD - (937 Class) Destroyer	AE02	2	0.83	0.50	0.0	4
DDG - Destroyer Guided Missile	AE02	2	1.00	0.45	0.05	4
DE - (1021 Class) Destroyer Escort	AE02	2	0.90	0.45	0.0	4
(1033 Class)	AE02	2	0.75	0.30	0.05	4
(1040 Class)	AE02	2	0.75	0.30	0.0	4
DEG - Destroyer Escort, Guided Missile	AE02	2	0.75	0.30	0.05	4
DLG - Destroyer Leader, Guided Missile	AE02	2	0.93	0.43	0.0	4
LPD - Amphibious Personnel, Landing Ship Dock	AE02	2	1.00	0.35	0.0	4
LPH - Amphibious Helicopter Assault Ship	AE02	2	0.97	0.43	0.0	4
LSD - Landing Ship Dock	AE02	2	0.73	0.23	0.0	4
LST - Landing Ship Tank (1032 and 1122 Classes)	AE03	1	1.00	0.0	0.0	4
MSC - Minesweeper, Coastal (198 Class)	AE03	1	1.00	0.0	0.0	4
SSBN - Submarine Ballistic, Nuclear	AE01	1	0.65	0.0	0.0	4
	AE03	1	0.01	0.0	0.0	4
SSN - Submarine, Nuclear	AE03	1	0.01	0.0	0.0	4

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3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Ship Service Turbine Generator Sets						
AO - Oiler	AP01 AP23 AP24 AP28 AP30 PA00	2	1.0	0.7	0	1
DD - (692 & 710 Class) Destroyer	AP00 PA00	2	0.86	0.52	0	1
DD - (931 & 945 Class) Destroyer	AP00 PA00	4	0.48	0.48	0	1
DDG - Destroyer, Guided Missile	AP00 PA00	4	0.59	0.59	0	1
DE - (1006, 1021 & 1033 Class) Destroyer, Escort	AP00 PA00	2	0.96	0.66	0	1
DE - (1040 Class) Destroyer	AP00 PA00	2	1.0	0.97	0	1
DEG - Destroyer Escort, Guided Missile	AP00 PA00	2	1.0	1.0	0	1
DLG - Destroyer Leader, Guided Missile	AP00 PA00 AR00 PE00	4	0.4	0.25	0	1
LPD - Amphibious Personnel, Transport Dock	AP00 PA00	4	0.62	0.64	0	1
LSD - (1156 & 1173 Class) Landing Ship Dock	AP00 PA00	4	0.54	0.38	0	1
SSBN - Submarine, Ballistic Missile, Nuclear	AP00 PA00	2	1.0	1.0	0	1
SSN - Submarine, Nuclear	AP00 PA00	2	0.98	0.98	0	1

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Motor Generator Sets						
AE - Ammunition Ship	QD00	1	0.05	0.00	0.0	4
AF - Stores Ship	QD00	1	1.00	0.08	0.0	4
AO - Oiler	QM00	2	0.50	0.0	0.0	1
	QD00	1	1.00	0.20	0.05	4
ATF - Tug, Ocean, Fleet	QD00	1	1.00	0.01	0.0	4
CVA - Aircraft Carrier						
(Missile)	QD00	6	0.25	0.05	0.05	4
(IC-10 KW)	QD00	4	0.50	0.50	0.50	4
DD - (692 & 710 Classes) Destroyer	QD00	2	0.50	0.30	0.0	1
DD - (931 & 945 Classes) Destroyer	QM00	2	0.50	0.05	0.05	1
DDG - Destroyer, Guided Missile	QM00	2	0.50	0.05	0.05	1
(Degaussing)	QM00	2	0.10	0.0	0.0	1
(100 KW)	QD00	2	0.50	0.25	0.05	1
(30/60 KW)	QD00	3	0.46	0.33	0.05	1/4
DE - (1006, 1021 & 1033 Classes) Destroyer	QD00	2	1.00	0.20	0.05	1
	QL00	2	0.50	0.05	0.0	1
DE - (1040 Class) Destroyer Escort						
(30 KW)	QD00	2	0.50	0.50	0.05	1
(Sonar - 24.5 KW)	QD00	2	0.50	0.025	0.0	4
DEG - Destroyer Escort, Guided Missile						
(Sonar 24.5 KW)	QD00	2	0.50	0.025	0.0	4
(FC - 30 KW)	QD00	1	0.95	0.20	0.20	4
(SS - 30 KW)	QD00	2	0.60	0.60	0.10	4
(Missile - 60 KW)	QD00	2	0.25	0.10	0.10	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Motor Generator Sets (continued)						
DLG - Destroyer Leader, Guided Missile	QM00	2	0.50	0.0	0.0	1
(Degaussing)	QM00	1	0.10	0.0	0.0	1
(SS - 200 KW)	QD00	3	0.42	0.33	0.33	1/4
(SS - 100 KW)	QD00	1	0.50	0.35	0.35	1/4
(Missile - 60 KW)	QD00	3	0.17	0.17	0.10	4
(1C - FC - 30 KW)	QD00	3	0.17	0.17	0.10	4
(60 KW)	QD00	5	0.8	0.8	0.25	1/4
(24.5 KW)	QD00	2	0.25	0.17	0.0	4
LPD - Amphibious Personnel Transport Dock	QM00	1	0.62	0.50	0.0	1/4
(30 KW)	QD00	2	0.35	0.10	0.02	4
(30 KW)	QD00	1	1.00	0.90	0.05	4
(60 KW)	QD00	2	0.33	0.10	0.025	4
LPH - Helicopter Amphibious Assault Ship						
(200 KW)	QD00	1	1.00	1.00	0.0	4
(60 KW)	QD00	1	0.25	0.05	0.0	4
LSD - Landing Ship Dock	QM00	2	0.75	0.50	0.0	1
(Degaussing)	QM00	2	0.10	0.0	0.0	1
	QD00	2	0.50	0.20	0.05	1
LST - (456 & 1173 Classes) Landing Ship Tank						
(Stern Anchor)	QM00	1	0.15	0.15	0.01	1
(Gyro Compass)	QD00	1	0.82	0.82	0.82	1
MSC - Minesweeper, Coastal (190 & 290 Classes)	QD00	1	1.00	0.05	0.0	4
MSO - Minesweeper, Ocean (488 Class)	QD00	1	1.00	0.05	0.0	4
MSO - Minesweeper, Ocean (508 Class)	QD00	2	0.05	0.05	0.0	1

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Motor Generator Sets (continued)						
SSBN - Submarine, Ballistic Missile, Nuclear						
(300 KW)	QD00	2	1.00	0.50	0.50	4
(64 KW)	QD00	2	0.50	0.50	0.50	1
(30/10 KW)	QD00	1	0.50	0.25	0.25	1/4
(5 KW)	QD00	2	1.00	0.75	0.75	1/4
	QL00/ QM00	2	1.00	1.00	1.00	1
SSN - Submarine, Nuclear						
(300 KW)	QD00	2	0.95	0.25	0.25	1/4
(43 KW)	QD00	2	0.95	0.25	0.25	1/4
(5 KW)	QD00	1	1.00	1.00	1.00	1
	QL00/ QM00	2	0.86	0.86	0.86	1
Stabilizer, Fin Type						
DE - Destroyer Escort (1045 Class)	BH01	2	0.20	0.0	0.0	4
DEG - Destroyer Escort, Guided Missile	BH03	2	0.20	0.0	0.0	4
Refrigeration Plants, R-11, R-12, Direct Expansion, Chilled Water						
AF - Stores Ship						
(Cargo)	AM01	1	1.00	1.00	0.20	4
(Cargo)	AM01	4	0.50	0.50	0.10	4
(Cargo)	AM02	13	0.38	0.08	0.0	4
(Ship Service)	AM02	2	0.50	0.50	0.30	4
AFS - Combat Stores Ship						
(Cargo)	AM02	1	0.90	0.70	0.24	4
(Cargo)	AM02	2	0.45	0.35	0.12	4
(Ship Service)	AM02	2	0.20	0.20	0.20	4
(Walk In)	AM02	1	0.75	0.75	0.75	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Refrigeration Plants, R-11, R-12, Direct Expansion, Chilled Water (continued)						
AO - Oiler	AM02	2	0.50	0.40	0.45	4
ATF - Tug, Fleet Ocean	AM02	1	0.38	0.38	0.35	4
DD - Destroyer (710 and 931 Classes)	AM02	1	0.38	0.38	0.35	4
DDG - Destroyer, Guided Missile	AM02	1	0.38	0.38	0.35	4
DE - Destroyer Escort	AM02	1	0.38	0.38	0.35	4
DEG - Destroyer Escort, Guided Missile	AM02	1	0.38	0.38	0.35	4
DLG - Destroyer Escort, Guided Missile	AM02	1	0.38	0.38	0.35	4
LPD - Amphibious Personnel Ship Dock	AM02	1	0.38	0.38	0.35	4
(1 and 7 Classes)	AM02	2	0.25	0.25	0.25	4
LPH - Helicopter Amphibious Assault Ship						
(Walk In)	AM02	1	0.33	0.33	0.33	4
(Ship Service)	AM02	1	0.38	0.38	0.38	4
LSD - Landing Ship Dock	AM02	2	0.25	0.25	0.25	4
LST - Landing Ship Tank	AM02	1	0.38	0.38	0.35	4
	AM02	2	0.19	0.19	0.17	4
MSC - Minesweeper, Coastal	AM02	1	0.38	0.38	0.35	4
MSO - Minesweeper, Ocean	AM02	1	0.38	0.38	0.35	4
SSBN - Submarine, Ballistic Missile, Nuclear	AM02	2	0.19	0.19	0.17	4
SSN - Submarine, Nuclear	AM02	2	0.19	0.19	0.17	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Air Conditioning Plants: AA03-R12 to Chill Water; AA04 - Self Contained; AA05 Lithium Bromide						
AE - (21 Class) Ammunition Ship	AA04	4	0.90	0.75	0.50	4
AF - (50 Class) Store Ship	AA04	Various	0.75	0.75	0.75	4
ATF - Tug, Fleet Ocean	AA04	Various	0.90	0.75	0.60	4
AFS - (1 Class) Combat Stores Ship	AA03	4	0.55	0.55	0.55	4
	AA04	3	0.75	0.70	0.70	4
AO - (106 and 143 Class) Oiler	AA03	Various	1.00	0.90	0.80	4
	AA04	Various	0.90	0.75	0.60	4
CVA - (59 and 63 Class) Attack Aircraft Carrier	AA03	Various	1.00	0.90	0.80	4
	AA04	Various	0.90	0.75	0.60	4
DD - Destroyer	AA04	Various	0.90	0.75	0.60	4
DDG - (2 and 31 Class) Destroyer Guided Missile	AA03	Various	1.00	0.90	0.60	4
	AA04	Various	0.90	0.75	0.60	4
DE - (1021, 1033, 1037, 1040 Class)	AA03	Various	1.00	0.90	0.80	4
	AA04	Various	0.90	0.75	0.60	4
DEG - (1 Class) Destroyer Escort Guided Missile	AA03	2	1.00	0.90	0.80	4
DLG - (9, 16, 26 Class) Destroyer Leader Guided Missile	AA03	Various	1.00	0.90	0.80	4
	AA04	Various	0.90	0.75	0.60	4
LPD - (1 Class) Amphibious Personnel Dock	AA03	4	0.75	0.35	0.35	4
	AA04	Various	1.00	1.00	1.00	4
LPH - (2 Class) Helicopter Amphibious Assault Ship	AA03	5	1.00	0.50	0.50	4
	AA04	Various	0.90	0.75	0.60	4
LSD - (28 Class) Landing Ship Dock	AA03	2	0.75	0.65	0.45	4
	AA04	Various	0.90	0.65	0.35	4
LST - (1173 Class) Landing Ship Tank	AA03	2	0.75	0.65	0.45	
	AA04	Various	0.90	0.75	0.60	4
MSC - (200 Class) Minesweeper, Coastal	AA04	1	0.90	0.75	0.60	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Air Conditioning Plants: AA03-R12 to Chill Water; AA04 - Self Contained; AA05 Lithium Bromide (continued)						
MSO - Minesweeper, Ocean	AA04	1	0.90	0.75	0.60	4
SSBN - (598, 608, 616, 640 Class) Nuclear Ballistic Missile Submarine	AA03	1	0.05	0.60	0.60	4
	AA05	1	1.00	0.02	0.0	4
SSN - (578, 593 Class) Nuclear Attack Submarine	AA03	1	0.05	0.60	0.60	4
	AA05	1	1.00	0.02	0.0	4
Capstan, Warping						
AFS - Combat Stores Ship	KK03	1	0.02	0.0	0.01	4
ATF - Tug, Fleet Ocean	KK03	1	0.15	0.01	0.0	4
DE - Destroyer Escort	KK03	1	0.01	0.0	0.005	4
DEG - Destroyer Escort, Guided Missile	KK03	1	0.01	0.0	0.005	4
DLG - Destroyer Leader, Guided Missile	KK03	1	0.02	0.0	0.01	4
LPD - Amphibious Personnel, Landing Ship Dock	KK03	2	0.04	0.0	0.02	4
LSD - Landing Ship Dock	KK03	3	0.04	0.0	0.02	4
Towing Machine, Auto-Elec.						
ATF - Tug, Fleet Ocean	KH05	1	0.25	0.0	0.0	4
Minesweeping Machinery						
MSC - Minesweeper, Coastal	LE01	1	0.20	0.0	0.0	4
MSO - Minesweeper, Ocean	LE01	1	0.20	0.0	0.0	4
Conveyor, Vertical Stores, Tray Type						
AF - Stores Ship (Cargo)	KT04	6	0.10	0.025	0.025	4
AFS - Combat Stores Ship						
85#	KT04	6	0.30	0.05	0.05	4
175#	KT04	3	0.10	0.01	0.01	4
3000#	KT04	2	0.20	0.01	0.01	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Conveyor, Vertical Stores, Trap Type (continued)						
CVA - Attack Aircraft Carrier	KT04		0.05	0.05	0.05	4
DE - Destroyer Escort (1045 Class)	KT04	1	0.05	0.05	0.05	4
DEG - Destroyer Escort, Guided Missile	KT04	1	0.05	0.05	0.05	4
LPD - Amphibious Personnel Ship Dock						
85#	KT04	1	0.20	0.10	0.05	4
3000#	KT04	3	0.05	0.02	0.02	4
Elevator, Cargo and Stores						
AE - Ammunition Ship	KT06/ KT07	4	0.07	0.02	0.05	5
	KT06/ KT07	2	0.10	0.05	0.05	4
AFS - Combat Stores Ship						
(16,000 #)	KT06/ KT07	1	0.20	0.10	0.10	4
(8,000 #)	KT06/ KT07	2	0.10	0.01	0.01	4
AO - Oiler	KT06/ KT07	2	0.05	0.02	0.05	4
LPD - Amphibious Personnel Landing Ship Dock	KT06/ KT07	1	0.21	0.06	0.04	4
Winch, Bathythermograph						
DDG - Destroyer, Guided Missile	K101	1	0.05	0.0	0.0	4
DEG - Destroyer Escort, Guided Missile	K101	1	0.05	0.0	0.0	4
DLG - Destroyer Leader, Guided Missile	K101	1	0.05	0.0	0.0	4
MSC - Minesweeper, Coastal	K101	1	0.05	0.0	0.0	4
MSO - Minesweeper, Ocean	K101	1	0.05	0.0	0.0	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Winches, Cargo						
AE - Ammunition Ship	KV02	16	0.02	0.05	0.005	4
AF - Stores Ship, Cargo	KV01	16	0.03	0.027	0.027	4
AFS - Combat Stores Ship						
(Inhaul, Outhaul)	KV02	20	0.011	0.001	0.001	4
(Hyline)	KV02	10	0.02	0.001	0.001	4
AO - Oiler						
(Cargo - Saddle)	KV02	12	0.03	0.0	0.0	4
(Hyline)	KV02	2	0.05	0.0	0.0	4
DDG - Destroyer, Guided Missile						
(Cargo)	KK01	2	0.025	0.01	0.001	4
DLG - Destroyer Leader, Guided Missile						
(Cargo)	KK01	2	0.025	0.01	0.001	4
LST - Landing Ship Tank						
(Snaking)	KV02	2	0.0	0.03	0.005	4
	KK01	1	0.0	0.05	0.01	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Winch, Fanfare Streaming						
DD - Destroyer	K102	1	0.01	0.0	0.0	4
DDG - Destroyer, Guided Missile	K102	1	0.01	0.0	0.0	4
DE - Destroyer Escort	K102	1	0.01	0.0	0.0	4
DEG - Destroyer Escort, Guided Missile	K102	1	0.01	0.0	0.0	4
DLG - Destroyer Leader, Guided Missile	K102	1	0.01	0.0	0.0	4
Winch, Stern Anchor						
LST - Landing Ship Tank	K123	1	0.02	0.001	0.001	4
Winch, Fueling at Sea						
DLG - Destroyer Leader, Guided Missile	K112	1	0.005	0.0	0.0	4
LPD - Amphibious Personnel, Landing Ship Dock	K112	1	0.005	0.0	0.0	4
Winch, Topping						
AE - Ammunition Ship	K113	10	0.001	0.05	0.01	4
AF - Stores Ship, Cargo	K113	6-8	0.001	0.05	0.01	4
AFS - Combat Stores Ship	K113	6	0.0	0.005	0.005	4
LST - Landing Ship Tank	K113	2	0.0	0.01	0.01	4
Winch, Main Deck Ramp						
LST - Landing Ship Tank	K123	1	0.006	0.006	0.006	4
Winch, Boat						
AE - Ammunition Ship	KC01	2	0.01	0.0	0.01	4
AF - Stores Ship (Cargo)	KC01	2	0.01	0.0	0.01	4
AFS - Combat Stores Ship	KC01	2	0.01	0.0	0.01	4

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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Winch, Boat (continued)						
AO - Oiler	KC01	2	0.01	0.0	0.01	4
DD - Destroyer	KC01	2	0.01	0.0	0.01	4
DDG -Destroyer Guided Missile	KC01	2	0.01	0.0	0.01	4
DE - Destroyer Escort	KC01	2	0.005	0.0	0.005	4
DEG - Destroyer Escort, Guided Missile	KC01	2	0.005	0.0	0.005	4
DLG - Destroyer Leader, Guided Missile	KC01	3	0.01	0.0	0.01	4
LPD - Amphibious Personnel Ship Deck	KC01	1	0.02	0.0	0.02	4
LPH - Helicopter Amphibious Assault Ship	KC01	2	0.01	0.0	0.01	4
LSD - Landing Ship Dock	KC01	2	0.10	0.01	0.01	4
LST -Landing Ship Tank	KC01	2	0.01	0.0	0.01	4
MSO - Minesweeper, Ocean	KC01	2	0.02	0.0	0.02	4
Anchor Windlass						
AE - Ammunition Ship	KG02	1	0.009	0.0	0.0	4
AFS - Combat Stores Ship	KG02	1	0.008	0.0	0.0	4
AO - Oiler	KG02	1	0.008	0.0	0.0	4
ATF - Tug, Fleet Ocean	KG01	1	0.027	0.0	0.0	4
CVA - Attack Aircraft Carrier	KG02	1	0.006	0.0	0.0	4
DD - Destroyer	KG01	1	0.008	0.0	0.0	4
DDG - Destroyer, Guided Missile	KG01	1	0.008	0.0	0.0	4
DE - Destroyer Escort	KG01	1	0.004	0.0	0.0	4
DEG - Destroyer Escort, Guided Missile	KG01	1	0.006	0.0	0.0	4
DLG - Destroyer Leader, Guided Missile	KG02	1	0.008	0.0	0.0	4
LPD - Amphibious Personnel Ship Dock	KG02	1	0.016	0.0	0.0	4

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Anchor Windlass (continued)						
LSD - Landing Ship Dock	KG02	1	0.011	0.0	0.0	4
LST - Landing Ship Tank	KG01	1	0.012	0.0	0.0	4
MSC - Minesweeper, Coastal	KG06	1	0.025	0.0	0.0	4
MSO - Minesweeper, Ocean	KG06	1	0.017	0.0	0.0	4
Main Propulsion System, Diesel Engines, Motors, Generators						
ATF - Tug, Ocean Fleet	1A00	4	0.83	0.18	0.0	1
	1B00	4	0.83	0.18	0.0	1
	1C00	4	0.83	0.0	0.0	1
	1C00	1	1.0	0.0	0.0	1
DE - (1033 Class) Destroyer	1A00	4	1.0	0.15	0.0	4
LST - (1066 Class) Landing Ship Tank	1A00	2	1.0	0.15	0.0	4
1156 Class	1A00	4	0.60	0.10	0.0	4
1173 Class	1A00	6	0.63	0.05	0.0	1
MSC - (094 and 280 Classes) Minesweeper, Coastal	1A00	2	1.0	0.16	0.0	4
MSO - (422 and 521 Classes) Minesweeper, Ocean	1A00	2	0.76	0.16	0.0	1
	A100 PG02	2	0.70	0.16	0.0	1
SSBN - (616 Class) Nuclear-Powered Ballistic Missile Submarine	1A00	1	0.04	0.0	0.0	4
SSN - (594 Class) Nuclear Powered Attack Submarine	1A00	1	0.067	0.0	0.0	4
Ship Service Diesel Generator Sets						
AO - Oiler	A100	3	0.10	0.025	0.0	4
ATF - Tug, Ocean Fleet	A100	3	0.86	0.14	0.0	1
	PF00*	3	0.86	0.14	0.0	1

*FOMs not to be developed - furnished for information only.

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Ship Service Diesel Generator Sets (continued)						
DE - (1033 Class) Destroyer Escort	A100 PE00	3	0.45	0.33	0.0	4
(1040 Class) Destroyer Escort	A100 PE00	2	0.02	0.24	0.24	1
DEG - Destroyer Escort, Guided Missile	A100 PE00*	2	0.02	0.24	0.24	1
LST - (1156 & 1173 Classes) Landing Ship Tank	A100 PE00	3	0.44	0.53	0.05	1
MSC - Minesweeper, Coastal						
(100 KW)	A100	2	0.60	0.50	0.0	4
(60 KW)	A100	2	0.60	0.50	0.0	4
(300 KW)	A100	2	0.10	0.0	0.0	4
MSO - Minesweeper, Ocean						
(185/200 KW)	A100 PE00	1	1.00	0.33	0.05	1
(100 KW)	A100 PE00	1	0.08	1.00	0.10	1
(60 KW)	A100 PE00	1	0.07	0.0	0.0	1
(T-6)	A100 PG00	1	0.05	0.0	0.0	1
Transmission Systems, Gears, Clutches, etc.						
DE - Destroyer, Escort (1033 Class)	1K00/ 1K04	4	1.00	0.0	0.0	4
LST - Landing Ship Tank (542 and 1156 Classes)	1K00/ 1K04	2	1.00	0.0	0.0	4
MSC - Minesweeper, Coastal	1K00/ 1K04	2	1.00	0.04	0.0	4
MSO - Minesweeper, Ocean	1K00/ 1K04	4	1.00	0.04	0.0	4
SSBN - Submarine Ballistic Missile,, Nuclear	1K00	1	0.04	0.0	0.0	4
SSN - Submarine, Nuclear	1K00	1	0.067	0.0	0.0	4

*FOMS not to be developed - furnished for information only.

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Gas Turbine						
WHEC - Coast Guard Cutter (378' Hamilton Class) FT4A		2	40-90 hours per quarter			4
Purifier, Fuel Oil, CTFGL, DeLaval, Sharples						
ATF - (091 & 159 Classes) Tug, Ocean, Fleet	1F28/ 1F30	1	0.60	0.15	0.0	4
DE - (1033 Class) Destroyer Escort	1F28	2	0.50	0.10	0.0	4
LST - (1161 & 1173 Classes) Landing Ship Tank	1F28	2	0.50	0.10	0.0	4
MSC - (190 Class) Minesweeper, Coastal	1F28	1	0.85	0.10	0.0	4
MSO - (490 and 521 Classes) Minesweeper, Ocean	1F28/ 1F30	1	0.85	0.10	0.0	4
SSBN - (588, 608, 616, 640 Class) Submarine Ballistic Missile	1F28/ 1F30	1	0.005	0.005	0.0	4
Purifier, Lube Oil, DeLaval/Sharples						
ATF - (091 & 159 Classes) Tug, Ocean, Fleet	1G43/ 1G44	1	0.85	0.20	0.0	4
DE - (1033 Class) Destroyer Escort	1G43/ 1G44	2	0.50	0.10	0.05	4
LST - (1161 & 1173 Classes) Landing Ship Tank	1G43/ 1G44	2	0.50	0.10	0.05	4
Purifier, Fuel Oil, DeLaval/Sharples						
AE - Ammunition Ship	AJG3/ AJG4	1	0.01	0.01	0.0	4
AO - (105 Class & 143 Class) Oiler	AJG3/ AJG4	1	0.01	0.01	0.0	4
AF - (56 and 58 Class) Stores Ship	AJG3	1	0.01	0.01	0.0	4

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
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3 - ARINC Research Pub. 594-01-2-960
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Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Purifier, Fuel Oil, DeLaval/Sharples (continued)						
CVA - (59 and 63 Class) Attack Aircraft Carrier	AJG3/ AJG4	4-8	0.01	0.01	0.0	4
(JP5)	AJ09	4	0.05	0.0	0.0	4
DD - (931 and 945 Class) Destroyer	AJG3	3	0.01	0.01	0.0	4
DDG-2 (2 and 31 Class) Destroyer Guided Missile	AJG3/ AJG4	3	0.01	0.01	0.0	4
DLG - (9, 16, and 26 Class) Destroyer Leader Guided Missile	AJG3/ AJG4	3	0.01	0.01	0.0	4
LPH - (2 Class) Helicopter Assault Ship	AJG3/ AJG4	2	0.01	0.01	0.0	4
(JP5)	AJ09	2	0.01	0.0	0.0	4
LSD - Landing Ship Dock	AJG3/ AJG4	1	0.15	0.01	0.0	4
Purifier, Lube Oil, DeLaval/Sharples						
AE - (25 Class) Ammunition Ship	ZU16	2	0.50	0.10	0.05	4
AF - (56 and 58 Class) Store Ship	ZU16	1	0.50	0.01	0.05	4
AFS - (1 Class) Combat Stores Ship	ZU14/ ZU16	1	0.85	0.01	0	4
AO - (106 Class) Oiler	ZU14/ ZU16	2	0.50	0.10	0.05	4
CVA - (59 and 63 Class) - Attack Aircraft Carrier	ZU14/ ZU16	4-6	0.50	0.10	0.05	4
DD - (931 and 945 Class) - Destroyer	ZU16	3	0.50	0.10	0.05	4
DDG - (2 and 31 Class) Destroyer, Guided Missile	ZU14/ ZU16	2	0.50	0.10	0.05	4

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
4 - ARINC Research/NAVSEC-Developed

Table 4-1. (continued)

Ship Type	EIC	Number of Equip-ments	Use Factor (K_u) Per Equipment			
			Underway Steaming	In-Port Steaming	Cold Iron	Source Code
Purifier, Lube Oil, DeLaval/Sharples (continued)						
DE - (1021 and 1040 Class) - Destroyer Escort	ZU14/ ZU16	2	0.50	0.10	0.05	4
DEG - (1 Class) Destroyer Escort GM	ZU14/ ZU16	1	0.50	0.10	0.05	4
DLG - (9, 16, and 26 Class) Destroyer Leader GM	ZU14	2	0.50	0.10	0.05	4
LPD - (1 and 7 Class) Amphi-bious Personnel Dock	ZU16	2	0.85	0.40	0.03	4
LPH - (28 Class) - Landing Ship Dock	ZU16	2	0.50	0.02	0.04	4
SSBN - (598, 608, 616, 640 Class) Submarine Ballistic Missile	ZU14	2	0.40	0.40	0.05	4
SSN - (578, 588, 593 Class) Sub-marine Attack Nuclear	ZU14	2	0.40	0.40	0.04	4
Ships Propeller, CPCH Prop. System						
LST - Landing Ship Tank (1156 Class)	1H10	2	1.00	0.0	0.0	4
MSO - Minesweeper, Ocean (421 and 519 Classes)	1H10	2	1.00	0.0	0.0	4

Source Codes:

1 - ARINC Research Pub. 933-02-3-1153
2 - ARINC Research Pub. 588-02-3-1058
3 - ARINC Research Pub. 594-01-2-960
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CHAPTER FIVE

DATA-ANALYSIS LOGIC

5.1 INTRODUCTION

This chapter describes the procedure employed in analyzing the data to develop the reliability and maintainability indices used in the data bank.

To obtain suitable indices for the selected equipments, it was necessary to analyze the MDCS data in a manner that would yield a count of corrective-maintenance (CM) events and would also identify the CM events that resulted from forced shutdown (failure) of the equipment. Mean Time Between Corrective Maintenance (MTBCM) and Mean Time Between Failures (MTBF) with 90-percent confidence limits were the reliability indices computed. Maintainability indices were computed separately for forced-shutdown (failure) corrective-maintenance events and for all corrective-maintenance events (including those resulting from failure). The indices are Mean Time to Repair ($\overline{MTTR}_f$, $\overline{MTTR}_{cm}$); Median Corrective Maintenance Man-Hours ($\widetilde{MCMM}_f$, $\widetilde{MCMM}_{cm}$), with the maximum observed number of man-hours for a single event; and Mean Corrective Maintenance Man-Hours ($\overline{MCMM}_f$, $\overline{MCMM}_{cm}$), with the Variance. Also provided is the Indicated Distribution of the Corrective-Maintenance Man-hours.

The procedure used to obtain the indices comprised the following steps:

- Data Screening
- Identification and classification of maintenance events
- Computation of equipment operating time
- Computation of indices

Maintenance events reported through the MDCS were identified and classified by applying a unique logic technique adapted to computer programs. The logic consisted of combining selected sets of when-discovered, action-taken, and how-malfunction codes to specifically classify each maintenance event reported. Events used to compute the reliability and maintainability indices were identified for each equipment by ship and by equipment serial number.

The logic was developed to provide a better assessment of the type of maintenance performed from a given set of data based on the type of equipment and level of EIC reported. The instructions for using the computer program for MDCS maintenance-event identification and classification are shown in Appendix C. An analysis of this type requires engineering-design knowledge of the equipment and its operation, and it results in a more accurate identification of actual equipment failures and anomalies.

Table 5-1 shows the MDCS code combinations that apply to planned, preventive, and corrective maintenance. The definitions for the MDCS codes from OPNAV-43P2 are included in Appendix A. The 95 how-malfunction codes are listed numerically in Part II of Appendix A of this volume and by equipment type in Appendix B of Volume II. These codes are divided into groups as they apply to the equipment: (1) indicating forced-shutdown failure, (2) indicating corrective maintenance only, and (3) indicating "no possible fit" or nonapplicability. The codes were initially assigned by engineers familiar with the operation of the equipments. Each code assignment was then reviewed with Navy engineering division personnel.

Except for an initial visual screening of the data to detect obvious errors in reporting, and the engineering analysis of rejected or incorrectly coded MDCS reports, the entire procedure was performed by automatic data-processing equipment.

5.2 DATA SCREENING

Upon selection of the equipment component-identification numbers (CIDs), the ships using these equipments were identified from the ship-to-component (E-Deck) list. The master tape was then screened to select the maintenance events reported for those ship equipment-identification codes (EICs) being utilized to develop the figures of merit (FOMs). This was accomplished by matching the data in the master tape against selected combinations of ship accounting numbers (SANs) and EICs and transferring the usable data to a screened working tape. For some EICs, it was necessary to make a printout of the data by EIC and number of reports assigned to the EICs so that obviously miscoded data could be changed to the proper code and re-entered on the working tape.

5.3 IDENTIFICATION AND CLASSIFICATION OF MAINTENANCE EVENTS

5.3.1 The Computer Program and Logic Technique

Maintenance events reported in the MDCS data concerning the selected equipments were identified and classified by automated data-handling techniques. Each such event was classified into one of three types of maintenance: planned, preventive, or corrective. The objective was, wherever possible, to distinguish positively and consistently between forced shutdowns and corrective-maintenance events and thus minimize the amount of engineering analysis required for individual maintenance events.

Table 5-1. CODE COMBINATIONS USED TO IDENTIFY MAINTENANCE EVENTS

Type of Maintenance	When-Discovered Code	Action-Taken Code	How-Malfunction Code
Planned Maintenance	B, E, F, M, or O	A or G	Any alphanumeric code or 000
Preventive Maintenance	A, B, C, D, E, F, G, J, K, M, or O	C, D, E, F, H, J, K, L, M, N, P, R, or S	000
	B, E, F, G, J, K, M, or O	B	000
	B, M, or O	B	Any alphanumeric code
	O	G	000
Preventive Maintenance Support	A, B, C, D, E, F, G, J, K, M, or O	Q, U, V, W, X, Y, or any "not-repairable-this-station" (NRTS) code	Any numeric code
Corrective Maintenance*	A, B, C, D, E, F, G, K, or M	C, D, E, F, H, J, K, L, M, N, P, R, or S	Selected numeric codes except 000 (See Appendix B, Vol. II
	J	C, D, F, H, J, K, L, M, N, P, R, or S	Selected numeric codes, except 000 (See Appendix B, Vol. II
Corrective Maintenance Support	A, B, C, D, E, F, G, J, K, M, or O	Q, U, V, W, X, Y, or any "not-repairable-this-station" (NRTS) code	Any numeric code

*Forced shutdown is identified by when-discovered code A or C, one of the action-taken codes applicable to corrective maintenance, and one of the how-malfunction codes listed for the affected equipment in Appendix B of Volume II.

5.3.2 Maintenance-Event Classes

5.3.2.1 Planned Maintenance

Planned maintenance events were not counted or analyzed. However, because some planned maintenance reports were included in the raw data, provision was made in the computer-program logic to identify them so that they could be deleted from the computer working tape.

5.3.2.2 Preventive Maintenance

Preventive maintenance events were not counted or analyzed for the data bank, since, by definition, these are not unscheduled (corrective) maintenance. It was necessary to identify and classify preventive maintenance events, and provision was made for this in the computer-program logic. Reports of preventive maintenance events were not deleted from the computer working tape, but they were not used in computing the indices.

5.3.2.3 Corrective Maintenance

The major objective of identifying and classifying maintenance events was to obtain an accurate count of CM and forced-shutdown events for reliability and maintainability indices. These events are recorded on the computer working tape.

Corrective maintenance can be coded by any action-taken codes except A and B. Codes must reflect at least one action other than a support maintenance action with a how-malfunction code other than 000. Also, a corrective-maintenance event cannot contain a when-discovered code of 0. By selective grouping of corrective maintenance actions that contain at least one action with the when-discovered codes of A or C and the predetermined how-malfunction codes for failure, as listed in Appendix B of Volume II, it is possible to establish a sub-set of corrective-maintenance events that are the result of forced shutdowns.

Forced-shutdown events must have when-discovered codes of A or C in conjunction with a proper how-malfunction code before they are classified as failures. How-malfunction codes listed as "no possible fit" were automatically eliminated from the count and printed out for separate engineering analysis.

5.3.3 Rejected Data and Engineering Analysis

Certain maintenance events are eliminated or rejected by the logic program rather than designated as scheduled preventive maintenance, corrective maintenance, or failure. The following criteria are used to determine which events should be rejected by the program and subjected to engineering analysis:

- The maintenance event was reported with a when-discovered code, an action-taken code, or both, not listed in Table 5-1.

- Support-maintenance actions were reported, but were not preceded or followed by a preventive- or corrective-maintenance-action report. (Support actions are also identified by repair-activity codes.)

- The event was coded by other than one of the 95 how-malfunction codes or the planned-maintenance alphanumeric periodicity codes.

- Deferred maintenance actions (action-taken codes H, J, or K) were not closed out by completion of a maintenance event.

It was necessary to screen each rejected maintenance event manually to determine if it could be classified as corrective maintenance or as a failure event. If this determination could be made, the event was re-inserted into the final data tape before the R&M indices were calculated.

The procedure followed in performing the engineering analysis is described in Appendix B.

5.4 COMPUTATION OF EQUIPMENT OPERATING TIME

Total equipment operating time is the total time all equipments selected within the design category operate. Equipment-use or -utilization factors (K_u) are required for equipments that do not have individually reported operating time. The utilization factor is the ratio of the equipment's operating time to some other known time base such as ship steaming hours, clock hours, or calendar hours. The Application Code preceding the utilization factor indicates what time base is being used.

In this study, two time bases are used:

Application Code	Time-Related Base
S	Steaming Hours
H	Calendar/Clock Hours

The Application Code can be followed by up to three utilization factors - A, B, and C. In the case of Application Code "S", all three utilization factors are used: A = percent of ship steaming hours under way (SHUW), B = percent of ship steaming hours not under way (SHNW), and C = percent of ship cold iron hours (CI). For Application Code "H", the single utilization factor "A" is used; it equals the percent of calendar or clock hours the equipment is in operation.

Ship steaming hours for the ships included in the study were extracted from the Master Fuel Report Monthly Summary tapes. The flow chart for this program, which is written in the Report Program Generator language for the IBM 360 computer, is shown in Figure 5-1. The basic mathematical operation used to develop operating time is as follows:

Application Code "S" steaming hours

$$T_{EOT_S} = \sum_{i=1}^{n} N_i \, (A_i \times SHUW + B_i \times SHNW + C_i \times CI)$$

where

T_{EOT_S} = total equipment operating time based on steaming hours

i = subscript to denote an individual ship

N_i = number of equipments on the i^{th} ship

n = number of ships included in computation

Application Code "H" calendar hours

$$T_{EOT_H} = \sum_{i=1}^{n} N_i \, (2 \, A_i \times 17{,}520 \text{ hours in two years})$$

where

T_{EOT_H} = total equipment operating time based on calendar hours

A_i = percent of calendar hours equipment operates on the i^{th} ship per year

N_i = number of equipments on the i^{th} ship

n = number of ships included in computation

5.5 COMPUTATION OF INDICES

The final event tape contains those events that were classified by the maintenance-event identification and classification program shown in Appendix C and those events that were hand-analyzed by using the logic provided in Appendix B. This final tape is then run with the selected-ship steaming-hours tape and the FOM programs in order to calculate the values of the

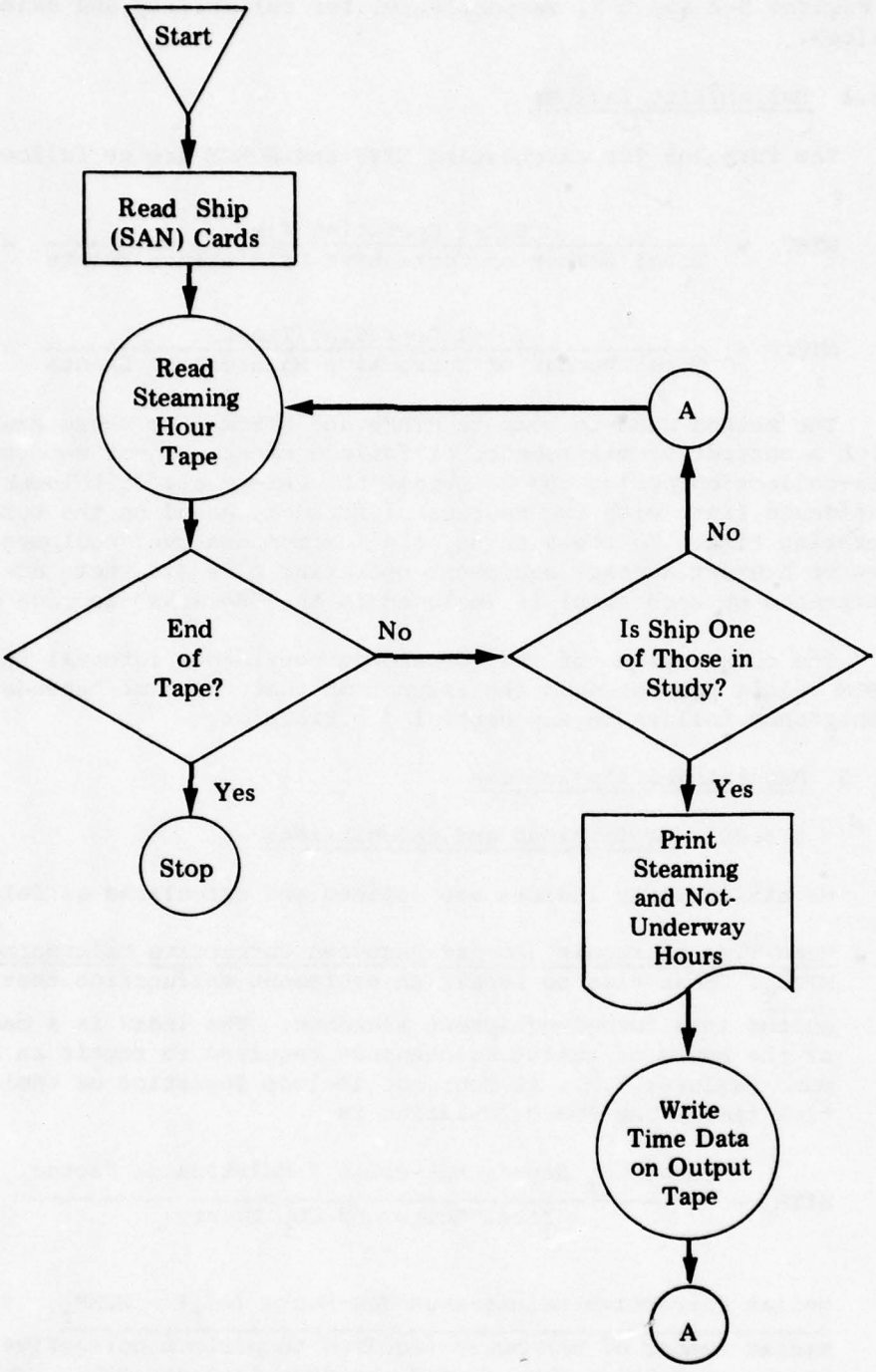


Figure 5-1. **PROGRAM TO SELECT SHIP STEAMING HOURS FROM MASTER TAPE**

Figures of Merit used in the report. These program flow charts are shown in Figures 5-2 and 5-3, respectively, for reliability and maintainability indices.

5.5.1 Reliability Indices

The formulas for calculating MTBF and MTBCM are as follows:

$$\text{MTBF} = \frac{\text{Total Operating Time}}{\text{Total Number of Corrective Maintenance Events}} = \frac{T_{EOT}}{CM_f}$$

$$\text{MTBCM} = \frac{\text{Total Operating Time}}{\text{Total Number of Corrective Maintenance Events}} = \frac{T_{EOT}}{CM}$$

The method used to compute MTBFs and MTBCMs for those equipments for which a corrective-maintenance or failure event was not reported during the data-collection period was to obtain the Chi-square (χ^2) lower 50-percent confidence limit with two degrees of freedom, based on the total equipment operating time. In these cases, the maximum observed equipment operating time or highest average equipment operating time (if there are a number of equipments on each ship) is included in the "Remarks" section of the format.

The computations of the 90-percent confidence interval for the MTBF and MTBCM values are based on the assumption that the time between corrective maintenance follows an exponential distribution.

5.5.2 Maintainability Indices

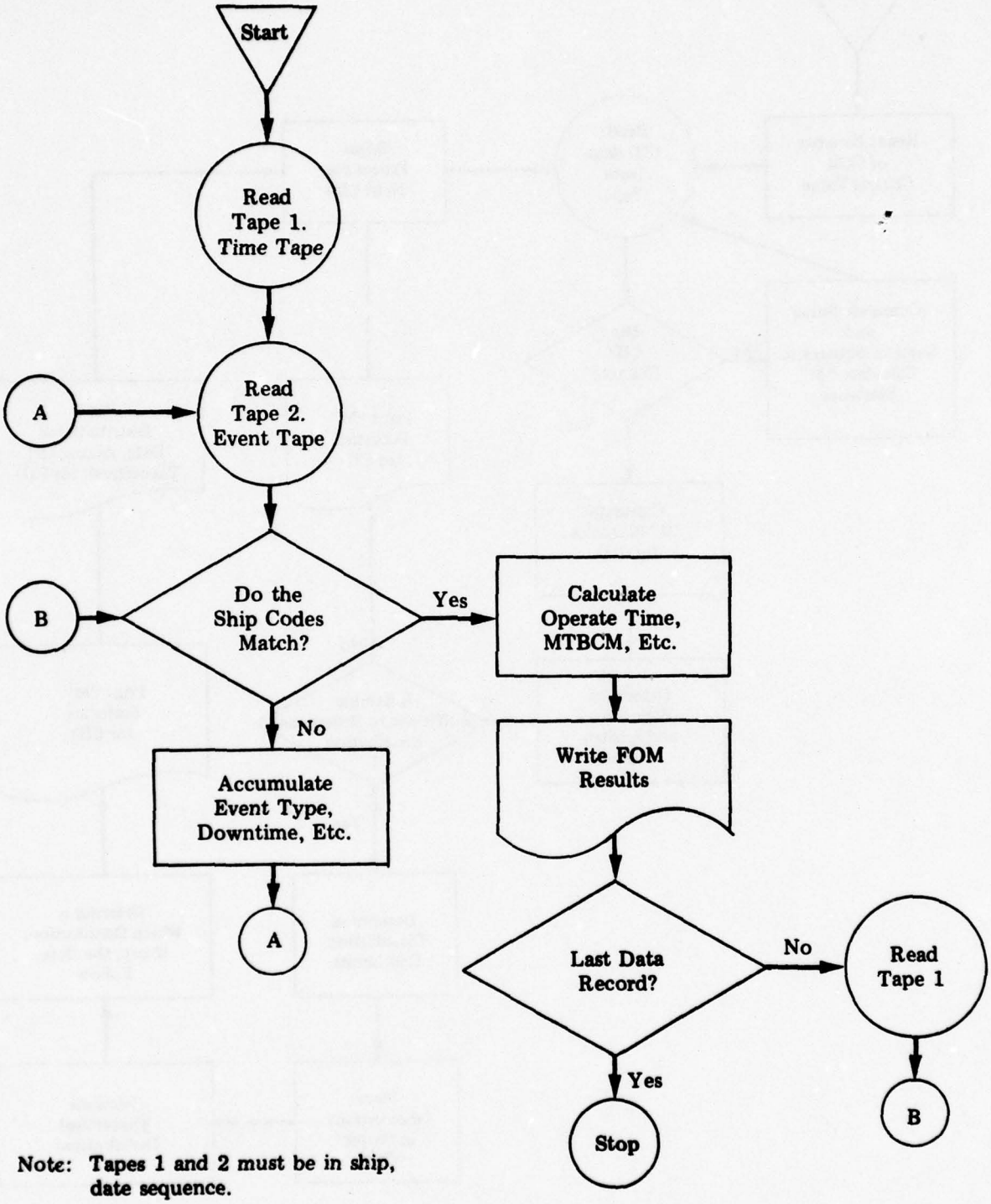
5.5.2.1 Definitions and Calculations

Maintainability indices are defined and calculated as follows:

Mean Time to Repair (Forced-Shutdown Corrective Maintenance) - $MTTR_f$. Mean time to repair an equipment malfunction that resulted in a forced equipment shutdown. The index is a measure of the hours of active maintenance required to repair an equipment failure; i.e., it does not include logistics or administrative time. The FOM calculation is

$$MTTR_f = \frac{\text{Total } CM_f \text{ Repair Man-Hours} \times \text{Maintenance Factor}}{\text{Total Number of } CM_f \text{ Events}}$$

Median Corrective-Maintenance Man-Hours (CM_f) - $MCMM_f$. The median number of man-hours required to perform corrective maintenance resulting from forced-shutdown failures only. This index is selected to aid in providing a better indicator of the distribution of maintenance man-hours. The literature indicates that maintenance man-hour distributions are most often log-normal; therefore, the median is often a more applicable measure of the central tendency.



Note: Tapes 1 and 2 must be in ship, date sequence.

Figure 5-2. **PROGRAM TO CALCULATE FOMs FROM EVENT TAPE AND STEAMING HOURS TAPE**

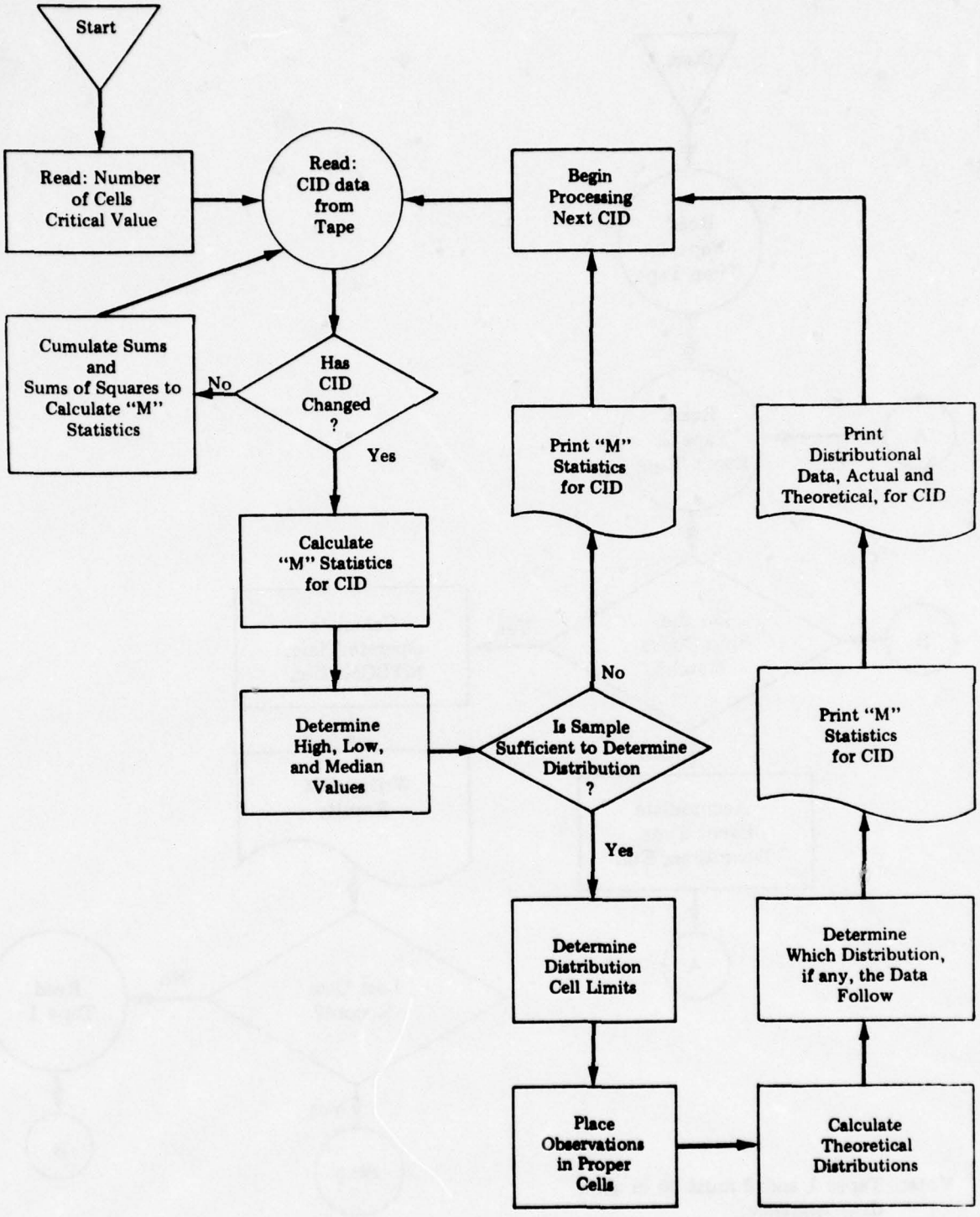


Figure 5—3. **PROGRAM TO CALCULATE MAINTAINABILITY FIGURES OF MERIT AND MAN-HOUR DISTRIBUTIONS FROM EVENT TAPE AND STEAMING-HOUR TAPE**

Maximum Observed Man-Hours (CM). The highest reported value of the corrective-maintenance man-hours resulting from all corrective-maintenance events.

Mean Corrective-Maintenance Man-Hours (CM_f) - $\overline{MCMM_f}$. The average man-hours to perform all corrective maintenance resulting from forced-shutdown failure. The FOM calculation is

$$\overline{MCMM_f} = \frac{\text{Total } CM_f \text{ Repair Man-Hours}}{\text{Total Number of } CM_f \text{ Events}}$$

Variance (CM_f). The variance of the forced-shutdown corrective-maintenance-event man-hours is calculated as follows:

$$\sigma^2 = \frac{1}{CM_f - 1} \sum_{i=1}^{CM_f} \left(CMM_{f_i} - \overline{MCMM_f}\right)^2$$

where

σ^2 = variance

CM_f = total number of forced-shutdown-failure CM events

CMM_{f_i} = individual forced-shutdown CM-event man-hours

$\overline{MCMM_f}$ = mean corrective-maintenance man-hours resulting from forced-shutdown failure

Mean Time to Repair (Corrective Maintenance) - $MTTR_{cm}$. Mean time to repair these equipments for all corrective-maintenance events including maintenance resulting from equipment failures. Same definition as $MTTR_f$ and calculated as follows:

$$MTTR_{cm} = \frac{\text{Total CM Repair Man-Hours} \times \text{Maintenance Factor}}{\text{Total Number of CM Events}}$$

Median Corrective-Maintenance Man-Hours (CM) - $MCMM_{CM}$. The median number of man-hours required to perform all maintenance. This index is provided for the same reason as $MCMM_f$ above.

Maximum Observed Man-Hours (CM). The highest reported value of all corrective-maintenance-event man-hours.

Mean Corrective-Maintenance Man-Hours - $\overline{MCMM_{cm}}$. The average man-hours to perform all corrective maintenance. The FOM calculation is

$$\overline{MCMM_{cm}} = \frac{\text{Total CM-Repair Man-Hours}}{\text{Total Number of CM Events}}$$

Variance (CM). The variance of the corrective-maintenance-event man-hours including forced shutdown failures is calculated as follows:

$$\sigma^2 = \frac{1}{CM - 1} \sum_{i=1}^{CM} \left(CMM_i - \overline{MCMM_{CM}} \right)^2$$

where

σ^2 = variance

CM = total number of corrective maintenance events

CMM_i = individual corrective-maintenance-event man-hours

$\overline{MCMM_{CM}}$ = mean corrective-maintenance man-hours for all CM events

5.5.2.2 Frequency-Distribution Methodology

The computer program used to compute the maintainability indices will also provide a frequency distribution of maintenance man-hours by using the actual man-hour data if the number of sample observations is large (50 or more). In this process, the lower limit for the distribution is set to zero, with the upper limit being set equal to the largest man-hour observation. This range is divided into cells, and the data are then placed in the appropriate distribution cell.

Theoretical distributions are calculated by using the means and standard deviations determined earlier in the program. The observed distribution is then compared with each of the theoretical distributions. The statistical test used is the Kolmogorov-Smirnov goodness-of-fit test, and the critical values used are based on a 10-percent level of significance. From these tests an indication of the possible distribution of the man-hour data is obtained.

CHAPTER SIX

EXISTING SHIPBOARD MACHINERY R&M INDICES

6.1 INTRODUCTION

Over the past several years, ARINC Research has made an intensive effort to develop reliability and maintainability indices for a number of shipboard mechanical equipments. Throughout this time, the techniques for screening, correlating, and handling Fleet data have been improved. As a result of this effort, a large number of indices have been computed and documented. Some of these results are still valid and should be used.

The purpose of this chapter is to review past results and extract those reliability and maintainability values which are still usable. These indices have been added to the data bank.

Some of the efforts that have been completed by ARINC Research and were reviewed for acceptability are listed in Table 6-1. The table identifies the types of systems or equipments and the number of designs for which indices have been computed, and it provides an indication of the acceptability of the indices computed for these equipments. The acceptability is based on the completeness of the indices and on whether or not the equipments are of a current design.

The results of any other work that has been performed on FOM indices for shipboard mechanical equipment were reviewed. The criteria for acceptance of developed indices for the data bank were based on whether the supporting documentation provided sufficient substantiation for each index and whether the method used for computation was consistent with the data-bank requirements.

In all cases other than those listed in Table 6-1, it was believed that the incompatibility of definitions, the methodology used in analyzing the data, and a lack of adequate results made the FOM indices unsuitable for inclusion in the data bank.

6.2 USABLE INDICES

6.2.1 *Reliability and Maintainability Analysis of Selected Mechanical Equipments,* ARINC Research Publication 594-01-2-960, April 1969

Publication 594-01-2-960 was prepared for the U.S. Naval Ship Engineering Center, Norfolk Division, U.S. Naval Station, Norfolk, Virginia, under

Table 6-1. MECHANICAL EQUIPMENT INDICES COMPUTED DURING PREVIOUS ARINC RESEARCH ANALYSES

Description of Work	Type of System or Equipment	Number of Designs	Acceptability of Indices
Availability, Maintainability and Reliability Analysis on DDG-17 1200 Psi Boiler, 1967	Propulsion System Boiler	 1	 No
Reliability and Maintainability Analysis of Selected Mechanical Equipments, 1969	Propulsion System Boilers Burners Blowers, Soot Blower Turbines Valves Main Feed and Condensate System Pumps Turbines Valves Fuel Oil Service System Pumps Turbines	 2 2 2 3 12 7 6 4 1 1	Partial - only boiler indices used
Pilot Program for Establishment of a Shipboard Machinery Reliability and Maintainability Data Bank, 1970	Propulsion System Boilers Burners Blower Turbines Main Feed and Condensate System Pumps Turbines Fuel Oil Service System Pumps Turbines	 2 1 2 3 1 1 1	Yes
Development of a Reliability Prediction Procedure for Shipboard Mechanical Equipments - Phase I, 1970	Ship Service Steam Generator System Turbines Pneumatic Systems High Pressure Compressors Low and Intermediate Pressure Compressors Propulsion System Pumps Turbines Condensate System Turbines Fuel Oil Service System Turbines Lube Oil System Pumps Water Purifier System Pump	 4 7 6 5 6 2 1 6 2	Partial* Partial*
Development of a Reliability Prediction Procedure for Shipboard Mechanical Equipments, Phase II, August 1971	Propulsion System Diesel Engines Generators Motors Pumps Turbines Electric Power Supply System Diesel Engines Generators Motors Motor/Generator Sets Ship Service Systems Generators Pumps Turbines Deck Machinery Systems Generators Water Circulating Systems Motors Pumps Turbines	 9 3 14 2 11 8 3 4 15 20 14 7 1 1 7 7	Partial*

**No Maintainability Indices*

Contract N00189-68-C-0956. Data obtained on 40 selected 1200-psig steam-generating equipments used on board the DLG-class ships were analyzed according to the procedures developed and documented in EMEC Report 25-68, "Procedural Techniques for Analysis of Historical Maintenance Data Relating to Shipboard Mechanical Equipments". The primary data source was the Maintenance Data Collection Subsystem (MDCS), supplemented with data from available technical manuals and boiler operating records, and data obtained from visits to ships, shipyards, and other Navy facilities.

The principal data were furnished by NAVSECNORDIV and were collected from 17 selected ships, covering the operation of 40 types of equipments during the period 1 July 1966 through 31 December 1967.

Forty-one reliability, maintainability, and cost indices were developed for 25 selected equipments.

Tests of hypothesis were made to determine the distributional form of the data for seven of the indices, and statistical tests of means were conducted to identify statistically significant differences in computed means.

The logic used to sort the raw maintenance data to derive the indices for the DLG-class 1200-psi boiler equipments did not detect forced-shutdown failures. The operating-time data, raw maintenance data, and utilization factors were stored, and thus it was possible to rerun them through the improved computer-logic program to obtain the new indices shown in Volume II of this report. The indices are computed by equipment manufacturer, which does not necessarily correspond to indices computed when the data are grouped by the equipment design.

6.2.2 *Pilot Program for Establishment of a Shipboard Machinery Reliability and Maintainability Data Bank,* ARINC Research Publication 588-02-3-1058, May 1970

Publication 588-02-3-1058 was prepared for the Naval Ship Systems Command, U.S. Naval Applied Science Laboratory, Brooklyn, New York, under Contract N00140-68-D-0446. This report presents the results of a pilot program to establish a reliability and maintainability data bank for shipboard equipments. The program was demonstrated by using Maintenance Data Collection Subsystem data on selected equipments in the 600-psi main propulsion boiler system used aboard the DE-1025 class ships.

Automated data-handling techniques were used to classify each equipment maintenance event into one of three types of maintenance (planned, preventive, or corrective) events. Corrective-maintenance events were further identified for those events which resulted from the forced shutdown of a given equipment. The maintenance events were identified and classified by applying a unique logic that consisted of combining selected sets of When Discovered, Action Taken, and How Malfunction codes applicable to a specific equipment type. The technique minimizes the requirements for engineering analysis of individual maintenance-event reports.

Equipment-utilization factors were developed to estimate equipment operating times based on reported boiler steaming hours. These and other modification factors, combined with the MDCS data, were used to compute indices for mean time between corrective maintenance, mean time between forced shutdowns, mean and median maintenance man-hours, mean time to repair, and equipment intrinsic availability.

The logic and methodology developed in the pilot program are the same as those being utilized in this study. The FOM indices were completely compatible and usable. It was necessary only to obtain the Federal Stock Number (FSN) for each CID and the NAVSHIPS Technical Manual.

6.2.3 *Development of a Reliability Prediction Procedure for Shipboard Mechanical Equipments,* Phase I - November 1970, Phase II - December 1971, ARINC Research Publication 933-02-3-1153

Publication 933-02-3-1153 was prepared for the Naval Ship Systems Command, Washington, D.C., under Contract N00024-69-C-5554. These reports describe the development of equations for predicting the reliability of selected shipboard mechanical equipments as a function of design and operational variables. The equations are obtained by regression analysis based on observed measures of reliability, as well as design and operational information on the equipments. Results are presented for shipboard air compressors, diesel engines, generators, motors, motor generator sets (single housing), pumps, and steam turbines.

The observed reliability measures, Mean Time Between Corrective Maintenance (MTBCM) and Mean Time Between Failures (MTBF), were obtained from data reported in the Navy's 3-M Maintenance Data Collection System (MDCS) and from ships' time logs. An automatic data-processing procedure was used to extract corrective-maintenance and failure-event information from the MDCS raw data tapes and to obtain estimates of equipment operating time.

Prediction equations were developed for Mean Time Between Failures (MTBF) and Mean Time Between Corrective Maintenance (MTBCM) for shipboard mechanical equipments by using the multiple-linear-regression technique to correlate design, operational, and environmental parameters with MTBF and MTBCM.

To complete this effort, it was necessary to generate reliability indices. Individual MTBCM and MTBF indices were measured for a total of 165 individual equipment designs (CIDs). No maintainability indices were developed. To incorporate these designs into the data bank, it was necessary to tabulate the maintenance man-hours to develop the maintainability indices.

The FOM indices for the equipments in this effort were derived from maintenance reported against the basic equipment. Certain assemblies or parts were not considered as part of the basic equipment, and maintenance performed on them was deleted from the data.

Appendix A of Volume II is a listing of EICs for all equipments in the shipboard-machinery R&M data bank. These EICs were taken directly from the MDCS Equipment Identification Code Manual dated March 1965. The items enclosed by a rectangle are those equipments, assemblies, or parts which were not considered to be elements of the basic equipment or involved in the maintenance performed on them, and therefore not included in the FOM.

The equipments from the prediction efforts described above are identified in the data bank (Volume II, Remarks) to assure that the user will be aware that special techniques were utilized.

CHAPTER SEVEN

GENERIC GROUPINGS

7.1 CRITERIA

The primary criterion for the selection of the generic groups is the equipment application, e.g., Main Propulsion Diesel Engines, Ship Service Diesel Electric Engine, Fuel Oil Purifier, Lube Oil Purifiers, H.P. Air Compressors, and L.P. Air Compressors. In this respect the groups follow the MDCS Generation I third-level EIC structure very closely and are similar to the list of initially selected equipment types, as shown in Figure 2-1 of Chapter Two. Equipment design is a criterion as it relates to capacities or ratings, e.g., Main Propulsion Diesel Engines of 450 HP to 1,000 HP, and Main Propulsion Diesel Engines in Excess of 1,000 HP; Air Conditioning Plants, R12 to Chilled Water, 8-60 Tons and 60-350 Tons; Distilling plant, Flash Type 2,000 to 12,000 Gallons Per Day and 12,000 to 100,000 GPD. The generic groups are listed in Table 7-1.

7.2 SELECTION AND SCREENING

The final selection of the generic groups is made following an analysis of the FOMs of the individual equipments. First, the MTBCMs are visually screened to identify those obviously higher or lower than the rest, and an attempt is made to determine the cause. If there is no ready explanation for extreme observations, a test for outliers is applied to the data. This is done by comparing the largest and smallest FOMs (MTBCM) of the individual equipments with the next lower or higher value, using the procedure shown in Table 7-2 at the 0.01 significance level. Equipments with an MTBCM determined to be an outlier are not included in the FOM computations for the generic groupings. Equipments so identified as outliers are listed in Appendix C of Volume II by generic-group categories.

7.3 FORMAT FOR GENERIC GROUPINGS

This section provides a description of the basic entries on the Data Bank Format as they are modified to accommodate the Generic Grouping information and FOMs.

Table 7-1. GENERIC GROUPINGS

EIC		Application	Design
Generation I	Generation III		
1A00		Propulsion Diesel Engine	450 HP to 1,000 HP
1A00		Propulsion Diesel Engine	Over 1,000 HP
A100		Diesel Engine Generator Drive	90 HP to 275 HP
A100		Diesel Engine Generator Drive	Over 275 HP
1F28/1F30		Fuel Oil Purifiers	All
AJ09		Fuel Oil Purifiers	All
AJG3/AJG4		Fuel Oil Purifiers	All
1G43/1G44		Lube Oil Purifiers	All
ZU05		Lube Oil Purifiers	All
ZU14/ZU16		Lube Oil Purifiers	All
1H10		Variable Pitch Propellers	All
AA01		Air Conditioning System, R-12 Direct Expansion	All
AA03		Air Conditioning System, R-12 to Chilled Water	Up to 50 tons
AA03		Air Conditioning System, R-12 to Chilled Water	Over 50 tons
AA04		Air Conditioner, Self Contained	Size 3 ton, 5 ton, 7½ ton
AA05		Air Conditioning Plant, Lithium Bromide Absorption	All
AB18		Air Compressor, HP RCIPG	All
AC01		Air Compressor, LP RCIPG	All
AC01		Air Compressor, IP RCIPG	All
AC10		Air Compressor, CTFGL Control Air Multiphase	All
AC43		Air Compressor, LP Ballast Blow	All
AE02		Distilling Plant, LP Flash Type	Up to 12,000 GPD
AE02		Distilling Plant, LP Flash Type	All over 12,000 GPD
AE03		Distilling Plant, Vapor Compression	All
AH17/AH26		Pump, Fresh Water Service and Booster	All
AH22		Pump, Priming, Fresh Water	All
AH31		Hot Fresh Water, Circ.	Up to 7 GPM
AH31		Hot Fresh Water, Circ.	Over 7 GPM
AJ27/AJ64/AJ77		Pump, JP-5 & Diesel, Service & Transfer, Aircraft Service	Rotary type up to 100 GPM
AJ82/AJ86/AJF3		Pump, JP-5 & Diesel, Service & Transfer, Aircraft Service	All over 100 GPM
AX04		Pump, CTFGL Aircraft Fueling and Defueling	CTFGL All
AX10/AX14		Pump, Aircraft Fueling and Defueling	All
AX05/AX11/AX15		Pump, Priming, Aircraft Fueling and Defueling	All
AM01/T501		Refrigeration System, R-11 to Brine	All
AM02		Refrigeration System, R-12 Direct Expansion	Up to 8 tons
AM02		Refrigeration System, R-12 Direct Expansion	All over 8 tons

Table 7-1. (continued)

EIC		Application	Design
Generation I	Generation III		
AM03		Refrigeration System R-12 to Chilled Water	All
BH00		Stabilizer, Fin Type	DE1045, DEG 1-7
K101/K102		Winch, Electric, Misc.	Up to 15,000 lb. pull
K112/K113		Winch, Electric, Misc.	15,000 lb. and over
K115		Winch, Elec./Hyd., Misc.	All
KC01		Winch, Boat, Electric	All
KG01/KG03		Anchor, Windlass, Elec.	All
KG02		Anchor, Windlass, Elec./Hyd.	All
KG06		Anchor, Windlass, Non-Magnetic	All
KH05		Towing, Machine, Auto-Elec.	All
KK03		Capstan, Vert. Elec. Warping	All
KT04		Conveyor, Vert. Stores, Tray Type	All
KT06/KT07		Elevator, Cargo & Stores	All
KU01		Winches, RAS Elec./Hyd., Autotentioning	All
KV01		Winch, Cargo, Electric	All
KV02		Winch, Cargo, Elec./Hyd.	All
LE00		Minesweeping Machinery	All
QD00		400 Hertz M/G Sets	0-25 KW
QD00		400 Hertz M/G Sets	25-150 KW
QD00		400 Hertz M/G Sets	150+ KW
ZA00		Boilers	600 PSI
ZA00		Boilers	1200 PSI
PA01		Generator, AC, SSTG Set	0-750 KW
PA01		Generator, AC, SSTG Set	750-2,000 KW
PE01		Generator, AC, SS Diesel Elec.	All
PF01		Generator, DC, SS Diesel Elec.	All
PF01		Generator, DC, Minesweeping and Propulsion Diesel Electric	
1B00		Generator, DC, Propulsion Diesel Elec.	All
QD03		Generator, M/G Set 400 Hertz	All
QM03		Generator, M/G Set Winch, AC-DC	All
ZH07		Motor, AC, Sea Water Circ. Pump	All
ZQ17		Motor, AC, Main Condensate Pump	All
ZQ18		Motor, AC, Main Feed Booster Pump	All
ZQ65		Motor, AC, Main Feed Pump	All
QD01/QM01		Motor, AC, 400 Hertz & DC M/G Sets	All
1C00		Motor, DC, Main Propulsion	All
QM00		AC-DC M/G Sets	All except 400 Hertz
AP23		Pump, SW Circulating, SSTG	All
ZH05		Pump, Main Condenser, SW, Circ.	All
AP28		Pump, Condensate, SSTG	All
ZQ01		Pump, Main Condensate	All
ZQ02		Pump, Main Feed Booster	All
ZQ03		Pump, Main Feed	All

Table 7-2. TESTING FOR EXTREME OBSERVATION (NO PAST DATA)

N	Criterion	Significance Level*		
		0.10	0.05	0.01
3	$r_{10} = \frac{X_2 - X_1}{X_n - X_1}$ if smallest value is suspected;	0.886	0.941	0.988
4		0.679	0.785	0.889
5		0.557	0.642	0.780
6	$= \frac{X_n - X_{n-1}}{X_n - X_1}$ if largest value is suspected.	0.482	0.560	0.698
7		0.434	0.507	0.637
8	$r_{11} = \frac{X_2 - X_1}{X_{n-1} - X_1}$ if smallest value is suspected;	0.479	0.554	0.683
9		0.441	0.512	0.635
10	$= \frac{X_n - X_{n-1}}{X_n - X_2}$ if largest value is suspected.	0.409	0.477	0.597
11	$r_{21} = \frac{X_3 - X_1}{X_{n-1} - X_1}$ if smallest value is suspected;	0.517	0.576	0.679
12		0.490	0.546	0.642
13	$= \frac{X_n - X_{n-2}}{X_n - X_2}$ if largest value is suspected.	0.467	0.521	0.615
14	$r_{22} = \frac{X_3 - X_1}{X_{n-2} - X_1}$ if smallest value is suspected.	0.492	0.546	0.641
15		0.472	0.525	0.616
16		0.454	0.507	0.595
17		0.438	0.490	0.577
18	$= \frac{X_n - X_{n-2}}{X_n - X_3}$ if largest value is suspected.	0.424	0.475	0.561
19		0.412	0.462	0.547
20		0.401	0.450	0.535
21		0.391	0.440	0.524
22		0.382	0.430	0.514
23		0.374	0.421	0.505
24		0.367	0.413	0.497
25		0.360	0.406	0.489

*Risk of rejecting a perfectly good extreme observation.

(Reproduced by permission from W. J. Dixon, "Processing Data for Outliers" Biometrics, March 1953, Vol. 9, No. 1, Appendix, Page 89)

7.3.1 Equipment Identification

Equipment identifiers are as follows:

Noun Name(s). The service application descriptor(s) assigned to equipment(s) as taken from the Equipment Identification Code (EIC) directory.

General Description. The range of design specifications as taken from the Ship Part Control Center (SPCC) Deck E Card Index "A" entries for the group requirements.

CID/APL Number(s). The Component Identification (CID) Numbers/ Allowance Part List (APL) Numbers assigned to the specific equipments. In the case of a system comprising many CID/APLs, the primary equipment/system CID will be listed. All the CIDs comprising the generic group will be identified.

Federal Stock Number (FSN). The Federal Stock Numbers will not be listed on the Generic Grouping data sheet. FSNs can be obtained by referring to the individual CID data sheets.

Equipment Identification Code(s). The seven-digit Equipment Identification Codes (EICs) as taken from the EIC Directory which are used to code the equipments in reporting maintenance data. Both the Generation I and Generation III EICs will be reported.

Technical Manual. The NAVSHIPS Technical Manual Numbers will not be listed on the Generic Grouping Data Sheet, but can be obtained by referring to the individual CID data sheets.

Manufacturer. The manufacturers of the equipments will not be listed, but may be obtained by referring to the individual CID data sheets.

7.3.2 Basic Data

The following are the basic data elements used in the development of the R&M indices:

Ship Population. The ship types, e.g., DD/DDG/LST, etc., containing the equipments comprising the Generic Grouping. Individual hull numbers can be obtained by referring to the individual CID data sheets.

Equipment Population/Ship. This information will not be listed for the Generic Grouping but may be obtained as described above.

Total Equipment Population in Data Base. The total number of equipments that comprise the data base.

Data-Assessment Period. The period of time that comprises the data period. Beginning month/year - ending month/year - number of months.

Utilization Factors (K_u). These are used for the individual equipment operating-time development and are shown on the individual CID data sheets.

Total Equipment Operating Time. The sum of total equipment operating times recorded on the individual CID/APL data sheets for those equipments included in the Generic Grouping.

Total Number of Failures (CM_f). This is the sum of the forced-shutdown corrective-maintenance events as recorded on the individual CID/APL data sheets for the equipments included in the Generic Grouping.

Total Number of Corrective-Maintenance Events (CM). Sum of all the CM events for the equipments in the Generic Grouping.

Total CM_f Repair Man-Hours. Sum of the total CM_f repair man-hours for the individual equipments in the Generic Grouping.

Total CM Repair Man-Hours. Sum of the total CM repair man-hours for the individual equipments in the Generic Grouping.

Maintenance Factor. The maintenance factors for the individual CIDs comprising the Generic Group are used to compute the active repair time of the Generic Grouping. The factors may be found on the individual CID sheets.

7.3.3 FOM Indices for Generic Groups

The reliability and maintainability FOMs for the Generic Groupings are computed exactly as they are for an individual equipment. The definitions and formula used are shown in Chapter Two, Sections 2.2.3 and 2.2.4. A sample data-bank sheet filled out for a generic grouping is shown in Figure 7-1.

SHIPBOARD MACHINERY
RELIABILITY AND MAINTAINABILITY DATA BANK

Equipment Identification

Noun Name: Generator, AC, SSTG Set
General Description: Generator AC 750-2000 kw
CID/APL Number(s): 161280013 *(1) Federal Stock Number: **
Equipment Identification Code: PA01000/310C700
Technical Manual: **
Manufacturer: **

Basic Data

Ship Population: DLG; SSBN; SSN Equip. Population/Ship: **
Equip. Population in Data Base: 19 Data Assessment Period: 7/1/67 - 6/30/69
Utilization Factors: **
Total Equip. Operating Time (hours): 275657
Total Number of: Failures (CM_f): 7 Corrective Maintenance Events (CM): 48
Total CM_f Repair Man-Hours: 21 Total CM Repair Man-Hours: 351
Maintenance Factors: 0.67

Reliability Indices

Mean Time Between Failure
(Forced Shutdown Corrective Maintenance)

$MTBCM_f$: 39380
90% Confidence Interval
Upper Limit: 82450
Lower Limit: 20610

Mean Time Between Corrective Maintenance

MTBCM: 5743
90% Confidence Interval
Upper Limit: 7521
Lower Limit: 4310

Maintainability Indices

Corrective Maintenance — (Forced Shutdown Failure Events Only)

$MTTR_f$: 1.95
$MCMM_f$: 2.0
Max. Observed MH: 7
$\overline{MCMM}_f$: 2.9
Variance: 4

Corrective Maintenance — (All Events)

$MTTR_{cm}$: 4.87
$MCMM_{cm}$: 3.5
Max. Observed MH: 76
$\overline{MCMM}_{cm}$: 7.3
Variance: 162

Indicated Distribution(s): Exponential ____ Normal ____ Log Normal ____

*REMARKS: (1) 161010010, 162500243, 162500242
**See individual CID data sheets.

Figure 7-1. SAMPLE GENERIC-GROUP DATA SHEET

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The Generation I MDCS data supplemented by operating-time data can be used to derive useful reliability and maintainability indices for shipboard mechanical equipments as shown in Volume II, the data bank. This compilation of equipment R&M indices will be an important decision-making tool for engineering and maintenance management in the selection of equipments for new ships now in the planning stage, and it should aid in improving judgments on the requirements and resources needed to support existing operational equipments. The data bank provides quantitative baselines for the preparation of equipment specifications. It will also allow a more accurate assessment of support studies prepared outside the Navy.

Care must be exercised, however, in the use of Generation I MDCS data for many of the auxiliary, deck, and aviation-type equipments because of the ambiguity of both the equipment uses and the EIC Manual Nomenclature for these equipments. These situations cause MDCS data-coding problems that are further complicated by the distribution of an entire EIC Manual to each ship rather than just the selected portion that applied to the equipments on a particular ship type. Because of the volume of data handled in this report, making it impractical to go over each record manually, it is assumed that some data were lost because they were miscoded and therefore not utilized in the generation of the R&M indices.

It requires considerable time and effort (and produces very rough estimates at best) to develop equipment-use factors by interviewing personnel for their estimate of operating time for equipments that are infrequently used, such as winches and anchor windlasses, or that are on the line and subject to demand-use operation, such as air compressors. In future studies of this type a considerable proportion of the effort must be allotted to obtaining or developing use factors on the equipments for which indices are to be computed unless steps are taken to provide better means for developing these factors.

8.2 RECOMMENDATIONS

It is recommended that a program be initiated within the Navy to systematically develop utilization factors on *selected* equipments on

which logs are not currently maintained. These factors are essential to the accurate assessment of the reliability of such equipments. Several approaches can be taken to acquire this information:

- Time meters can be installed on equipments.
- Logs can be maintained on specific equipments.
- Questionnaires can be sent to Fleet personnel and collected so that new estimates can be developed from their past experience and current estimates of equipment use.

The last method is time-consuming and is the least reliable way to accomplish this task. Future studies of equipment reliability could be performed much more rapidly and accurately with such a program already in effect.

It is recommended that NAVSHIPS/NAVSEC make an effort to develop "Maintenance Factors" for converting maintenance man-hours into "Active Maintenance Time". This effort would consist of selecting, on a random basis, current reported maintenance actions on the equipments of interest and interviewing the maintenance personnel responsible for the reports to determine the number of people involved in the event and the actual "active maintenance time". The result of this effort would be to increase the accuracy of the maintainability FOM Mean Time to Repair, Corrective Maintenance ($MTTR_{cm}$) for planning the manpower needs to support various equipments.

It is recommended that a historical-data baseline of maintenance events (at least six years) be assembled for specific equipments by combining Generation I and Generation III MDCS data so as to establish, through full-maintenance-cycle observation, the minimum acceptable reliability and maintainability procurement standards and test criteria. This is particularly important for those equipments which did not experience a failure or corrective maintenance action during the two-year period of this study.

It is recommended that an evaluation be made of the effect of the Source Data Automation Program on the problem of coding errors in the MDCS data-reporting system. This program should help to eliminate future problems (such as those encountered in this study) in identifying maintenance-event data with the equipment for which the information was reported. An analysis of data from ships using the Source Data Automation Program versus data from ships not using the program could either provide justification for more rapid expansion of the program or serve to point out any problem areas before large volumes of data are accumulated.

APPENDIX A

PART I

CODING DEFINITIONS FOR WHEN-DISCOVERED AND ACTION-TAKEN CODES

PART II

HOW MALFUNCTION CODE LIST

Part I

DEFINITIONS OF WHEN-DISCOVERED AND ACTION-TAKEN CODES (OPNAV 43P2, September 1968)

WHEN-DISCOVERED CODES

A — When lighting off/starting

B — When securing

C — During equipment operation

D — Entered when documenting corrective maintenance discovered during PMS or PM other than PMS.

E — Special inspections (INSURV, material or other requirements specified by Technical Bureaus or Fleet-Type Commanders.

F

F — Underwater hull inspection

G — During repair or up-keep

H — Upon receipt from supply stores

J — Unknown

K — Not otherwise coded

L — During development, test, and evaluation (for specified equipment only)

M — Entered when documenting off-equipment maintenance action

O — Entered when documenting PMS or PM other than PMS, or when the how-malfunction code is 000.

ACTION-TAKEN CODES

A — **Planned Maintenance** — This code will only be used to show compliance with a maintenance requirement card (MRC) in the planned maintenance system. All MRC actions, except daily and weekly, will be reported. Corrective maintenance arising from a PMS action will be documented as a separate maintenance action using when-discovered code D.

B — **Preventive Maintenance (Other than MRC)** — This code will be used to show compliance with preventive maintenance requirements specified by Technical Bureaus or Fleet/Type Commanders and are *not* contained in MRCs under PMS.

C — **Repair (Use of Spare Parts)** — This code will be used when the repair is accomplished by the installation of parts. It is not used when only minor consumables are installed.

D — **Repair (No Spare Parts Required)** — This code will be used when the repair is accomplished without the use of spare parts except for minor consumable items, such as gaskets, packing, solder, welding, fasteners, nuts, bolts, etc.

E — **Test or Adjust** — This code will be used only when the total maintenance action consists of testing and adjusting or both testing and adjusting the item identified in the EIC.

F — **Troubleshoot** — This code will be used only on the 4700-2B form. It is used to show that most or all of the manhours (Block 13) represent time spent in locating malfunctions rather than actual repair time. It will be used only if no other action-taken code is more appropriate.

G — **Alteration** — This code will be used for the installation of SHIPALTS, ORDALTS, BOATALTS, field changes, etc.

Three following "Deferral" codes (H, J, K) will be used to document the manhours spent in a maintenance action (including unsuccessful troubleshooting) which cannot be completed because of the ship's operations, supply, or because the ship is awaiting outside assistance.

H — **Ship's Operations** — Ship's operations are defined as ship movements or activities that prohibit maintenance.

J — **Supply, Lack of Parts** — Supply is defined as lack of parts or material required to complete a maintenance action (parts or material *not* on board).

K — **Outside Assistance** — Outside assistance is defined as maintenance actions that cannot be accomplished or completed aboard ship because of a lack of authorization, insufficient equipment, facilities, funds, etc.

L — **Remove** — The code "remove" will be used only when the total maintenance action consists of the removal of the item-identified EIC.

M — **Installed/Completed** — This code will be used only when the total maintenance action consists of the installation of an item, or inspection and acceptance of a maintenance action completed by another activity.

N — **Assembly/Disassembly** — This code will be used only when the total maintenance action consists of the assembly, disassembly, or both, of the item identified in the EIC.

P — **Manufacture** — This code will be used when the manufacture of an item is in direct support of maintenance.

Q — **Manufacture (Habitability and Miscellaneous Items)** — This code will be used only by repair ships and facilities to show actions on nonmaintenance items.

R — **Service** — This code will be used only when a service action such as rigging, staging, lighting, docking, etc., is in direct support of maintenance.

S — **Survey (Non-Repair Activities Only)** — This code will be used only when manhours have been expended on an item which is found to be beyond economical repair and it is surveyed.

T – **Cancel** – This code will be used to document the cancellation of any maintenance action, when the action is cancelled by proper authority.

WORK-REQUEST ACTION CODES

U – **Disapproved** – This code will be used only by squadron or division commanders to indicate that a requested job has been disapproved.

V – **Will Investigate Further** – For repair activity use only.

W – **Job Accepted with Modification** – This code will be used to indicate that a work request has been accepted but will be modified by the repair activity and will not be fully complied with as requested.

X – **Accepted** – For repair activity only.

Y – **Exchange** – This code will be used when the "On Equipment" maintenance action consists of replacing a failed item with a like item and turning the failed item into stock for "Off-Equipment" maintenance.

NRTS CODES (REPAIR ACTIVITIES)

1 – **NRTS – Repair Not Authorized** – This code will be entered when the repair activity is not authorized to accomplish the repair. This code will not be used unless the repair of the item is specifically prohibited by current technical directives.

2 – **NRTS** – *Lack of equipment, tools, facilities, or skills. This code will be entered* when the repair cannot be accomplished for one of the following reasons:

- The repair is beyond the capability of the tender
- The repair requires Navy Yard work
- Technically qualified people are not available to perform the repair.

3 – **NRTS-Rejected** – This code will be used when a work request is rejected as being ship's force work, because standard stock items are to be used.

4 – **NRTS-Lack of Parts, Material** – This code will be entered when parts or material are not available to accomplish repair.

5 – **NRTS-Shop Backlog** – This code will be entered when repair cannot be accomplished because of excessive shop backlog, (insufficient shop capacity).

6 – **NRTS-Lack of Technical Data** – This code will be entered when a repair cannot be accomplished because maintenance manuals, drawings, or data which describe detailed repair procedures and requirements are not available.

7 – **NRTS-Work Not Delivered** – This code will be entered when a repair is requested (ship to shop) and the work is not delivered to the repair activity.

8 – **NRTS-Insufficient Availability** – This code will be entered when a job is investigated and the time required to accomplish it is not within the ship's manpower limitations.

9 – **NRTS-Beyond Economical Repair** – This code will be entered when the item cannot be economically repaired and is to be processed for reclamation, salvage, or survey, and replacement is recommended.

Part II

HOW MALFUNCTIONED CODES - Numerical Order

000	No Malfunction
004	Low GM or Emission
007	Arcing, Arced
008	Noisy
015	Broken Glass
020	Worn Excessively
021	Overloaded
023	Blown
050	Blistered
051	Failed to Tune
054	Faulty Part, Material
068	Inoperative
070	Broken
080	Burned Out
088	Low Gain
091	Low Sensitivity
093	Missing Part
099	Other
116	Cut
117	Deteriorated
120	Chafed
127	Adjustment, Improper
135	Binding
148	Eroded
160	Contacts Connection Defective
161	Output, Incorrect
169	Voltage, Incorrect
170	Corroded
175	Clearance over Max
180	Clogged
185	Contaminated
190	Cracked
196	Shorted or Grounded
214	Grooved
225	Manufacturer's Defect
226	Excessive Play
230	Dirty
231	Elongated
233	Erratic
235	Dry
239	Improper Fit
242	Failed to Operate
255	No Output
259	Oversize
270	Frozen
275	Under Size
276	Weak
300	Grounded
315	RPM Fluctuating
346	Misaligned
360	Intermittent Operation
370	Jammed
374	Internal Failure
381	Leaking
428	Incorrect Reading
439	Plugged
440	Old Age
450	Open
458	Out of Balance
462	Output Too Low
464	Overspeed
472	Fuze Blown
512	Split
524	Pressure Too Low
476/576	Ruptured
585	Sheared
649	Sweep Malfunction
660	Stripped
665	Terminals Reversed
680	Unstable
690	Vibration Excessive
692	Video Faulty
693	Audio Faulty
700	Weak Electrically
701	Warped
710	Bearing Failure
720	Brush Failure
722	Weld Cracked or Broken
730	Loose
748	Frequency-Erratic
750	Missing
771	Scale Excessive
780	Bent
819	Contacts Do Not Open/Close Properly
884	Lead or Terminal Broken
900	Burned
910	Chipped
928	Pelling
935	Scored
947	Torn
962	Low Power
978	Wall Thickness Not to Specification
984	Low Specific Gravity
991	Salinity Too High
992	Lost at Sea

APPENDIX B

DIRECTIONS FOR ENGINEERING ANALYSIS OF MAINTENANCE DATA REJECTED BY THE COMPUTER MAINTENANCE LOGIC PROGRAM

Table B-1. PROCEDURE FOR ANALYZING MAINTENANCE DATA REJECTED BY THE COMPUTER

Reason for Rejection	Action
The event is a one-action deferral event not followed by corrective maintenance	a. Check part-card printout to determine whether there is a second, identical EIC/CID/SAN/MCN code for a second date. If so, insert closing date. b. If action was completed in one day, insert appropriate date. c. If man-hours are minimal (less than 1.0) and no other data are available, the action remains rejected
The how-malfunction code is designated as no possible fit (see Appendix B, Volume II)	a. Certain how-malfunction codes -- such as 093 - Missing Part, 276 - Weak, 750 - Missing, or 900 - Burned -- under certain conditions (as determined from tbe serial/noun name or from the associated parts cards) indicate a CM event. Data on these events are either reinserted or left rejected on the basis of engineering judgment. For example, if the event is described by a how-malfunction code of 276, Weak, if the noun name is Valve Springs, and if the number of man-hours indicates a major repair, the data are reinserted. As another example, if an event has a how-malfunction code of 750, Missing, if the noun name is Gage Board, and if the number of man-hours is minimal, the data are rejected. b. Data on all how-malfunction codes which fall into the no-possible-fit category, except those named above in step (a), remain rejected.
The action-taken/when-discovered code combination has not been classified	a. When the action-taken code is T, and when an excessive number of man-hours were expended (as determined by engineering judgment or indicated by the how-malfunction code), and/or if parts were used in performance of the event, the data are reinserted. If man-hours expended were fewer than 1.0 (usually 0.5), and no parts were used, the data remain rejected.
Periodicity code used in combination with action-taken/when-discovered code is other than that used for periodic maintenance or scheduled periodic maintenance	a. Recode the event appropriately for periodic maintenance and reinsert the data.
Data reflect support maintenance, but do not indicate whether action was corrective or preventive support maintenance	a. If how-malfunction/action-taken/when-discovered code combination indicates preventive or corrective maintenance, reinsert the data.

APPENDIX C

PART I

INSTRUCTIONS FOR USING COMPUTER PROGRAM FOR MDCS MAINTENANCE-EVENT IDENTIFICATION AND CLASSIFICATION

PART II

LOGIC FLOW CHARTS FOR COMPUTER PROGRAM FOR MDCS MAINTENANCE-EVENT IDENTIFICATION AND CLASSIFICATION

Part I

INSTRUCTIONS FOR USING THE MDCS MAINTENANCE-EVENT IDENTIFICATION AND CLASSIFICATION COMPUTER PROGRAM

This program was written in FORTRAN for use on an IBM 360/30 with 65K bytes of storage and four tape drives. Two of the tape drives are used only for scratch information, and the speed of processing data could be greatly increased on a machine with more storage area — either core storage or direct access storage — such as a disk.

The basic MDCS data record is an 80-column card. The cards are stored on a data tape. The basic record was increased from 80 to 90 columns to accommodate the hull type (81-84) and hull number (87-90). The data records must be sorted on the following fields:

(1) EIC — Equipment identification code (first 4 digits only)

(2) SAN — Ship accounting number

(3) MCN — Maintenance control number

(4) CT — Card type

where EIC is the major sort field. The sorted records *must* be blocked by a factor of 2, which means that every time the program reads from the data tape, 180 characters, or two 90-character records, are read into the computer for processing.

The preceding information specifies the raw-data ordering and blocking that must be used; the following discussion will enable one to provide variable data into the program in order to analyze any type of MDCS data.

The following cards must be used:

CARD 1: Alphabet card. The first 36 columns in this card contain the complete alphabet (A to Z) and the integers 0 through 9.

CARD 2: Failure Code card. Columns 1-2, 4-5, 7-8, 10-11, 13-14, etc., contain the indices of alphabetic codes that have special meaning, such as a failure code, in the event analysis; e.g., if "A" were a failure code, one of the indices punched on this card would be "1".

CARD 3: Numeric Code card. Columns 1 through 9 contain the integers 1 through 9. These digits are read into the program in a special manner and are used by the function IRI049 to convert a variable such as the How Malfunction code, which is read as if it were always alphabetic, into its proper numeric code.

CARD 4: How Malfunction Code cards. Columns 1-3, 5-7, 9-11, 13-15, etc., contain all the numeric malfunction codes that are used for maintenance events that are associated with the equipments under study.

CARD 5: Equipment Identification Code card. Columns 1-4, 6-9, 11-14, 16-19, etc., contain the first 4 digits or letters of the equipment identification codes (EIC). Every code on the data tape *must* be entered on this card.

CARD 6: Failure Table Index card. Columns 1, 3, 5, 7, etc., must all contain the value "1". This code is used for internal program control.

CARD 7: Serial Number Format cards. Columns 1-4, 6-9, 11-14, 16-19, etc. (left justified) contain the serial numbers used in this study. The possible numbers to be searched for are listed below by group:

Group 1 — NR1

Group 2 — NR1, NR2, NR3, ... ,NR9

Group 3 — 1A, 1B, NR1, NR2

Group 4 — 1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B

Group 5 — 1A, 1B, 1C, 2A, 2B, 2C

Group 6 — 1A1, 1A2, 1B1, 1B2.

The remaining card types are repeated by EIC groups for each EIC on the data tape. There *must* be a group of cards for each EIC on the data tape, and the EIC groups must be in exactly the same sequence as that of the data tape or the program will stop.

CARD 8: EIC Group Header card. Columns 1-7 contain the EIC code where columns 5-7 are all zeroes. Columns 10-12 contain the number of ships that are to be analyzed for this EIC.

CARD 9: Failure Code Header card. Columns 1-3 contain the number of How Malfunction codes that indicate failure (forced shutdown), and columns 5-7 contain the number of codes that indicate corrective maintenance.

CARD(s) 10: Failure How Malfunction Code card(s). Columns 1-3, 5-7, 9-11, 13-15, etc., contain the How Malfunction codes that indicate failure (forced shutdown). More than one card may be required, and the number of codes *must* agree with the number specified in columns 1-3 of Card 9.

CARD(s) 11: Corrective Maintenance How Malfunction card(s). Columns 1-3, 5-7, 9-11, 13-15, etc., contain the How Malfunction codes that indicate corrective maintenance. More than one card may be required, and the number of codes *must* agree with the number specified in columns 5-7 of Card 9.

CARD(s) 12: Ship Information cards. The number of these cards *must* agree with the value in columns 10-12 of Card 8. Columns 1-5 contain the ship's account number (SAN). Columns 7, 9, 10, 11 contain 1-digit codes that are associated with the serial-number configuration on this ship for this particular equipment identification code. Column 7 contains any digit from 1 to 6, and this digit refers to the type or group of serial numbers to be searched for. The groups are listed under Card 7. Column 9 is the number of serial numbers in the group; it can range from one to nine. Column 11 contains the number of numeric codes to be searched for; it can range from 1 to 9, while column 13 contains the number of alphabetic characters to be searched for and can range from 1 to 4 (A to D).

Example 1: A ship uses the following six serial numbers: 1A, 1B, 1C, 2A, 2B, 2C. The codes would be Col. 7, 5; Col. 9, 6; Col. 11, 2; Col. 13, 3.

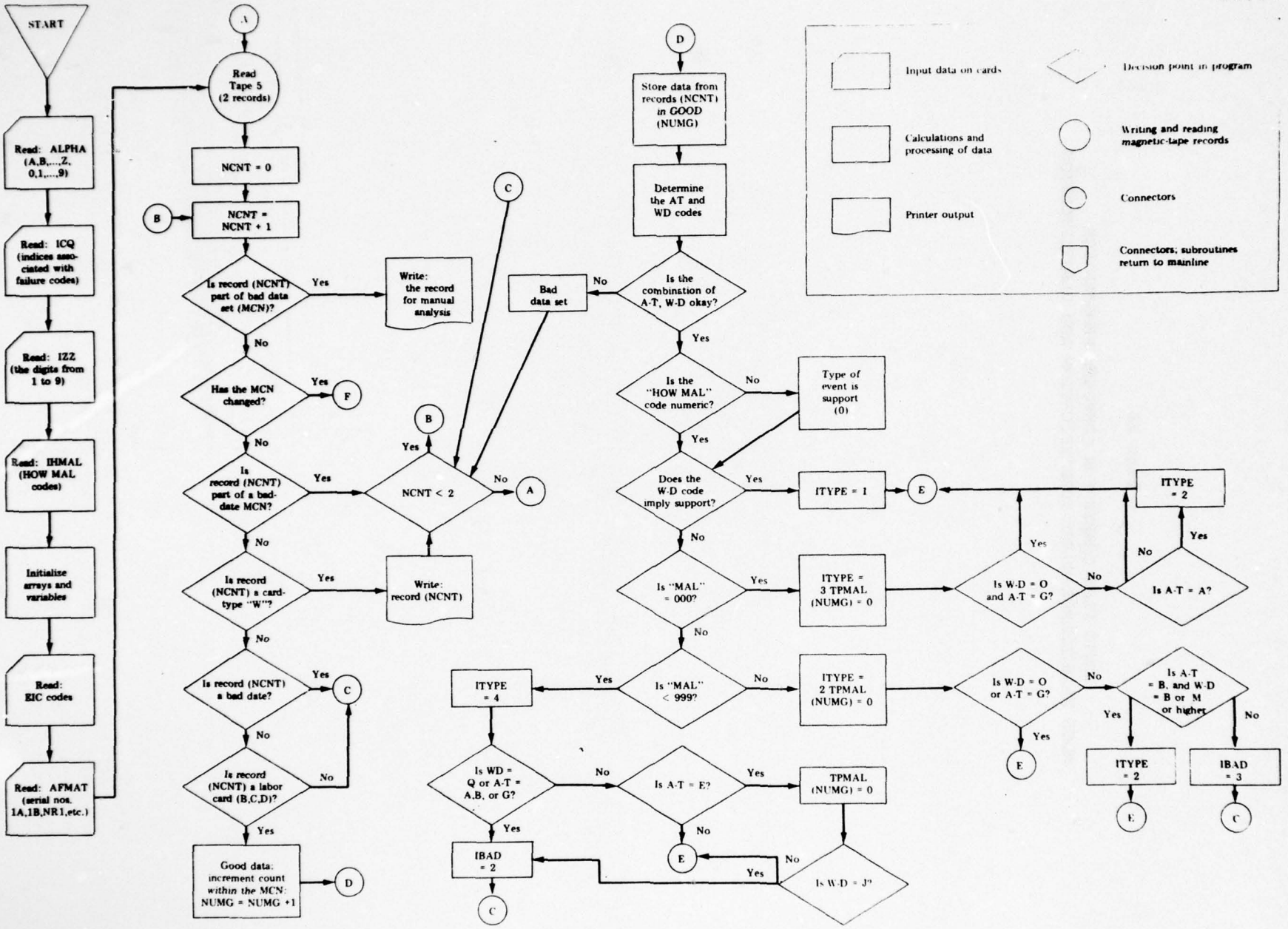
Example 2: A ship uses the following four serial numbers: 1A, 1B, 2A, 2B. The codes would be Col. 7, 4; Col. 9, 4; Col. 11, 2; Col. 13, 2.

For serial-number group 6, the numeric character to be searched for is the third digit in the serial number. For serial numbers in group 2, the number of alphabetic characters to be searched for is disregarded by the program.

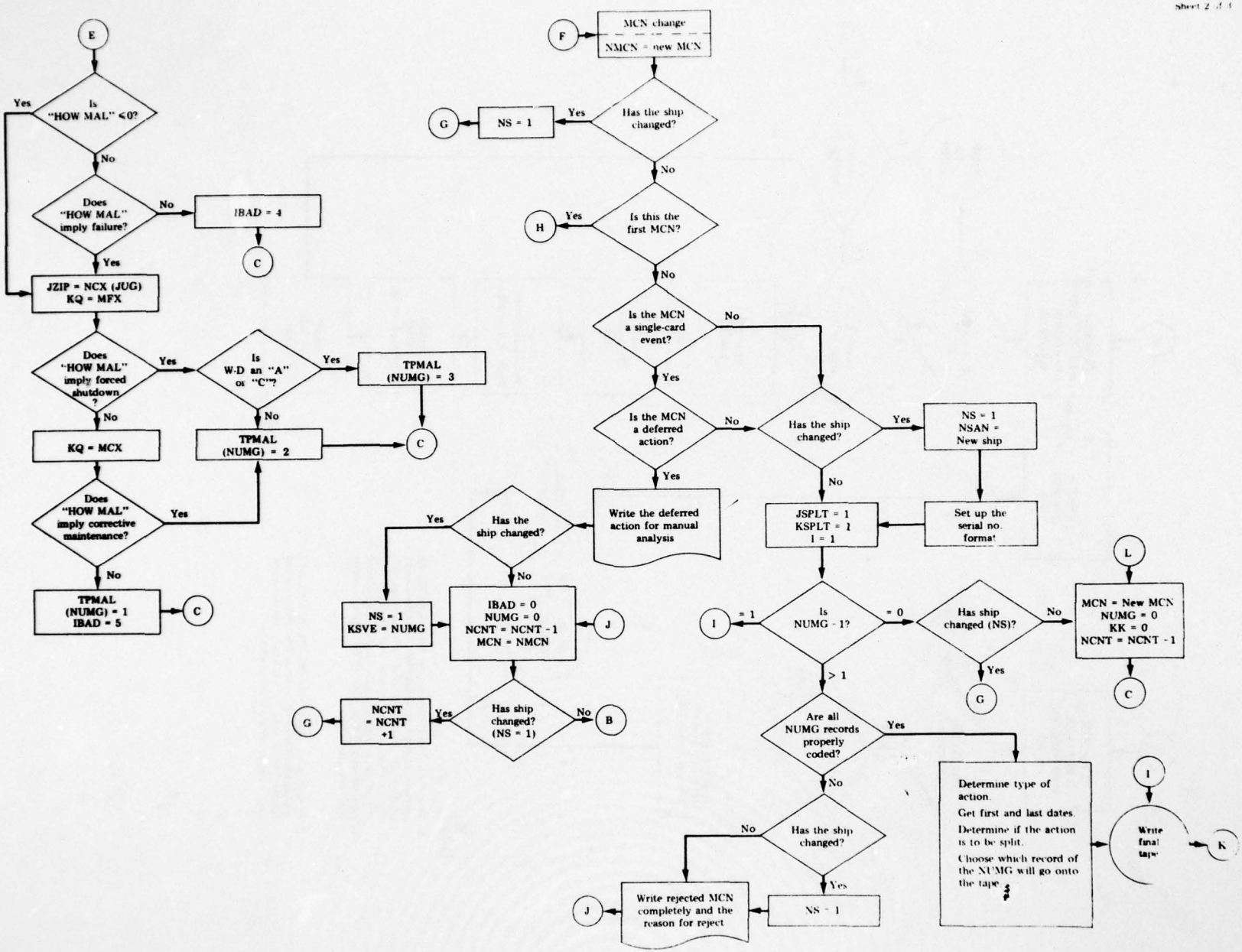
Card numbers 8 through 12 are repeated for each EIC code on the data tape, and there must be a card group for each one on the tape, and vice versa.

Part II

LOGIC FLOW CHARTS FOR COMPUTER PROGRAM FOR MDCS MAINTENANCE-EVENT IDENTIFICATION AND CLASSIFICATION



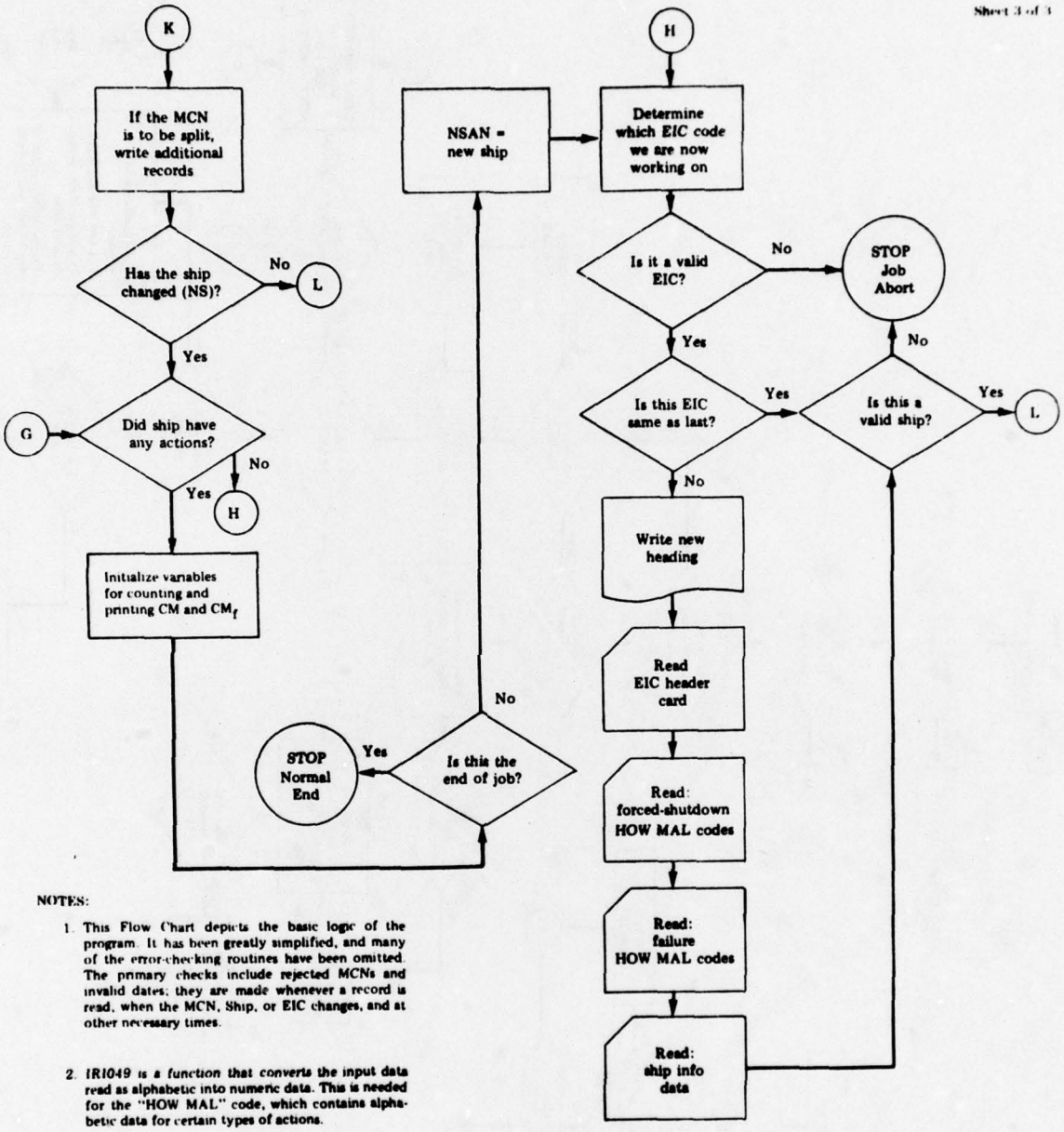
MDCS MAINTENANCE-EVENT IDENTIFICATION AND CLASSIFICATION COMPUTER PROGRAM


E
Is "HOW MAL" ≤0?
Yes
No
Does "HOW MAL" imply failure?
No
IBAD = 4
C
Yes
JZIP = NCX (JUG)
KQ = MFX
Does "HOW MAL" imply forced shutdown ?
Yes
Is W-D an "A" or "C"?
Yes
TPMAL (NUMG) = 3
No
KQ = MCX
No
TPMAL (NUMG) = 2
C
Does "HOW MAL" imply corrective maintenance?
Yes
No
TPMAL (NUMG) = 1 IBAD = 5
C
F
MCN change
NMCN = new MCN
Has the ship changed?
Yes
G
NS = 1
No
Is this the first MCN?
Yes
H
No
Is the MCN a single-card event?
No
Yes
Is the MCN a deferred action?
No
Has the ship changed?
Yes
NS = 1 NSAN = New ship
Yes
Write the deferred action for manual analysis
No
JSPLT = 1 KSPLT = 1 I = 1
Set up the serial no. format
Yes
Has the ship changed?
No
NS = 1 KSVE = NUMG
IBAD = 0 NUMG = 0 NCNT = NCNT - 1 MCN = NMCN
J
G
NCNT = NCNT +1
Yes
Has ship changed? (NS = 1)
No
B
I
= 1
Is NUMG - 1?
= 0
Has ship changed (NS)?
No
MCN = New MCN NUMG = 0 KK = 0 NCNT = NCNT - 1
L
C
Yes
G
> 1
Are all NUMG records properly coded?
Yes
No
Has the ship changed?
No
Yes
Write rejected MCN completely and the reason for reject
J
NS = 1
Determine type of action.
Get first and last dates.
Determine if the action is to be split.
Choose which record of the NUMG will go onto the tape.
I
Write final tape
K

AD-A054 499 ARINC RESEARCH CORP ANNAPOLIS MD F/G 13/10
ESTABLISHMENT OF RELIABILITY AND MAINTAINABILITY DATA BANK FOR --ETC(U)
MAR 73 E J LUTZ, D J HOFFMAN N00024-72-C-5388
UNCLASSIFIED 0E13-01-1-1224-VOL-1 NL

2 OF 2
AD
A054499

END
DATE
FILMED
6-78
DDC



NOTES:

1. This Flow Chart depicts the basic logic of the program. It has been greatly simplified, and many of the error-checking routines have been omitted. The primary checks include rejected MCNs and invalid dates; they are made whenever a record is read, when the MCN, Ship, or EIC changes, and at other necessary times.

2. *IR1049 is a function that converts* the input data read as alphabetic into numeric data. This is needed for the "HOW MAL" code, which contains alphabetic data for certain types of actions.