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RELIABILITY ANALYSIS OF LARGE COMMERCIAL VESSEL ENGINE ROOM AUTOMATION SYSTEMS

VOLUME II

Appendices A - C

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November 1982

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16. Abstract

This Volume II presents Appendices A through C. Appendix A contains the Document Log, Cross Reference Matrix, and individual abstracts which summarize the results of the literature review.

Appendix B contains the system failure effects summary, and the detailed failure modes and effects analysis for Ship A.

Appendix C contains the system failure effects summary, and the detailed failure modes and effects analysis for Ship B.

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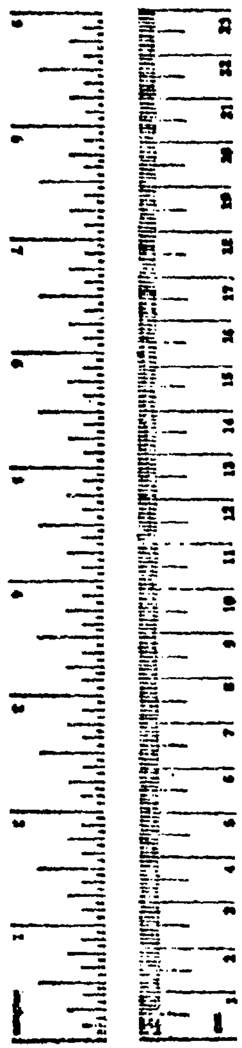
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

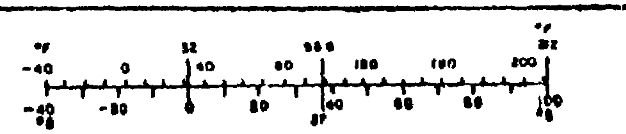
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



APPENDIX A

TASK I LITERATURE SEARCH

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TASK I LITERATURE SURVEY, DOCUMENT LOG

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Log #001: "Improved Marine Boiler Reliability; Task 5 Report"
C-E Marine Power Systems
PB-252-675, April 1976

This document reports on an investigation of marine boiler design factors related to the reliability of the steam generating system. Areas investigated ranged from superheater tube corrosion to energy consumption of components. The Task 5 investigation is particularly pertinent. It focused on instrumentation to enable monitoring of processes/parameters affecting boiler reliability. Existing instrumentation practices were examined, and improvements were recommended.

The discussions in this report fall into 2 major categories:
1) The types of boiler instrumentation available, their principals of operation, and factors impacting their use in marine service (i.e., the state-of-the-art); and 2) The reasons (together with background information) that boiler reliability could be enhanced through additional or improved instrumentation. A simple example of this last category is monitoring to prevent the buildup of combustible gasses following flame-out.

The reliability considerations in this report center around the prevention of boiler failure modes or the mitigation of their effects. Quantitative reliability factors are not discussed.

DOVAP expects this document to be useful during the present study in the identification of failure effects. For instance, if a particular boiler instrument failed to function, the end result could be one of the undesirable boiler conditions described. This document might also prove useful in considerations involving the state-of-the-art of instrumentation.

Log #002 Bjorn Svenning et al,
"The Periodically Unattended Engine Room On The T.T. Thorshammer"
SNAME Annual Meeting, New York, New York
November 1971

The T.T. Thorshammer was the first turbine tanker to receive unattended engine room operation (EO) classification from DetNorske Veritas. This paper describes her machinery plant and automation system, and discusses some of the problems encountered and their solutions. Since the primary purpose of this paper is to describe the system and its operation, reliability, per se, is not considered. The problems described, however, do have an impact on reliability.

The paper reports that most of these problems involved burners and their flame scanners, vibration and displacement probes, and some remote valve operators. It is also reported that small items such as the foregoing caused more problems than did major machinery. Due to vibration, some sensors and connector boxes had to be relocated. Other problems included oil and water contamination of the air supply.

The paper stresses that system performance depends on suitable sensors which are properly installed and maintained. It also points out that there is no guarantee that instruments which perform well ashore will function properly aboard ship.

DOVAP expects that the problems described in this paper, such as those summarized above, will be useful in failure mode considerations during the present study. Also, this paper contains excellent hardware configuration information which could prove useful in defining functional requirements that the hardware must meet.

Log #003: A. Wade Blackman
"U.S. Ocean Shipping Technology Forecast and Assessment"
COM-75-10001, June 1974

This document describes an evaluation of the state of technology in the maritime industry, and a projection of technological capabilities over a period of 25 years. Emphasis is on social and economic impacts, so that "pure technological" aspects receive only brief mention. For this reason, the document has little applicability to the DOVAP study except to note that increased use of gas turbines and nuclear propulsion is predicted for the future.

Log #004A: U.S. Maritime Administration
"Standard Specifications for Merchant Ship Construction"
PB 290-400, January 1979

Log #004B: U.S. Maritime Administration
"Standard Specifications for Diesel Merchant Ship Construction"
PB 257-261, 1976

These two related documents provide complete specifications for the design and construction of merchant ships (Log #004A) and diesel merchant ships (Log #004B). The overall objective of both documents is to provide guidance to the U.S. Maritime industry in the preparation of complete specifications. One of the primary purposes of the specifications is to establish levels of quality as a benchmark for Federal Government Assistance (i.e., the Construction Differential Subsidy).

Each document contains a complete section on propulsion controls. No quantitative reliability or maintainability requirements are specified, but numerous "qualitative" requirements are specified to enhance R&M. This includes the requirement for a failure modes and effects analysis of the most probable failures "as a part of the initial throttle control system" (sic). Also, requirements for built-in test provisions are stated, as are environmental requirements.

Log #005: "Spare Part Provisioning for Merchant Ships"
Mystech Associates, Inc.
PB 299-864, PB 299-865, PB 299-866 (3 Volumes)
September 1979

This document reports on a study conducted for MarAd to assess the scope of spare parts provisioning, utilization, and control within the Maritime industry. Volume I consists of an executive summary; Volume II describes the assessment; Volume III, which is not applicable to the DOVAP study, considers merchant ship supply requirements during wartime.

A survey of a number of U.S. Flag and International shipowners/operators, as well as of selected marine equipment manufacturers, distributors and suppliers provided information on spare part practices. In addition, spare parts requirements for a typical merchant vessel were assessed. Other areas assessed in the study included prevailing practices and experiences with spare parts numbering identification, inventory control, and procurement. Attitudes towards such concepts as centralized inventorying, warehousing, and pooling were also investigated.

The major overall conclusion of this report is that individualistic approaches and lack of commonality in the maritime industry "dilutes the ability to develop general conclusions that may be expressed as being 'typical' of the industry." The report also states that:

> "The shipowners/operators recommended provisioning levels for spare parts were based on subjective experience which tended, in many cases, to be greatly influenced by recent equipment failures. The lack of good engineering practices or sound business judgement in the establishment of spare parts support systems is widened by deficient records of spare parts consumption and frequently, an excessive range and depth of inventory."

The report cites a number of problems with prevailing practice, with many of them stemming from the lack of an objective approach. Nevertheless, the study found that ship delays due to lack of spare parts are practically non-existent because of temporary repairs, loans, substitutions, etc.

The study reported in this document also attempted to quantify spare parts usage. The MarAd Maintenance and Repair Data Processing and Evaluation System Master Data Base was utilized for this purpose. The data base presented several deficiencies for this application, but it was still the best available. Data were obtained from a number of equipment categories, including automation, for the C-4 class vessel for the period 1970 to 1974. From this, M&R actions involving the use of parts were tabulated. For automation, the 5-year mean was 0.200 actions per ship per year.

Log #006: P.D. Andre
"Reliability Appraisal for Complex Equipment"
Paper presented at Annual Reliability and Maintainability Symposium, 1978

This paper describes the first phase of a study into reliability demonstration test procedures as applied to short production runs of large and complex Naval equipment. The underlying rationale for the approach described is that:

> "System failure will occur as a result of the system experiencing a stress condition or level to which the component parts are susceptible or when inadequate protection has been provided."

Based on this rationale, a test approach is proposed and its salient features are discussed. The outlines of the test methodology and scope are also provided.

Of special interest to the DOVAP study are two observations offered in the paper. These are summarized as follows:

a) Over 60% of failures are not "random," but rather are due to such attributable causes as environmental conditions, burn-in and wear-out, maloperation, mismaintenance, design oversights, etc.

b) For one type of equipment, it was found that the proportion of "attributable" failures and their classifications had not changed significantly through the evolution from electronic tubes to transistors to TTL integrated circuits.

Log #007: National Transportation Safety Board Marine Accident Report
"U.S. Motor Tankship Sealift China Sea Ramming of the Italian Motor Cargo Vessel Lorenzo D'Amico, Los Angeles Harbor, January 15, 1978"
NTSB #MAR-79-13, August 16, 1979

This document reports on the investigation of the National Transportation Safety Board into the ramming indicated above. An extremely simplified synopsis of the accident is that the "Lorenzo D'Amico" was moored, and the "China Sea" was maneuvering in a turning basin. The engine control system on the "China Sea" was inoperative and hand signals were being used by the engineering crew to relay orders. The pilot called for half astern, but the hand signals were misinterpreted to mean half ahead. The pilot then called for full astern, and again the orders were misinterpreted and full ahead was applied. The ramming followed.

Among the contributing factors of the accident cited by the NTSB were inadequate design of the engine control system and inadequate measures to maintain, repair, and provide spare parts for the engine control system. Other contributing factors cited were lack of an installed, reliable method to transmit engine orders to the local control station and the inadequate telephone system between the engine control room and the local control station.

This investigation brought out several factors that could be of interest during the DOVAP study. This includes the history of the problems with the engine control system and its maintenance. (For instance, there had been a series of problems, the crew stated they did not have adequate trouble-shooting and repair documentation, and spares had been difficult to obtain.) Perhaps of more significance to this DOVAP study, the report provides a vivid example of the chain of events culminating in an accident. For instance, by themselves neither the lack of an adequate telephone system nor the failure of the engine control system would necessarily lead to an accident. Knowledge regarding such "chains of events" is essential for thorough Failure Modes and Effects Analyses and Fault Tree Analyses.

Log #008: L. Chavanet
"Unattended Machinery Spaces in Steam Turbine Tankers"
Paper presented at Institute of Marine Engineers/ Nautical Institute Joint Automation Conference
March 6, 1974

This paper describes the salient features of six tankers belonging to Shell which are automated for unattended engine room operation. All six ships have the engine room control center on the bridge, and maintain no engine watch except in busy areas. The experience with these vessels, which represents 20 accumulated ship-years, is discussed. Both quantitative and qualitative information is given concerning this experience.

In the quantitative area, the number of both true and false alarms are tabulated and discussed. The trends for both types are reported to be about the same. The number of alarms decreases until about the second year of operation, after which it levels off to about one "true" alarm per ship every three days and about three "false" alarms per ship per month. After about the fifth year of operation, a slight increase in the number of "true" alarms is reported. Various curves and histograms are provided to depict this data as a function of time and as a function of the type of alarm.

The data depicting types of alarms is quite comprehensive, and should be useful on the DOVAP study. It shows the average number of each alarm (e.g., high exhaust line pressure, low superheated steam temperature, etc.) per month for each of the ships and for the six ships as a whole. It also indicates which alarms caused loss of propulsion power and boiler unavailability. This data constitutes failure effect frequencies in its reported format. In addition, if operating hours are estimated from narrative descriptions in the paper, rough estimates of failure rates can be obtained.

In the qualitative area, the chapter reports on some observations from operational experience. These include:

a) Faulty automation equipment is located almost exclusively in the engine room, and consists primarily of transducers. This is attributed to the high ambient temperatures.

b) Recorders are a permanent source of trouble.

c) The reliability of the machinery is better than that of some of the instrumentation/control equipment. This is possibly because the instrumentation, in many cases, was developed for non-marine applications.

Log #009: J.M. Cruikshank
"Unattended Operation of Turbine Driven Vessels"
Paper presented at Institute of Marine Engineers/
Nautical Institute Joint Automation Conference
March 6, 1974

This paper examines operational experience with unattended machinery spaces from the standpoint of original design policy and details as a means for evaluating the adequacy of the design approach. The paper is very design oriented and therefore contains little information applicable to reliability. It does report that several "blackouts" occurred, and that these were caused by testing/adjustment in all cases but one. The exception was due to a broken wire in a vibration detector. Also, the paper reports that the total time per ship spent in testing, re-adjusting, and minor servicing of the control equipment is two to six man-hours per day.

Log #010: M. Hattfield
"User Experience of a Computer Based Watchkeeping and Control System"
Paper presented at Institute of Marine Engineers/
Nautical Institute Joint Automation Conference
March 6, 1974

This paper describes experiences over two years of operation with the computer-based system aboard the 1,137 GRT British fishing vessel "M.T. St. Jasper." This system consists of electronics -- including the computer, relays, and electro-pneumatic and solenoid operated valves, a paper tape unit and a typewriter. The vessel operates in the North Atlantic with significant periods within the Arctic Circle.

No quantitative R&M information is provided in this paper, but a number of points relating to qualitative R&M factors are described. These include the following:

a) Actuators (electro-pneumatic and 24-volt solenoid operated valves) caused little trouble in service.

b) Throughout commissioning, wiring errors were the biggest source of trouble.

c) Installation problems were encountered with the transducers.

d) Aluminum transducer heads are not ideal in the marine environment.

e) Butyl rubber insulated cable gave excellent service.

f) The typewriter gave good service.

g) The relay-based control sequencing equipment had a down time of practically zero.

h) Most faults in the computer-based "watchkeeper" equipment were on logic boards.

A major conclusion of the paper is that a computer-based system is not feasible without an on-board specialist. Trouble-shooting and repair often took two men two days, and was sometimes deferred because of other duties. Out of seven voyages, five failures occurred which resulted in the computer-based "watchkeeper" being shut down for the remainder of the voyage. Diagnostic tapes were available but were of little use because control processor failures usually prevented feeding-in the tapes. Also, interpretation of the tape output data was beyond the skill of the crew.

Log #011: F.D. Glover
"The Benefits and Pitfalls of Marine Automation for the Ship-Handler"
Paper presented at Institute of Marine Engineers/ Nautical Institute Joint Automation Conference
March 6, 1974

This paper presents a rather generalized discussion of how to avoid some of the pitfalls of automation based on the author's experience with six vessels. Information applicable to R&M considerations is limited, and generally concerns controllable pitch propeller failure modes and effects.

Information of possible interest to the DOVAP study includes the following:

a) The engine overspeed shut down limits must be carefully set to allow for a slight overspeed yet still stop a run-away engine. An unscheduled engine overspeed shut down caused a major collision in a river.

b) The paper stresses the need for cleanliness of hydraulic and control air systems.

c) The dirty conditions in shipyards are stressed, as well as the concomitant need to protect control systems from contamination while the ship is under construction or laid up.

d) On some vessels, sections of the automation systems were out-of-service for months due to lack of spare parts.

Log #012: L. Johansson
"The Application of Electronic Systems in Ship's Engine Rooms"
Paper presented at Institute of Marine Engineers/ Nautical Institute Joint Automation Conference
March 6, 1974

This paper discusses some views and practical experience from the use of on-board automation systems, particularly those associated with unmanned machinery spaces operation. Considerable R&M information -- both qualitative and quantitative -- is covered.

The author's firm, Salen, first began unmanned operation in 1967. In the time frame covered by the paper, 24 ships were operating with unmanned engine rooms.

In the area of quantitative reliability, an alarm summary covering five tankers for a total period of 11 months is given. Since some of the alarms were due to equipment failure, some rough MTBF's can be computed from the data. Also, a considerable amount of availability data is provided for several automation functions. These functions include computer steering, remote control of the main engine, the computer, the test and alarm program, etc. From the data provided, the number of down-time hours and percentage availability can be computed for the functions.

Alarm frequencies are also discussed, and these average out to 20 alarms per ship per month.

Estimates of the time required for planned maintenance of instrumentation equipment is also given. This indicates the time per unit (various valves, transducers, etc.) expected to be spent once a year during normal dry-docking.

In the area of qualitative R&M considerations, a variety of points are covered. The more salient of these are summarized below:

a) It is extremely important that the ship be fully completed when handed over to operating personnel. Sea trials should include trials of the automation system.

b) Equipment in the interface between the process being monitored and the automatic controls represent the weak link in R&M. Increased use of electronics to replace pneumatic and mechanical equipment should improve this.

c) Problems with hydraulics and pneumatics are leakage and dirt, and moisture in the air system.

d) Electronic equipment failures were due to vibration and moisture. Also, transient current surges and radio transmissions have caused false alarms.

e) Early problems involved main boiler and burner supervision equipment. At that time, no equipment for unmanned operation had been tested. Fully electronic equipment was eventually used.

f) Safety systems are tested each month; other points are tested at intervals of two weeks to one year, depending on the consequences of a fault. (Comprehensive test instructions and frequencies are provided in an Appendix to this paper.)

g) The need for a qualified, on-board electrotechnician is stressed.

Log #013: L.B. Ward
"Effective Control of Naval Steam Plant Systems"
Paper presented at 2nd Ship Operation Automation Symposium, Washington, D.C.
August 30 - September 2, 1976

This paper describes monitoring requirements for a steam plant in considerable detail. It is directed to Navy ships, but the details are generally appropriate to other types of vessels. The applicability of this paper to the DOVAP study is in the area of hardware configuration/details.

Log #014: N. Tam and G. Milano
"The Application of Microprocessors to Direct Digital Control of a Marine Boiler"
Paper presented a 2nd Ship Operation Automation Symposium, Washington, D.C.
August 30 - September 2, 1976

This paper describes the use of a microprocessor for marine boiler automation. A system description is provided, and the advantages of a microprocessor-based system are discussed. The applicability of this paper to the DOVAP study lies solely in the area of a subsystem configuration information.

Log #015: R.K. Kill and E.L. Coffman
"Ships of the U.S. Merchant Marine"
Naval Engineer's Journal, October 1976

This paper provides a survey of the U.S. Merchant Marine, and describes the American Flag Fleet. The Construction Differential Subsidy program is discussed, especially in terms of its impact on ship design. Ship construction standards, such as fire protection, subdivision and automation, are assessed. Typical ships are described, and on-going research is covered.

The applicability of this paper to the DOVAP study lies in the background information it provides. This includes background information into the types of ships having automation, some historical aspects of maritime automation, typical types of propulsion systems, and R&D in the automation area. Since this paper "covers a lot of ground," each point is necessarily brief, but valid information nevertheless.

Log #016 Maritime Transportation Research Board, Ship Research Committee
"Review and Recommendations for the Interagency Ship Structure Committee's Fiscal 1982 Research Program and Five-Year Research Program Plan"
National Academy Press, Washington, D.C.
March 31, 1981

This document sets forth recommendations for the Ship Structure Committee's Fiscal 1982 research program, and outlines a five-year research planning program. Areas cited as of significant concern over the next five years are fracture, vibration, ice-strengthening, fatigue, and corrosion.

This document is applicable to the DOVAP study in that it provides background information into the likely course of ship structure research in general, and of vibration in particular.

Log #017 A. Binski
"Process Control Instrumentation for Use On-Board Ship"
Instrument Practice, July 1971

This article consists of an overview of the uses, requirements, and operating environments of on-board instrumentation. It is directed to the design engineer, and contains little in the way of R&M considerations.

It does point out that moving coil instruments are subject to vibration effects and should not be used. It also points out that, similarly, motion balance instruments are less suitable for marine use than force balance types. Other points of possible interest include the potential for maltreatment of equipment by maintenance crews at sea and shore, and the fact that anti-vibration mounts prolong instrument life. Also, the author cites engine and boiler temperatures in excess of +55 degrees C, and states that sensors mounted near exhausts will be subjected to much higher temperatures.

Log #019: "New Monitoring Technique for Electric Motors"
Naval Research Review, November 1976

This brief "news release" type item cites research at the David W. Taylor Naval Ship Research and Development Center concerning a possible condition monitoring approach for electric motors. The approach compares measured motor coastdown time versus calculated time to obtain an indication of friction, and therefore, of the mechanical condition of the motor.

Log #020: Steinar Espestoyl
"Computerized Engine Room Automation and Condition Monitoring"
Paper presented at 2nd Ship Operation Automation Symposium, Washington, D.C.
August 30 - September 2, 1976

This paper describes experiences with the "Data Chief" system built around the Nord 4 computer for engine room automation and condition monitoring. The experiences cover 9 systems over the time frame 1973 to 1975. Both quantitative and qualitative R&M information are provided.

In the quantitative area, MTBF's are given for a number of system modules. These include the CPU, the memory module, analog to digital (A/D) converter, multiplexer, etc. A design goal of an MTBF of 100,000 hours was established for each module. Only the A/D converter, with an observed MTBF of 80,000 hours, and the real time clock, with a MTBF of 30,000 hours, did not meet this goal.

System availability is reported to have run at least 99%. This availability is attributed to system redundancy, short repair times, and to the fact that some failures were in systems not vital for unmanned operation.

In the qualitative area, several points concerning maintainability are cited. These include:

a) Except for three memory failures, all failures were corrected by the crew. Diagnosis was sometimes aided via telex or telephone communications.

b) Successful maintenance was attributed to 1) crew skill, 2) simple system architecture, 3) the high level of self-checking and dianostics "built into" the system, and 4) the fact that the CPU was always working and able to execute diagnostic routines.

c) Providing one spare module aboard for each type of module would have been prohibitive. Instead, 15 spare modules were provided based on those vital to ship operation. This is reported to have been sufficient.

d) The situation reported for condition monitoring was that the data allowed maintenance to be performed before degradation occurred; therefore, the predictions indicated "no change" in condition. The main savings are reported to have been in reducing degradation and spare parts usage.

Log #021: T. Heimly and A. Ostensen
"Electromagnetic Interference, A Neglected Problem in Shipboard Integrated Systems"
Paper presented at 2nd Ship Operation Automation Symposium, Washington, D.C.
August 30 - September 2, 1976

This paper describes electromagnetic interference (EMI) control tecnniques and methods. It surveys the most important parameters of EMI suppression, and includes discussions of wiring separation, shielding and grounding, and testing of completed installations. A minimum EMI program is described.

The authors (of DetNorske Veritas) report they have measured unexpectedly high levels of EMI in machinery and bridge systems. They stress the need for EMI protection considerations during design and installation, and provide a comprehensive tutorial discussion of practical approaches.

To illustrate the potential danger of EMI, the authors cite measurements that show that off-on devices like telephone bells, alarm horns and relays often generate the most dangerous transients on common supply lines. Transients of up to 600 - 700 volts are reported to be quite common.

Log #022: A. Hagen and N. Hammer
"Shipboard Noise and Vibration From a Habitability Point of View"
Marine Technology, January 1969

This article discusses problems of noise and vibration on commercial ships, and their effects on shipboard habitability. Human sensitivity levels to noise and vibration are reviewed, and the results of MarAd shipboard noise and vibration surveys are described. Since a large portion of this article focuses on human sensitivity and habitability, it is pertinent to the DOVAP study only in terms of the vibration levels actually measured aboard ships.

Log #023: W.J. D. Jones
"Materials in a Marine Environment"
Journal of the Society of Environmental Engineers
September 1974

This paper discusses the effects of the marine environment on structural and hull materials. Since it primarily deals with materials that are directly exposed to the marine environment, it is not applicable to the DOVAP study.

Log #024: C. Boe and O.J. Tveit
"Reliability Engineering and Safety At Sea"
IEEE Transactions on Reliability
August 1974

This paper surveys the field of reliability as related to marine engineering, and provides a tutorial discussion on how to apply reliability engineering techniques to marine systems. Most of the points made are well known within the discipline of reliability engineering, but possibly not that well known in marine engineering.

Two points noted by the authors that might be of special interest are:

1) Marine equipment often consists of low population items, sometimes made to order. Thus two items of the same design may not be alike. Since there is, therefore,

no "representative" sample in statistical terms, failure data statistics should be used with care; and

2) The constant hazard rate (or failure rate), and therefore, the exponential distribution, is applicable in most cases for marine equipment. Application of a time-dependent failure rate does not justify the extra time and labor it takes to apply it.

DOVAP feels it should be noted that neither of the points would be non-controversially accepted by the reliability engineering community.

Log #025: T.A. Stansell, Jr.
"Achieving Reliability in Automatic Navigation Equipment"
paper presented at 2nd Ship Operation Automation Symposium, Washington, D.C.
August 30 - September 2, 1976

This paper describes the reliability aspects of the Magnavox MX-1102 Satellite Navigator. The evolution of the MX-1102 is discussed, and an overview of the Transit Navigation Satellite is provided.

Since this paper is concerned with navigation equipment, it is applicable to the DOVAP study only in the area of the quality assurance (QA) provisions utilized by the manufacturers. These provisions are in the "better" area between commercial provisions on the "low" side and military QA provisions on the "high" side. For instance, it is reported that the "better" grade of integrated circuits and piece parts are used both to enhance reliability and to reduce production costs through fewer failures at burn-in. Other QA provisions described include environmental testing and test levels.

Two points of possibly special interest to the DOVAP study are:

1) During sea trials, problems with power line transients required additional power supply filtering, and

2) Plastic integrated circuit packaging is most commonly used in commercial applications, but since it does not provide a perfect hermetic seal, it can cause problems in humid environments.

Log #026: William H. Campbell, Jr.
"Single Boiler Reliability Experience on U.S. Flag Ships"
paper presented at 2nd Ship Operation Automation Symposium, Washington, D.C.

August 30 - September 2, 1976

This paper presents a quantitative and qualitative analysis of single boiler ship reliability in the U.S. Flag Fleet.

Apprehension as to the reliability of single boiler vessels and how these vessels may affect the marine environment prompted the study described in this paper. During this study, casualties occurring on the 20 single boiler vessels in the U.S. Flag Fleet and those occurring on a comparable group of multi-boiler vessels were examined. Data were obtained from the Coast Guard commercial vessel casualty files, and from surveys of ship owners/operators.

The results of the data analysis, which are tabulated in the paper, consist of the number of casualties per ship per year for single and multi-boiler vessels, and a summary of the ship owner/operator survey data.

The overall conclusion of the paper is that single boiler vessels are not less reliable than multi-boiler vessels. Other conclusions/observations resulting from the study are that:

1) The "debugging" phase on the single boiler fleet ranged from 1 to 3 years, with 1.75 years being the mean, and

2) There appears to be a direct relationship between the shipyard constructing the vessel and the vessel's casualty rate. The author attributes this relationship to the degree of quality control exercised during manufacture and installation.

Log #027: "Nautical Language About Safety"
Shipcare and Maritime Management
June 1981

This reference is an editorial from the above periodical, and it cites a memorandum just issued by the Nautical Institute (British). DOVAP felt that the existence of this memorandum should certainly be noted, and that it might warrant some kind of follow-up in the future.

A higher percentage of world tonnage (if not ship numbers) was lost in 1979 than in 1950. The purpose of the above noted memorandum is to generate some action toward improving this situation. Among various recommendations, two of potentially special interest are:

1) Better test of marine equipment to improve reliability, and

2) Recognized procedures for reporting into coastal states by vessels suffering breakdowns and equipment malfunctions affecting the vessel's navigation within a hundred miles.

DOVAP feels it should be noted that this second recommendation would involve a reliability data reporting system, as opposed to casualty reporting systems now in existence.

Log #028: "Machinery Vibration Surveys Increasing"
Shipcare and Maritime Management
June 1981

This brief news release type article indicates that business is increasing for a Singapore firm conducting pre-drydock vibration surveys. DOVAP has noted this through its logging system since it might be of interest later in the area of the status of condition monitoring.

Log #029: E. Scott Dillon
"Report on Ship Vibration Symposium '78"
a summary report prepared for the Ship Structure Committee, #SSC-292, October 1978

This document summarizes the key conclusions and recommendations from the 18 papers presented at the 1978 Ship Vibration Symposium. It focuses on "where we are now and where we should be headed." The intent of the summary report is to serve as a key planning document and basic reference for the next 5 to 10 years.

Although the papers summarized deal chiefly with hull and structural vibrations and vibration causes, the document provides considerable background information. It is pointed out that "topics of vibration and noise are not fully mastered," and also that there are "controversy and conflicting views over the subject." Higher powered, complex ships complicate the problem, and a "major long range effort is still required to fully understand the underlying phenomena and provide design tools."

Long lists of complaints from shipowners and maritime labor are reported. These primarily concern recently delivered ships, and include:

-One owner had to relocate or shock mount radars and communications equipment.

-Some navigation equipment was rendered useless at various speeds.

-Factory shock mounts for electronic equipment failed at half normal life expectancy.

-Alarm panels falsely activated.

-Frequent calibrations were required

Log #030: R.J. Bradford and J.W. Dirriwachter
"The San Diego Class Tanker"
paper presented at 2nd Ship Operation Automation Symposium, Washington, D.C.
August 30 - September 2, 1976

This paper describes the San Diego class tanker, with emphasis on control functions and arrangements not formerly seen aboard U.S. Flag vessels. The tanker was designed and built by the National Steel and Shipbuliding Co. of San Diego, CA, for trade between Alaska and other U.S. West coast ports. Complete automatic engine room supervision controls were provided by General Regulator.

Little R&M information is provided in the paper. Some redundant control equipment is provided, particularly for sensor input transmitters which, due to their environment, are cited as being the most likely items to fail.

The applicability of this paper to the DOVAP study lies in the system descriptions and hardware configuration information it contains.

Log #031: Jacques Harbonn
"The 'Terebel' Dynamic Positioning System - Results of Six Years of Field Work and Experiments"
Journal of Petroleum Technology, March 1972

This article describes the dynamic positioning system of the French experimental drilling ship "Terebel." Performance of the system over a period of six years is also discussed.

This article is applicable to the DOVAP study only in that portions of the dynamic positioning system share similarities with marine control systems, in general. The points of interest are as follows:

-The "Terebel" uses a specially built analog computer. This was believed a more dependable approach than use of a digital computer which could be more sensitive to current variations, static, heat, humidity, etc.

-The computer room is not air conditioned.

-No computer or sensor deterioration was ever found.

-Over a period of 8,000 hours of dynamic positioning, only one breakdown occurred -- a failure of a drive shaft universal joint. This performance is attributed to the quality of the material and the preventative maintenance program.

-This program consists of a complete checkup once per year. Efforts include comparing output characteristics of sensor and computer circuits to the original requirements. Also, transmission links are inspected. These experience a lot of wear and tear, and many have to be replaced each year.

Log #032: J.G. McIntire and G.E. Holland
"Design of the AO177 Machinery Plant"
Naval Engineer's Journal, February 1976

This paper describes the machinery plant, with special emphasis on the central control system of the Navy's A0177. This vessel is a 27,000 ton steam powered oiler designed for minimum manning. The ship and its propulsion sub-systems are discussed in detail, and both quantitative and qualitative R&M considerations are covered.

In the area of quantitative R&M, the reliability block diagram of the propulsion system is depicted, and MTBF's and MTTR's for the blocks are provided. This data was derived primarily from the Navy's 3M system. The resulting reliability and availability figures are given.

In the area of qualitative R&M information, a manning study based partially on potential "casualties" is cited. These casualties are actually failure effects (jammed throttle, hot bearing, fuel leak, etc.) and a list of them is provided. Other information cited includes:

-Reed relays have proven unreliable and are not allowed.

-Centralized control is in an air conditioned, enclosed operation station.

-To enhance R&M and the centralized control approach, some thermal efficiency was sacrificed. (For example, high maintenance steam air preheaters were not included with the boilers at a loss of about 1% in boiler efficiency. Also, electric drive pumps were used in lieu of steam for all applications except the two main feed pumps and the main lube oil service pump.)

-Filter capacitors in power mains are not recommended since surges can be higher than their rated voltage.

Log #037: M.A. Prohl et. al.
"The Control of Propulsion Power Aboard Steam Propelled Ships"
Naval Engineer's Journal, October 1977

This paper discusses automated controls for steam propulsion systems, with emphasis on current requirements. Control system dynamics are covered, with particular emphasis on new turbine throttle control and monitoring systems.

Functional descriptions of automated plant subsystems are provided, and a number of reliability-design features are cited. These include:

-Reliable systems cannot be achieved without proper systems management.

-Circuit elements should be segregated to dedicated functions. Time sharing and scanning should be avoided.

-Circuits should connect as directly as possible to their sensors/alarms. This simplifies trouble-shooting and reduces the number of sensitive components.

-Critical and non-critical functions should be separated.

-Continuous on-line data logging printers have a short service life due to continuous duty and a large number of data points.

-It should be assumed that the crew is not going to repair or adjust a complex device, and that trouble-shooting capability is minimal.

-Based on the above point, a system should have a minimum MTBF of 16,000 hours.

Log #038: S.D. Judge and P. Luetjen
"Determination of Shipboard Repair Parts Level"
Naval Engineer's Journal, April 1979

This paper describes a method for evaluating Naval Vessel Coordinated Shipboard Allowance Lists to relate spare parts usage and requirements to reliability. Since the paper is extremely oriented toward Navy policies, it does not generally apply to the DOVAP study. It might be of interest to note, however, that the paper recommends spares provisioning based on a "bad apples" list, that is, a list of the major contributing items to unreliability.

Log #039: M.R. Hauschildt and L.B. Ward
"U.S. Naval Machinery Automation Concepts"
Naval Engineer's Journal, April 1973

This paper outlines machinery plant control practices in the U.S. Navy, and describes some of the more advanced automatic controls. Since it is oriented toward Navy practices, it is not generally applicable to the DOVAP study. It does point out, however, that the reliability of transducers is in need of improvement, and that the ease of replacing them needs attention.

Log #040: U.S. Coast Guard
"Guide for the Automation of Main and Auxiliary Ship's Machinery"
Navigation and Vessel Inspection Circular 1-69
January 8, 1969

The overall purpose of this document is to provide a guide to the marine community in reducing the manning of machinery spaces through automation without compromising the safety of life and property. It is pointed out that the guide is not mandatory but does represent the judgement of the Coast Guard.

A number of general requirements are given, including that R&M be considered and evaluated. Some specific requirements are also stated, including redundant equipment to be provided, parameters to be alarmed, allowed re-start procedures, etc. Also, it is mandatory to obtain Coast Guard approval of plans for automation, and for the operation and maintenance program. Regular tests must be conducted and for approval, a period of proven operation must follow "de-bugging."

Log #041: EDO Corp.
"Selection of Materials for Transducers and Other Structures in Marine Environments"
AD-A043-818 October 1964

This document discusses material problems EDO has had with the transducers they manufacture. Since most of the "transducers" appear to be hydrophones and the like which are submerged in seawater, the document is not applicable to the DOVAP study. It might be interesting to note, however, that EDO reports substantial porosity problems with castings for transducer housings, and especially with stainless steel. They recommend that castings be avoided where other production methods are available.

Log #042: R. Comstock
"Destroyer Engineered Operating Cycle, System Maintenance Analysis, DDG-37 Class Ship's Service Turbine Generator"
AD-A058-521 July 1978

This document presents the results of a review of experience of Navy DDG-37 class ship's service turbine generator. This review is based on an evaluation of historical maintenance experience, and is intended to identify the areas/items requiring attention. This "attention" can consist of overhaul tasks, improved training or on-board maintenance policies, acquisition of more reliable hardware, etc. Quantitative and qualitative data are provided to justify recommendations.

Mostly, the data is not applicable to the DOVAP study because it involves hardware approaches/policies unique to the Navy. The following points, however, may be of interest:

- Each ship's service turbine generator system received an average of 459 maintenance man-hours per ship year.
- Problems with the governor and lube oil/control oil systems dominate. These are primarily due to susceptibility of the oil to contamination. The filtering system is reported to be inadequate.
- The other major problem is improper lubrication of the main lube oil pump bearings (ball).

Log #043: Lewis M. Ewing et. al.
"Reliability Analysis of Vessel Steering System (Dual Electro-Hydraulic Type)"
AD-AO15-821 July 1975

This document reports on a study conducted for the Coast Guard to assess the reliability of a dual-electro-hydraulic steering system for large commercial vessels. Recommendations are given to assist the Coast Guard in design review, vessel inspections, and accident investigations. The study results are discussed in terms of their potential application to the reliability analysis of navigation systems and other maneuvering systems. The reported effort included contacts with Coast Guard inspectors, ABS surveyors, shipyard supervisors, and ship owner-port engineers and chief engineers. A literature search was conducted and documented, as was an evaluation of vessel casualty reports and listings.

The study reported in this document is similar in many respects to the DOVAP study. The tasks are similar, data source considerations are somewhat similar, and the analytical approaches utilized are essentially the same. The major difference, of course, is the hardware involved. Thus, overall, many of the findings of the reported study are pertinent to the DOVAP study. The salient ones are summarized below in the detail required.

- -Available field failure data was very sparse.

- -Some failure data was obtained from the Navy's 3M system for large (type LKA) vessels. This type of vessel is reported to be similar to large commercial vessels. The data obtained consisted of Mean Time Between Repair Actions, and through various adjusting procedures, these were converted to failure rates.

- -The report points out that MTBF's cannot be obtained from such maritime data bases as Coast Guard casualty data, ABS data, etc. because total operating time is not available.

- -Electronic part failure rates were obtained from standard compilations. "K" factors to account for the specific environment were obtained by assumptions such as the existence of some type of reliability program and low stress levels.

- -Failure rates are listed in an appendix. They are broken down by the type of reliability program, stress levels, etc.

- -The reported effort included modelling, Failure Modes and Effects Analyses (FMEA), single point failure analyses, fault trees, and reliability predictions.

- -No stress analyses or availability or maintenance analyses were conducted.

- -The FMEA approach is described. Structural failures were not considered.

- -Due to time constraints, and because design data was proprietary, the level of detail considered for most components was limited to that contained in diagrams and texts of operations and maintenance manuals. The report states that this is believed to be sufficient for identification of critical features.

-A more detailed design review approach is recommended.

Log #014: "Steam Propulsion Control System Study: Phase I; Throttle Control System Reliability Improvements" prepared for MarAd by American President Lines, PB-292-150, December 1976

This document examines electro-hydraulic and electro-pneumatic throttle control systems with the objective of recommending reliability improvements. It is primarily concerned with the throttle control system. The primary data source was a survey of shipowners regarding failure modes that had occurred. The complete results of this survey are not provided. Rather, several case histories reported to be typical are described. The history of automated propulsion systems is covered in considerable detail, and hardware details/implementation are thoroughly described. No quantitative reliability data is provided. The report's conclusions, recommendations, and observations that appear significant are summarized as follows:

1) Due to costs and the difficulties in identifying all possible failure modes, it is not practical to provide the means for safe operation under single failure conditions for all possible failure modes.

2) Training is needed to prevent operator error since present control systems do not accommodate all situations where the operator can err.

3) For new construction, a reliability program including failure modes and effect analyses, quality control standards, systematic training, and a failure reporting system is recommended.

4) Component failures (e.g., amplifiers, limit switches, motors, etc) are probably the largest cause of throttle control system failures.

5) The reliability improvements recommended mainly involve redundancy or back-up provisions.

6) Various degrees of failure detection capability are recommended, as are failure communications provisions (e.g., to the bridge).

Log #045: C.P. Beyers
"Destroyer Engineered Operating Cycle; System Maintenance Analysis, FF-1052 Class Combustion Air System"
AD-A063-913, December 1976

The intent and approach of this system maintenance analysis is the same as that described for Log #042. This system maintenance analysis is for the combustion air system on the Navy's FF-1052 class vessel. Coverage is of 96 ships over a five year period.

The combustion air system evaluated consists of steam turbine-driven forced air blowers, motor-driven lighting-off blowers, and various ducts, valves, etc. No automation is provided.

Points that may be of interest to the DOVAP study are as follows:

1) About 25 maintenance man-hours per blower per ship is required.

2) Contaminated lube oil was a major problem. This was due to clogged filters causing the relief by-pass valve to open so that unfiltered oil flowed into the lubrication system.

3) Numerous types of leaks caused the steam admission valve to be a high problem area.

Log #046: R.S. Coffey et. al.
"Development of Accident Trees and Evaluation of Safety System Failure Modes for the Nuclear ULCC"
PB-272-711, February 1977

The purpose of the effort reported in this document was to identify and develop an event tree for each ship accident with the potential for damaging the nuclear power system of the nuclear powered ULCC then under development by MarAd.

This document is not applicable to the DOVAP study except, perhaps, to note that it exists and describes a developed methodology. The methodology is quite similar to that for land-based nuclear power system safety studies, such as that applied to Environmental Impact Studies or the Reactor Safety Study ("Rasmussen Report," Wash-1400). The document presents no probabilities for the various events/states.

Log #047: "Program Management Plan: Reliability and Maintainability Improvement Program for the U.S. Merchant Fleet"
ARINC Research Corp., Santa Ana, California PB-268-565

May 1977

In April, 1976, MarAd initiated a 4-phase program for R&M improvement in the U.S. Merchant Fleet. This report marks the conclusion of the first phase, and the program it describes are for the remaining 3 phases. The overall objective of the program was to assist the maritime industry in establishing certification requirements and equipment acquisition procedures that would result in improved R&M.

This report discusses the need for an R&M improvement program, and provides an overview of the entire program. The management and technical approaches to be utilized are described. Each phase of the program and the expected benefits are also described.

The report points out that for success, the program must be a joint effort between MarAd and the U.S. shipping industry. A steering committee would be under the auspices of the ABS; MarAd would provide technical consulting services. The program phases (beyond Phase I) are as follows:

Phase II - Prepare pilot program plan (1 year)
Phase III - Conduct pilot program (1 year)
Phase IV - Implement continuing program

Some of the specific tasks to be conducted are as follows:

1) Review existing data bases for possible inclusion into and R&M data base. Candidate data bases include GIDEP, the MarAd M&R data base system, and the U.K. Systems Reliability Service data base for the Atomic Energy Authority.

2) MarAd would develop a model to relate system availability to voyage cost over a selected route.

3) Survey R&M practices of selected European certification societies (e.g., Germanischer Lloyd, Det Norske Veritas, Registro Italiano Navale, etc.).

Shipboard electronic equipment has been defined as an area of immediate concern by the merchant shipping community, according to the report. Therefore, electronic navigation and engine room control equipment should receive initial attention in the program. During the Phase III pilot program, shipping companies would collect R&M data on electronic equipment to initiate this effort.

The report recommends a flexible survey approach such as the one under investigation by DetNorske Veritas. This approach consists of basing surveys on the number of failures rather than on a rigid time schedule. It is believed that this would encourage participation in R&M efforts as well as reducing survey frequencies in many instances.

Log #048: "Reliability Improvements for Vessel Steering Systems; Final Report"
J.J. Henry Co., Inc., New York, NY; PB-293-066
December 1978

This document summarizes a study for MarAd to develop and evaluate improvements to the design, specifications, installation and operation of vessel steering systems. The overall objective of the study was to enhance reliability, safety, performance and integrity.

The study analyzed steering system failure data, and quantitatively assessed the relationship between hydraulic system design pressure and system reliability.

MTBF's for steering system components were developed from the MarAd M&R data base and ABS data. This was accomplished by assuming operating times, and the report states that the resulting MTBF's are optimistic. These MTBF's cover electrical and hydraulic components and are provided in the report.

The report states that the study found that hydraulic system reliability exhibits a steep decline over the first 3 or 4 years of service. Also, the study found that hydraulic system reliability decreases as hydraulic pressure increases. This is not due to the pressure increase, per se, but rather to closer tolerance moving parts, and more opportunity for contamination. The report stresses the need for system cleanliness.

Log #049: "Shipboard Maintenance and Repair System"
Pacific Gulf Marine, Inc., New Orleans, LA
PB-285-543, September 1978

This document reports on a maintenance and repair system put into operation on the M.V. Sugar Islander. The system is actually a maintenance management system and is entirely "software" (e.g., system documentation, checklists, etc.). Considerable attention to preventative maintenance is given in the system's approach.

This document covers the period subsequent to that reported on in Log #056. Overall, a high degree of success is claimed for the system through such factors as reduced costs, better spares inventory control, discovery of impending failure during PM activities, etc. Due to various problems not involving the maintenance system, however, it was not exercised extensively during the period covered.

Log #050: "Shipboard Systems Operations and Logistics Support Program. Final Report, Phase 1A, Requirements Assessment"
Mystech Associates, Inc., Mystic, Conn.
PB-271-961 June 1977

This document presents the results of a study to identify the major concerns of the U.S. maritime industry in the areas of shipboard maintenance, repair, and logistics support. Through analysis of these concerns, requirements were formulated to provide the basis for further efforts. A number of shipowners, operators, repair facilities and seafarer's unions were interviewed.

The study identified 39 problem areas related to M&R and logistics. The recommendations generally parallel the problems in that possible solutions are recommended. The report points out that few of the problem solutions would require new or unavailable technology. The report also points out that rising M&R costs, which was widely cited as a problem, are in reality the result of many other problems.

Some of the problems/findings of special interest to the DOVAP study are summarized below:

1) Spare parts provisioning policies are extremely ineffective and haphazard.

2) The true status of shipboard spare parts inventories is generally unknown.

3) Very little R&M trend analysis is performed.

4) More emphasis is needed on formalized shipboard maintenance programs.

5) There is a definite need for computerized M&R support functions.

6) The status of PM is not being fully exploited in the merchant fleet.

7) Unions are concerned about excessive reliance on crew overtime to accomplish maintenance. They favor "riding crews" assigned to ships on a fluctuating basis to perform underway maintenance.

8) There are concerns over the problem of declining crew maintenance capabilities, and also lack of new maintenance capabilities for electronic and automated systems.

9) Crew training solutions offered include union schools, on-board cassettes, video tapes, etc.

10) Lack of adequate M&R history hinders repair facilities' trouble shooting efforts.

11) Problems with equipment occur due to moisture during lay-up. Heat lamps to prevent moisture are normally used, but they are not usually well placed.

Log #051: Ronald "J" Booth
"How to Make the 3M System Work For You"
Naval Engineer's Journal, April 1980

This paper provides a little background information into the Navy's 3M system, but it is completely slanted to Navy personnel and therefore, not applicable to the DOVAP study.

Log #052: W.B. Stocking
"Ship Maintenance Planning System"
Paper presented at 7th Offshore Technology Conference Houston, Texas, May 1975

This paper describes a maintenance management system for ocean drillships. The system is quite similar to military maintainability approaches. It consists of 5 "Modules," 1) Condition Baseline Survey, 2) Corrective Maintenance Requirements, 3) Preventative Maintenance Plan, 4) Overhaul Planning, and 5) Maintenance Data Collection and Analysis. One of the overall objectives of the system was to avoid over-sophistication, which would introduce too much paper work and therefore induce a negative response from the system users.

The paper reports that it usually takes 3 to 5 days to familiarize the crew with the preventative maintenance plan and its use.

Log #053: D. Gray
"Safety at Sea; Automation and Ship Safety"
paper presented at 2nd West European Conference on Marine Technology, London, May 23-27, 1977

This paper presents a subjective discussion of shipboard automation from the standpoint of safety. The author touches on a number of points concerning various types of automation (bridge, engine room, electric supply, etc.) and offers practical suggestions and observations related to safety. Some of these include:

1) There are generally more alarms by day than by night. This is attributed to machinery being driven into the alarm state by crew activities during the day.

2) There are indications that machinery faults prevent unattended operation more often than control and instrumentation faults.

3) There are opinions that, in some cases, system design has become over complicated, and that reliability would be improved if system complexity was reduced.

4) In ships built in recent years, EMI can be a problem. This could be aggravated by the current aft-end construction of modern ships.

5) Little work has been done in the area of EMI. The author feels interface conditions need to be better defined.

Log #054: Gerald F. Rester
"Application of Ferrographic Lube Oil Analysis to U.S.N. Ship Systems"
paper presented at the 26th Meeting of the NBS Mechanical Failure Prevention Group,
Chicago, Illinois, May 17-19, 1977

This paper describes a Navy program of ferrographic lube oil analysis that is reported to be effective in predicting mechanical failure. The oil sampling and analysis procedures are described, as are the training and skills requirements for the Ferrogram analyst.

Log #055: John W. Griswold
"PHM/Jetfoil Reliability and Service Experience"
Hovering Craft and Hydrofoil, October 1977

This paper describes 2 hydrofoil vessels, one military and one commercial, built by Boeing in the same time frame. Similarities and differences are reviewed from an R&M standpoint.

The paper is not applicable to the DOVAP study except to note that one of its conclusions is that it is false economy to reduce screening and quality control.

Log #056: T. Higashi, et. al.
"Digital Electrohydraulic Governor for Steam Turbine"

Hitachi Review, December 1978

This paper describes a microprocessor-based steam turbine governor. Reliability was a design consideration, and the paper discusses how it was implemented. This includes:

> 1) A 2 out of 3 redundancy was applied for analog circuits, dual redundancy for the CPU and I/O unit, and a back-up power supply was provided.
>
> 2) The hydraulic oil is a separate system from the lube oil.
>
> 3) A simulator is provided for testing.
>
> 4) Provisions are implemented for "bumpless" switching between redundant units.

Log #057: "Ancillary Equipment Integrates Main Propulsion Engines with Vessel"
Marine Engineering/Log, October 1977

This article describes some new developments in engine monitoring and automation equipment. These include shaft horsepower meters that electronically control RPM and torque, a microprocessor controlled fuel management system, an exhaust gas temperature monitoring system for engine "health" monitoring, and a centrifugal oil purifying system. The article is applicable to the DOVAP study in the area of the state-of-the-art of sensors.

Log #058: W.L. McCarthy and R.P. Wallace
"VIDEC After One Year - Installation and Operation"
Marine Technology, October 1975

This paper describes the VIDEC (Vibration Analysis and Deviation Concept) system from concept development through the first year of operation. VIDEC is a condition monitoring system that was under evaluation aboard the S.S. President Johnson. Design and installation details are described, and some findings are discussed, although overall system performance analysis was not reported because the authors felt that would be premature. (Log #112 is an earlier paper on VIDEC.)

Among the design details discussed, the EMI protection features are described. This includes the use of integral signal conditioners on each sensor to the extent possible, and use of local acquisition stations to minimize cable length. Extensive grounding and shielding were employed, and special software-controlled treatment of sampled data was used to eliminate noise transients.

Use of commercial, off-the-shelf hardware for VIDEC was a major goal. The authors report that this presented no significant problems.

The reliability of the VIDEC equipment is discussed both quantitatively and qualitatively. In the quantitative area, the numbers of failures for various components is given. In the qualitative area, the authors point out that the most sophisticated components -- computer disk, digital processing and display equipment -- were also the more reliable. The most severe conditions encountered by the VIDEC system are reported to have occurred during handling in the shipyard installation phase. Twenty percent of all failures are reported to have been caused during shipyard installation.

Among the findings of the operational period, the authors report that operation and maintenance of the system is not beyond the capability of responsible, operating marine engineers. They also report that vibration appears closely related to draft, displacement, sea state and wind as well as shaft horsepower. Squat also appears to have an influence on vibration levels.

Log #059: "State-of-the-Art for Propulsion Monitoring"
Diesel and Gas Turbine Progress
May 1980

This article describes a few features of Megasystems, Inc. "Seamatic II" monitoring and control system for diesel engines, and lists some of the vessels using the equipment. Since this is a fairly new system, its applicability to the DOVAP study lies in the area of state-of-the-art.

Log #060: S. Anderson
"Initial Wear of Gears"
Tribology International, August 1977

This article describes running-in experiments to determine the initial wear of gears. The experiments are reported to show that the running-in period is less that about 0.3×10^6 revolutions, and that initial wear is rather small but increases with running speed and applied loads. This paper is applicable to the DOVAP study only if failure prognosis becomes a consideration.

Log #061: American Bureau of Shipping
"Rules for Building and Classing Steel Vessels"
1981 Edition

This document contains the rules for constructing steel vessels in compliance with the American Bureau of Shipping (ABS) requirements. Section 41 covers "Shipboard Automatic and Remote Control Systems"; Appendix D contains the "Guide for Automatic and Remote Control Systems for Integrated Propulsion Installations"; Appendix E contains the "Guide for Spare Parts." Other sections and appendices provide comprehensive coverage of all aspects of ship design and construction.

No quantitative reliability and maintainability requirements are given, although "qualitative" requirements to enhance reliability and maintainability are in evidence throughout. These include the environmental parameters that equipment must be capable of withstanding.

Log #062: "IEEE Recommended Practice for Electric Installations on Shipboard"
IEEE Standard #45-1977, June 30, 1977

This document contains practices recommended by the IEEE for shipboard electrical installations. The equipment ranges from cabling to switchboards and generators, and a section is devoted to automatic control systems. No quantitative R&M requirements are stated, but a number of features to enhance R&M are specified throughout. Environmental requirements are also specified.

Log #063: "Destroyer Engineered Operating Cycle (DDEOC) System Maintenance Analysis, Class CG-16 and CG-26, Navy Tactical Data Systems, Review of Experience"
ARINC Research Corp., AD-A074-227, August 1979

Log #064: "Destroyer Engineered Operating Cycle (DDEOC), System Maintenance Analysis, Class FF-1052, Interior Communications System, Review of Experience"
ARINC Research Corp., AD-A050-431, September 1977

The intent and approach of these two system maintenance analyses is the same as that described for Log #042.

The system maintenance analysis reported in Log #063 covers Navy Tactical Data Systems, and is of possible applicability to the DOVAP study because it reports maintenance rates and failure modes for a cathode ray tube type displays.

The system maintenance analysis reported in Log #064 covers ship interior communications, and is of possible applicability to the DOVAP study because it reports some maintenance rate and failure mode data.

Log #065: R.L. Harrington, et. al.
"Reliability and Maintainability Analysis of Shipboard Systems"
Marine Technology, January 1970

This paper discusses R&M analyses from a tutorial standpoint. It is directed to Navy projects, and the analyses cited (FMEA's, Maintainability Analyses, etc.) are primarily those either required or described (or both) through Military Specifications.

Log #066: Vincent W. Ridley
"Designing Reliability into Marine Steam Power Plants"
SNAME Annual Meeting, New York, NY
November 12-13, 1970

This paper identifies steam power plant areas which are least reliable, and provides data from the analyses from which these identifications were made. The steam cycle is discussed in terms of how reliability can be improved, and some impacts of operating environmental factors on reliability are considered. The paper covers some quantitative data, and to a larger extent, qualitative data.

In the area of quantitative data, histograms and "pie charts" are provided that cover stops at sea, delays in port, and shutdowns at sea. For each of these situations, the number of occurrences, the length of time, and the equipment causing the situation is given. This data was reported to have been obtained from operational log data, repair summaries and the like. The analysis indicates that boilers and accessories, taken together are the least operationally reliable major units in the propulsion system. The paper further reports that boilers cause the majority of steam ships stopping at sea, and are the most common cause of the propulsion system operating in a degraded mode. Major areas of concern, in addition to boilers, are reported to be main feed pumps, main condensers, and main turbines.

In the area of qualitative reliability, a number of points are cited. The more salient ones are summarized below:

1) Because of the increase in power levels, steam conditions, and the number of manufacturers entering the marine field, the "mature design" is rarely encountered.

2) The increasing emphasis on the formal study of marine steam plant reliability has resulted in new types of contract clauses requiring component manufacturers to state, and some cases guarantee, the reliability of their equipment.

3) Most reliability studies encounter the unfortunate

fact that there is not sufficient data.

4) Failure in a marine power plant is often because operating conditions are different from equipment design parameters.

5) "Only in a few cases does chasing BTU's in itself make a ship less reliable. Certain complexities of a cycle control, which are more associated with crew reduction than steam conditions, have made certain failures more evident, and the blame for these should not be attributed to the desire for cycle efficiency (i.e., flame failures devices)." (sic)

6) Burning with low excess air improves the boiler operating environment.

7) Single boiler ships have an advantage in that the boiler is essentially used continually. Securing, cold storage and lighting off of boilers not continuously used have resulted in boiler mistreatment and failures during these operations.

Log #067: F.R. Hill
"A Method for Determining Maintenance Requirements for Electronic Equipment"
Coast Guard Engineer's Digest
July/August/September 1976

This article describes the methodology for statistically computing maintenance requirements (i.e., maintenance man-hours and costs) for a given equipment. The methodology utilized data from the EICAM (Electronic Installation Change and Maintenance) data base.

Log #068: Maritime Transportation Research Board
"Critical Issues in Maritime Transportation"
National Academy Press, Washington, D.C.
June 1981

This document identifies and describes the critical issues which the Maritime Transportation Research Board regards as in need of examination. Each issue is considered urgent, thus no priority ranking is applicable. The issues are as follows:

- Cargo for U.S. Flag Vessels
- Federal Aid
- National Security
- Federal Regulation
- Shipping Industry Practices

-Shipbuilding and Repair
-Maritime Safety
-Harbor Improvements
-Energy Transport on Inland Waterways

The issue which most closely relates to aspects of the DOVAP study is Maritime Safety. This was designated as an "issue" because vessel accidents of all types are increasing. The document states that extensive efforts have been undertaken to alleviate the problem. Their emphasis has been on physical solutions (design, contruction, redundancy, etc.). It is pointed out that the most serious aspect of the safety problem involves people. The nebulous nature of the problems to be solved are also pointed out, and a real need for research on personnel is cited.

Log #069: T. Heimly and A. Ostensen
"Electromagnetic Interference in Ship Installations Determined by Measurements"
paper presented at 1st Symposium and Technical Exhibition on Electromagnetic Compatibility, Montreux, Switzerland, May 20-22, 1975

This paper describes measurements of EMI made by Det Norske Veritas on-board a highly automated, 162,000 DWT tanker. Signal leads as well as power cables were subjected to measurements.

On one power line, a transient of about 500 volts was measured when a fan on the same line was switched off. Also, signal leads which should have read DC-voltages had AC components with frequencies in the 120 Hz to 10 MHz range.

The authors report that stationary EMI levels were lower than expected beforehand. This particular vessel had an EMI program that was developed early in the construction phase. This was a "rule of thumb" program utilizing some very basic and well-known EMI protection techniques. The authors conclude that if such well-known techniques were applied, many of today's EMI problems in ship systems would disappear.

Log #070: S. Shields, et. al.
"Ship Maintenance: A Quantitative Approach"
published for the Institute of Marine Engineers by Marine Media Management Ltd., 76 Mark Lane, London EC3R 7JN, copyright 1975 (Order from International Scholary Book Services, Inc., Dept. EN 2130 Pacific Ave., Forest Grove, Oregon 97116)

This small book describes methodologies for ship maintenance planning and programs based on quantitative analyses. Maintenance costs are discussed, and their reduction constitutes the basic criteria for the maintenance planning. The use of operations research techniques for maintenance studies is discussed, as is computerization and data collection. Maintenance strategies are considered, and the means for optimizing them is described.

Log #071: Alan L. Rowen
"Marine Diesel Application Impediments; An Assessment of Shipowner Opinions"
Webb Institute of Naval Architecture
PB-81-155038, April 1980

This report documents the results of a survey of U.S. Shipowners to identify problem areas in the wider application of Diesel propulsion. Twenty ship owner representatives were interviewed, and their opinions assessed. Reliability, maintainability and spare parts availability were among the interview topics. In these areas, the document reports:

1) Diesel ship operators usually identified the job of pulling and replacing a piston as the major routine maintenance task. In their experiences, this requires 5 to 16 hours, depending on the number of men involved (from 2 to 4), skills, difficulties involved, etc.

2) As a rough estimate, one ship in 10 or 20, regardless of type of propulsion, suffers a major failure (gear breakage, crankshaft fracture, etc.) over a 20-year lifetime.

Log #100: Jay Dor and Joseph Lidiak
"New Ship Automation"
Naval Engineer's Journal, August 1974

This paper describes a baseline system for Navy ship automation. This, in essence, constitutes a conceptual system, and its objectives are flexibility and "universality" (i.e., directly usable on different types of Navy ships). A functional description of the conceptual system is provided, as is a brief history of the automation of Navy ships.

The primary need for the "universality" of the automation is so that crews transferring from one type ship to another do not need additional training. Although the Navy (at that time, at least) did not use its AN/UYK-20 processor in control systems, it is proposed as part of the conceptual system to contribute to universality. The processor's failure rate and repair times are given.

Some qualitative reliability criteria for the conceptual system are given. This includes the use of multiplexed signals to avoid the need for multi-cabling. Also, independent power sources for redundant equipment would be required, as would "fail gracefully" system architecture.

Log #102: J.A. Barker
"A Contractor's Approach to the Navy's Requirements for Reliability and Maintainability in Shipbuilding
Naval Engineer's Journal, June 1967

This paper describes a management approach for meeting the Navy's R&M requirements in shipbuilding. It emphasizes the correct interpretation of military specifications. It also emphasizes that where quantitative evaluations are not possible, subjective analyses should be thorough and systematic.

Log #104: M.W. Walczak, et. al.
"Translating MTBF's into Dollars - A User's Prospective"
Naval Engineer's Journal, February 1975

This paper describes a methodology for conducting reliability trade-off studies to optimize life cycle costs. A conceptual airborne radar system is assessed to demonstrate the application of the methodology.

Log #106: Pierre Tullier
"Determining Reliability and Degradation of Shipboard Machinery"
paper presented at 1976 Annual Reliability and Maintainability Symposium

This paper is based on an investigation of the Navy's Maintenance Data Collection System (MDCS) to determine its utility in evaluating alternate maintenance policies. Data on shipboard machinery were analyzed, and the results are discussed.

Considerable discussion is provided on the data obtained, how it was manipulated, and the assumptions required. The reliability measure developed was the distribution of times between failures (e.g., between the first failure and the second failure). This was used instead of MTBF because MTBF implies that the equipment is renewed following each failure.

The resulting data is presented for several types of mechanical equipment (e.g., motors, pumps, compressors, etc.). For each equipment, the mean operating time to first failure and to second failure after overhaul is given. The average corrective maintenance actions per equipment per quarter after overhaul is also given. The author advises care in the application of these reliability figures. He stresses that they are optimistic, and that the manner in which they were derived should be considered before applying them.

It is also pointed out that for the mechanical components analyzed, a decline in reliability over time is suggested by the fact that, on average, the second failure occurs more quickly than the first.

Log #108: George E. Fouch
"R and M Part 4 - Military: The Logistics Challenge"
Mechanical Engineering, May 1966

This article describes the Department of Defense's view of R and M as a factor in logistics costs. It is rather out of date at this time, but does provide tutorial coverage of some R&M philosophies advanced by DOD.

Log #110: Daniel H. Conway
"The Marine Gas Turbine Reliability Data Program"
Naval Engineer's Journal, April 1976

This paper describes a program to obtain R&M data on the General Electric LM2500 gas turbine engine. It is reported that over 50,000 hours of operational data were obtained from operation of the engine on the G.T.S. Adm. Wm. Callaghan, and from various tests conducted by the Navy.

The R&M data program included failure analysis, engineering investigations and statistical analyses. The approach to the statistical analysis is described in considerable detail. MTBF, MTBR (Mean Time Between Removal) and availability data are given.

Log #112: Charles B. Dickenson
"A Method of Propulsion Plan Performance Evaluation for Marine Applications"
IEEE Transactions on Industry Applications, Vol. IA-10 No. 2
March/April 1974

This paper describes the VIDEC (Vibration Analysis and Deviation Concept) system that was installed aboard the "President Johnson" for evaluation. The background of VIDEC is discussed, and system hardware is described.

VIDEC was an outgrowth of the "deviation concept," conceived by

J.K. Salesbury in 1961, for heat cycle analysis. VIDEC was the first application of the technique to shipboard steam cycles, and was tailored to suit shipboard conditions. VIDEC is composed of two techniques -- vibration analysis of rotating machinery and thermal analysis of the heat cycle. The basic approach is to collect data during the maiden voyage of the vessel, then utilize this as a baseline to identify rapid or excessive parameter deviations. Changes in vibratory characteristics are indicators of incipient failures. Deviations in thermal data indicate deteriorations in machinery performance.

The VIDEC system utilizes 104 vibration sensors and 124 channels of thermal data. The associated signals feed into 12 signal conditioning stations which, in turn, interface with the computer center. A special VIDEC console is utilized. The computer center is located in an environmentally controlled space above the engine room. The remainder of the system, including the console, are located in the engine room.

(Note: Document #058 also discusses the VIDEC system.)

Log #114: Gary L. Steckman
"An Automated Ship Maintenance System"
Naval Engineer's Journal
April 1973

This paper discusses the maintenance of shipboard computer systems from the standpoint of the software needed for monitoring and diagnosis. The author emphasizes that this software should be defined and developed concurrently with the hardware system, not "after the fact." The subject software would constitute the "components" of an automated maintenance system, and objectives and design philosophy are discussed for the various software packages that would constitute the system.

Log #116: Thomas McCarthy, et. al.
"Status of Reliability and Maintainability Technology in the U.S. Merchant Marine"
ARINC Research Corp., Annapolis, MD, PB-167-446
September 1976

This document reports on the status of R&M technology in the U.S. Maritime community, in general, and as applied to shipboard electronic equipment in particular. The study on which this document was based was conducted for MarAd as part of its R&M Improvement Program.

One overall finding of the study is reported as follows:

> in this report, it became evident that reliability of shipboard equipment was determined on the basis of a general opinion about a particular class of equipment rather than from accurate data on equipment failure history. However, it was noted that knowledgeable individuals within the industry considered electronic equipment failure more prevalent than it 'should be'."

A second overall finding is reported as follows:

> "...during the process of ship design, little if any formal reliability engineering was applied. During the ship construction process, however, the shipbuilder does attempt to introduce reliability considerations into the specifications for shipboard equipment. The specifications used by the shipbuilder in acquiring shipboard electronic equipment are often written by the electronic equipment vendors themselves, in contrast to the procedure followed for ship machinery. The shipbuilder finds himself constrained to a small number of vendors when he is required by contract to purchase U.S. made equipment."

One more overall finding is reported as follows:

> "During the construction process, the shipbuilder will adhere to the construction rules of the American Bureau of Shipping (ABS) in order to receive the ABS certification for the vessel. However, our research indicated that these rules are directed primarily to the structural integrity of the vessel rather than to shipboard electronic systems -- although the ABS <u>Guide for Centralized Control and Automation</u> does address electronic equipment aboard ship when such equipment is used to control the ship's engine room."

The above 3 overall findings provide an overview of the status of R&M technology in the U.S. Maritime industry. A number of more specific findings are reported. They deal with various aspects of the acquisition process for electronic equipment, the R&M efforts expended (or not expended) by designer, builder and vendor, the role of governmental/classification organizations, and prior work related to R&M in the Maritime industry. The more pertinent of these specific findings are summarized as follows:

1) Data on electronic equipment failures are closely held and treated in a quasi-proprietary manner.

2) Some of the more salient prior work includes an R&M program formulated for the U.S. Merchant fleet by Dunlap and Associates in 1965, and the establishment of baseline environmental specifications by Raytheon in 1974.

3) The marine market is too small for electronic equipment manufacturers to put much effort into R&M.

4) Data bases maintained by the U.S.C.G. are not adequate for R&M engineering purposes.

5) Prior research found to be applicable was conducted from 1971 to 1975, and was sponsored by MarAd, the U.S. Navy, and SNAME.

The conclusions of this report concur with those of the applicable, prior research. Namely,

> "...a comprehensive program is needed within the U.S. Merchant Shipping Industry to improve the reliability of U.S. ships and equipment, that a data base on equipment R&M should be established, that the environmental requirements for shipboard equipment operation must be more precisely defined, and that standard industry specifications for electronic equipment should be developed."

The report further concludes that:

> "An essential element of the R&M program should be the operation, on an industry-wide basis, of an information system related to marine equipment failure."

Log #118: J.D. Vitkauskas and J.R. Peters
"Testing of Automated Systems from the Safety Point of View"
Marine Technology, July 1981

This article provides insights into the testing of the vital safety systems of automated systems as specified in the Coast Guard NVIC 1-69. The authors point out that the test procedure guidelines provided in NVIC 1-69 are general, and the intent of the paper is to deal more specifically with what needs to be tested, why the testing is required, and what techniques are acceptable.

A safety testing decision logic tree is depicted which indictes the factors to be considered in determining whether, and what, to test. Information is given on the safety testing usually required for Diesel installations, and the authors note that NVIC 1-69 for the most part does not specify Diesel system test requirements.

Features often overlooked in the initial development of test procedures are listed. Also, two examples of partial test procedures are provided in the appendices.

Log #500: Improvement in Non-Reheat Steam Propulsion-
Retrofit and New Construction"
DeLaval Turbine, Inc. PB-273-052
September 1977

This document investigates boiler design/system improvements from the standpoint of economic advantages and disadvantages. The basis for the economic considerations is capital cost and fuel consumption.

Since this document is oriented towards economics, much of it is not applicable to the DOVAP study. Some state-of-the-art and hardware configuration information, however, is provided. Also, the document recommends that new boilers operate at low (5%) excess air, which can be controlled with automatic combustion control equipment utilizing an oxygen sensor to trim airflow.

Log #502: A Practical Operating Guide for Tuning Steam Turbine
Propulsion Systems"
Seaworthy Engine Systems, Inc., Essex, Conn.
PB-284-590, July 31, 1978

This document provides procedures, guidelines, and recommendations for tuning steam propulsion systems and related auxiliaries. It is intended for the shipboard operating engineer, and was developed around Freedom and Leader Class vessels, but is reported to be generally applicable to other steam turbine systems.

This document is applicable to the DOVAP study in two areas. First, instrumentation components are described in some depth. Second, detailed preventative maintenance procedures are given for instrumentation and control system components.

Log #504: N.J. Scarlett
"Catalog of Techniques Supporting Ship Maintenance Management"
ARINC Research Corp., Annapolis, MD, AD-A051-704
June 1976

As indicated by the title, this document is indeed a catalog. It lists various R&M techniques (e.g., FMEA, modelling, etc.), and provides a brief description of the technique. References are given to enable the acquisition of documents describing the techniques in more detail.

Log #506: Shipboard Maintenance and Repair System. Basic System Design and Diesel Plant Prototype"
Pacific Gulf Marine, Inc., New Orleans, LA
PB-275-409, August 1977

This document reports on the maintenance and repair management system aboard the M.V. Sugar Islander. It is an earlier document on this system than the one covered in Log #049.

During the period covered by this document -- the first year of the system's operation/evaluation period -- the ship suffered a number of casualties so that only limited system data was collected.

(NOTE: See Log #049 for a summary description of the system.)

Log #508: "Final Report; Establishment of Reliability and Maintainability Data Bank for Shipboard Machinery"
ARINC Research Corp.
March 1973

Log #508A: Volume I, #AD-A054-499

Log #508B: Volume II, #AD-A054-500

This report is a summary of corrective maintenance data for shipboard machinery. Reliability and maintainability indices derived from 3M data are given for Navy equipment. This includes pumps, boilers, turbines, compressors, distilling plants, generators, motors, motor/generators, air conditioning plants, capstans, and diesel engines. Many of the components, and their related R&M indices, are listed by manufacturer. Also, use factors are given to cover steaming (cruise), in-port steaming, and cold iron.

Volume I describes the techniques used to obtain the indices. Volume II presents the indices in tabular form.

The report is highly applicable to the DOVAP study. The indices it provides (MTBF's, repair times, etc.) were derived from shipboard data, and thus reflect the shipboard environment. However, since Navy equipment, and its associated MIL-SPEC quality requirements, are involved, "K" factors need to be applied to adjust the data to reflect commercial quality levels.

Log #510: J. Reines and J.P. McCormick
"The Use of Maintenance Data to Improve Fleet Maintenance Practices"
Naval Engineer's Journal
December 1978

This paper discusses the use of historical Navy maintenance data, and the value thereof, for developing improved Fleet maintenance practices. Specific data, and its sources, that have proved useful are identified. A general analysis approach is described, and six case studies are given to illustrate the approach and the data capabilities.

The four most commonly used Navy data sources are 1) the Maintenance Data System (MDS), 2) the Casualty Reporting System (CASREP), 3) the Ship Alteration and Repair Package (SARP) and departure report, and 4) the Coordinated Shipboard Allowance List (COSAL). A number of other sources of Navy data are also cited. The authors point out that:

> "In most cases, these sources have been designed and implemented for purposes other than analysis and evaluation of equipment history and maintenance. Thus, when used singly, they often provide an incomplete or erroneous picture. We have found, however, that when considered in combination or collectively, they provide the required history and insights into problems to support the study process."

The six case studies, in each of which an analysis is conducted and data sources are described, involve: 1) Firepumps and motors, 2) Automatic boiler and main feed pump controls, 3) Distilling plant water meter, 4) Line shaft bearing, 5) Distilling plant sea water heater drain pump, and 6) 400 Hz motor generator sets.

This paper would be applicable to the DOVAP study in the event that Navy data of the types described were utilized. Also, the case study involving the automatic boiler and main feed pump controls is somewhat applicable. This analysis indicated that 25% of the CASREP's concerned problems were associated with system calibration. MDS narratives substantiated this. Further investigation revealed that on-board technicians did not have adequate training and operational experience to "fine tune" the system.

Log #512: Donald Stogoski
"Elimination of Main Steam Boiler Tube Failures Caused by Excessive Vibration on AFS-1 Class Surface Ships"
Naval Engineer's Journal
December 1975

This paper describes corrective actions taken to eliminate boiler tube fatigue failures caused by resonant vibration conditions. The failures resulted from violent, "harp-string-like" bending vibration induced by propeller blade rate hull vibration. The corrective actions involved retrofit of stiffening bars.

This paper is applicable to the DOVAP study in that it discusses the fundamental causes of ship vibration, and also that it illustrates the severity of the problems that can be caused by vibration.

APPENDIX B

SHIP A FAILURE MODE SUMMARIES AND DETAILED FMEA

INDEX-B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.1 Purge Control Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
NOTE:	1 Required Per Boiler	
P.1	Power to all cards and local panel shorted out; lose ERC and local panel.	1B
P.2	Lose auto and semi-auto purge capability (i.e., from burner on PB, from purge start PB, and from boiler safety trip).	1A, 2A, 6B, 8A, 9A, 11B, 15B, 16B, 18A, 22,B,23A, 24A, 29A, 30A, 30B, 32B, 33A, 34A, 35A, 36A, 37A
P.3	No purge following light-off initiated by burner-on PB.	5A
P.4	No purge following boiler safety trip.	7A, 10B
P.5	No purge following activation of purge start PB.	4A
P.6	Purge cycle terminates as though normal but without airflow due to second failure (e.g., fan fail, A/R fail to open).	11A, 13A, 25A, 26A, 28A, 29B, 32A, 34B, 35B
P.7	Purge cycle fails and purge fail alarm occurs.	21B, 25B, 26B, 27B, 28B
P.8	Purge not inhibited if burner valve open; purge not effective if master F.O. valve open and second failure caused burner valve to stay open.	22A
P.9	In auto mode, "false" purge occurs, resulting in boiler shutdown; no further purge possible; boiler could not be relit.	4B, 5B, 7B, 10A, 15A
P.10	Lose ability to trip burner valves on flame-out; also lose burner fail alarms; also burner could not be lit from ERC.	3A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.1 Purge Control Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.	
P.11	"False" purge during normal operation. No effect while steaming. Burners would blow-out at low demand rates.	18B, 21A	
P.12	Lose check for A/R's closed at end of purge; if A/R's failed too close, air flow would be too high for light-off.	36B	
P.13	Purge cycle would not terminate and boiler could not be lit.	8B	
P.14	Lose purge timer redundancy; same as #2 above if FMEA item #30B occurs.	33B	
P.15	"False" purge when burner valves closed.	2B, 6A, 16A	
P.16	Boiler trip would not occur if fan stopped if redundant counterpart incurred same failure mode.	12A, 14A	Boiler Safety #18A
P.17	Boiler would shutdown.	12B, 17B	Boiler Safety #18B
P.18	Purge would occur with master F.O. valve open--safety hazard.	17A	Boiler Safety #19A
P.19	Purge sequence could be terminated before complete--safety hazard.	19A	Prelight #14B
P.20	Boiler could not be lit from ERC.	19B	Prelight #14A/1A
P.21	A/R stays open; no effect during steaming; effected burner could be blown out at low demand rates. Air flow would be too high for light-off.	20A	Burner B #2A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS

1.1.1 Purge Control Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.	
P.22	Air Reg. stays closed during purge cycle; purge fail.	20B	Burner B #2B
P.23	Burner fail logic stays enabled in manual mode.	3B	
P.24	Purge can be initiated manually via purge start PB or burner on PB when burner is already on. No effect during steaming. Burner would blow out at low demand rates.	9B	
P.25	Start purge lamp stays lit.	31A	
P.26	Start purge lamp never lights.	31B	
P.27	No effect.	13B, 14B, 23B, 24B, 27A, 37B	

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.2 Prelight Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Boiler	
P.1	Power to all cards and local panel shorted out]; lose ERC and local panel.	1B
P.2	Boiler could not be lit from ERC.	1A, 2B, 3B, 4B, 5B, 6B, 7B, 10B, 11B, 13A, 14A, 22B, 23B, 24A, 26B
P.3	Purge sequence terminates before complete.	14B
P.4	Boiler ready status generated without regard to purge status; boiler could be lit without purging.	23A
P.5	Boiler could be lit too long after expiration of purge sequence.	27B
P.6	Light off not inhibited if atomizing steam pressure not OK; if second failure caused lack of atomizing steam, eventual flame-out and trip should occur.	2A
P.7	Light off not inhibited if F.O. header pressure not OK; if second failure caused inadequate F.O. header pressure, eventual flame-out and trip should occur.	3A
P.8	Light off not inhibited if F.O. temperature not OK; if second failure caused inadequate F.O. temperature eventual flame-out and trip should occur.	4A
P.9	Light off not inhibited if A/R's open; if second failure caused A/R's to open, flame would blow-out and trip should occur.	26A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.2 Prelight Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.10	Light off not inhibited by any prelight condition (F.O. header pressure, F.O. temperature, atomizing steam pressure); if second failure caused one of these conditions, eventual trip should occur.	10A, 11A, 12A
P.11	No auto or semi-auto purge; safety hazard.	15A, 16B, 19B, 20A, 22A, 25A, 28B
P.12	Purges would not terminate and boiler could not be lit.	15B, 16A, 17A, 18A, 19A, 20B, 27A
P.13	Purge not inhibited if burner valve open; purge not effective if master F.O. valve open and 2nd failure causes burner valve to stay open.	17B, 18B
P.14	Purge cycle terminates as though normal but without air flow due to second failure (e.g., fan fail, A/R fail to open)	25B
P.15	Lose check for A/R's closed at end of purge; if A/R's fail to close, air flow would be too high for light-off.	28A
P.16	Boiler could be lit when trip condition exists.	6A
P.17	Lose inhibit against starting a light-off sequence when one is already in progress.	12B
P.18	Boiler ready/purge complete lamp stays lit.	9A, 21A
P.19	Boiler ready/purge complete lamp never lights.	9B, 21B
P.20	No effect.	5A, 13B, 24B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.3 Boiler Safety Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Boiler	
P.1	Power to all cards and local shorted out; lose ERC and local panel.	1B
P.2	Master F.O. valve de-energizes (closes); boiler shutdown.	1A, 2B, 3A, 4A, 8B, 9B, 18B, 19B, 21B, 22B, 23A, 25B, 26A, 27B, 28B, 29B, 30B, 31B, 33B, 34B, 35B, 36B, 39B, 41B
P.3	Boiler could be lit without purging.	15A, 16A, 17A, 24A, 25A, 37A, 38A, 39A, 40A
P.4	Boiler could be lit when trip condition exists.	32A
P.5	F.O. recirculation valve stays open; F.O. header pressure decrease, flame-out and trip	14A
P.6	Master F.O. valve stays open; boiler trips would still close burner valves if circuitry non-failed.	2A, 5A, 7A, 34A
P.7	Master F.O. valve would not close for purge cycle; burner valves would be closed if non-failed.	19A
P.8	Boiler trip would not occur on burner flame-out; burner valves would still close if non-failed.	21A
P.9	Master F.O. valve could not be tripped (closed) manually.	3B, 4B
P.10	Boiler could not be lit from ERC.	10B, 32B
P.11	Deleted.	
P.12	Lose auto and semi-auto purge credibility; (i.e., from burner on P.B., purge start P.B. and from boiler safety trip)	11B, 12B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.3 Boiler Safety Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.	
P.13	"False" purge when burner valves closed.	11A, 12A	
P.14	Deleted.		
P.15	Boiler could not be lit if redundant "leg" incurred same failure mode; redundancy is as shown at right.		(#16B and #17B) redundant with #40B
P.16	Boiler would not trip on drum level low-low if both "legs" of redundancy incurred same failure mode; redundancy is as shown at right.		#22A redundant with #41A
P.17	Boiler would not trip if fan stopped if both "legs" of redundancy incurred same failure mode; redundancy is as shown at right.		#18A redundant with #35A
P.18	Boiler would trip if both "legs" of redundancy incurred same failure mode; redundancy is as shown at right; either of the two redundant configurations could cause the trip.		Configuration 1: #15B redundant with #37B Configuration 2: #24B redundant with #38B
P.19	Boiler would not trip if trip condition occurred.	27A, 28A, 29A, 30A, 31A	
P.20	Master F.O. valve could be commanded open manually for recirculation when a burner valve was open if both "legs" of redundancy incurred same failure mode; redundancy shown at right.		#6B redundant with #13B
P.21	Master F.O. valve could be opened manually during a purge (would require human error plus this failure mode).	20B	
P.22	Master F.O. valve could not be opened manually for recirculation.	5B, 6A, 7B, 13A, 14B, 20A	

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.3 Boiler Safety Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.23	Boiler trip alarms would occur when boiler was shutdown (nuisance).	9A, 33A
P.24	No effect.	8A, 10A, 23B, 26B, 36A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4A Burner Logic A Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Burner	
P.1	Power to all cards and local panel shorted out; lose ERC and local panel.	1B
P.2	Effected burner could not be lit via ERC PB or auto demand control.	1A, 2B, 4B, 5B, 6B, 7B, 8B, 9B, 10B, 12B, 13A, 14A, 15A, 16A, 28B, 44A
P.3	Effected burner would trip and stay off.	17A, 18A
P.4	Effected burner could not be lit or shutoff via ERC PB or auto demand control.	3B
P.5	Effected burner could not be shutoff via ERC PB or auto demand control.	17B
P.6	Effected burner would not trip on flame-out; purges could occur with effected burner valve open if second failure caused open burner valve.	27B
P.7	Ignitor could be inserted with effected burner valve open if second failure caused open burner valve.	28A
P.8	Purge would not occur after boiler trip nor after activation of purge start PB or burner on PB.	27A
P.9	Effected burner cannot be lit via auto demand control and burner on lamp stays lit.	22A,
P.10	Effected burner cannot be lit via auto demand control and burner on lamp never lights.	22B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4A Burner Logic A Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	Lose inhibit against starting a purge if a purge is already in progress.	5A
P.12	Lose inhibit against starting a purge if a burner is lit.	8A
P.13	Lose inhibit against starting a light-off if light-off already in progress.	6A, 7A
P.14	Lose all inhibits in 11, 12, and 13 above.	9A
P.15	On/off PB's and auto demand control active for effected burner in manual mode. If on PB erroneously activated, burner would light without purge.	3A
P.16	False activation of burner off lamp and alarm for effected burner.	24A
P.17	False burner off alarm for effected burner.	23A
P.18	Lose burner off alarm for effected burner.	23B, 24B
P.19	Burner Off Lamp for effected burner never lights.	21B
P.20	Burner off lamp for effected burner stays lit.	21A
P.21	No effect.	10A, 15B, 16B, 18B
P.22	In auto mode, purge occurs, resulting in boiler shutdown. No further purge possible; boiler could not be re-lit.	2A, 4A, 12A, 13B, 19A
P.23	No purge following light-off initiated via burner - on P.B.	19B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4A Burner Logic A Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.24	Purge terminates as though normal but without airflow due to second failure (e.g., fan fail, A/R fail to open) safety hazard.	36A
P.25	Purge cycle fails and purge fail alram occurs.	36B
P.26	Deleted.	
P.27	Continuous cycling of burner valve open/close and ignitor insert/retract on effected burner; could create explosion hazard; also, could cause boiler trip because of timing errors. BmB-8A	20A
P.28	Light Off sequence not successful; effected burner could not be lit from burner on P.B. or auto. demand control. BmB-8B	11B, 20B, 33A
P.29	Effected burner valve would be opened and ignitor inserted before purge complete if Burner Logic A item 9A failure occurred. BmB-9B	11A
P.30	Effected ignitor could be inserted when burner valve open if another failure caused burner valve to be open. BmB-10B	33B
P.31	Lose burner trip protection if ignitor commanded to retract when it is already retracted. BmB-18B	26A, 26B
P.32	Deleted. BmB-19A	26B
P.33	Deleted. BmB-25A	25B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4A Burner Logic A Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.34	Effected burner valve stays open whenever. No trips present. If burner not lit, this would eventually cause a boiler trip. BmB-25B.	25A
P.35	Deleted. BmB-26A	44A
P.36	Effected burner valve stays open; cannot be closed automatically. BmB-26B	44B
P.37	Flame-out of effected burner and boiler trip. BmB-38A	40A
P.38	If flameout occurred, BV would stay open--safety hazard. BmB-38B	40B
P.39	Effected burner valve stays closed (burner valve solenoid de-energized) BmB-49A	32A, 35A, 37B
P.40	Lose burner trip protection if effected burner valve open/close command same as burner valve status. BmB-49B	32B
P.41	Deleted. BmB-55A	
P.42	Lose burner trip protection for effected burner if A/R open/close command same as A/R status. BmB-55B	35B, 37A
P.43	Boiler could not be lit from ERC.	38B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4A Burner Logic A Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.44	Boiler could be lit without purging.	43A
P.45	Boiler trip would occur if redundant counterpart incurred same failure mode.	43B
P.46	Purge cycle terminates as though normal but without airflow due to 2nd failure (e.g., fan fail, A/R fail to open)	29A
P.47	Purge cycle would stop and purge fail alarm would occur. Burner would go out and stay out. (Same as P3 and P25 above)	29B
P.48	Light-off not inhibited if A/R's open; if 2nd failure caused A/R's to open, flame would blow out and trip should occur. Also, effected burner valve stays closed (burner valve solenoid de-energized)	30A, 38A
P.49	Boiler could not be lit from ERC. Also, lose burner trip protection for effected burner if A/R open/close command same as A/R status.	30B
P.50	No purge following a boiler safety shutdown. Also, boiler could not be lit from ERC.	31A
P.51	In auto mode, "false" purge occurs, resulting in boiler shutdown. No further purge possible. Boiler coild not be relit.	31B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4A Burner Logic A Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.52	Purge could occur while a burner was on if purge start pushbutton depressed (human error or switch failure) or if burner on pushbutton depressed. Also, purge cycle would not terminate and boiler could not be lit.	34A
P.53	No auto or semi-auto purge; Also, Master F.O. valve could not be opened manually via reset switch for F.O. recirculation	34B
P.54	No lose auto and semi-auto purge capability; also, if flame-out occurred, BV would stay open.	39A
P.55	Lose auto and semi-auto purge capability (i.e., from burner on PB, from purge start PB, and from boiler safety trip). Also, burner valve would close and boiler would trip.	39B
P.56	Lose auto and semi-auto purge capability (i.e., from purge start P.B., burner - on P.B., and from boiler safety trip). Also, boiler could be lit without purging.	42A, 42B, 41A
P.57	Deleted.	
P.58	Deleted.	
P.59	Lose auto and semi-auto purge capability (i.e., from burner on PB, from purge start PB, and from boiler safety trip).Also, boiler trip would occur if redundant counterpart incurred same failure mode. Also, effected burner valve stays open; cannot be closed automatically.	41B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4B Burner Logic B Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Burner	
P.1	Power to all cards and local panel shorted out; lose ERC and local panel.	1B
P.2	Flame-out of effected burner and boiler trip.	3A, 4B, 5B, 6A, 7A, 38A, 39A, 40A, 43B
P.3	Light-off sequence not successful; effected burner could not be lit from burner - on P.B., or auto demand control.	8B, 9A, 10A, 11B, 13B, 14B,15A, 16B, 20A, 25A, 26A, 30B, 42B, 60B, 61A, 62B,
P.4	Fail signal from effected burner causes boiler trip.	18A, 19B, 21A, 22B, 23A, 24B, 12A
P.5	Effected burner valve stays closed (burner valve solenoid de-energized).	1A, 27B, 28A, 29B, 31B, 32B, 34B, 35A, 44B, 45A, 47A, 48B, 49A, 53A, 54B, 55A
P.6	Effected burner valve stays open after flame-out; explosion hazard.	38B, 39B, 40B, 43A
P.7	Efected burner could not be shutdown by burner off PB or via aut demand control; if in auto demand control mode, possible overpressure at low demand rates.	27A, 28B
P.8	Air register stays closed during purge cycle; purge fail.	2B
P.9	Air register stays open; no effect during steaming; effected burner could be blown out at low demand rates. Air flow would be too high for light off.	2A, 3B, 4A, 5A, 7B
P.10	Effected ignitor could be inserted when burner valve open if second failure caused burner valve to be open.	10B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4B Burner Logic B Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	Effected burner valve stays open whenever no trips are present. If burner not lit, this would eventually cause a boiler trip.	25B, 30A, 31A
P.12	Effected burner valve stays open; cannot be close automatically.	26B, 32A, 34A
P.13	Effected ignitor would not retract; would destry ignitor.	16A
P.14	Lose auto protection if effective air register does not close on close command.	6B
P.15	Effected burner valve will be opened and ignitor inserted before purge complete if second failure causes burner logic A card FMEA item #9A.	9B
P.16	Continuous open burner valve and insert ignitor commands for effected burner; during steady state ignitor would be destroyed; during light-off, probable explosion since fuel and ignition source would be present prior to purge.	13A
P.17	Continuous cycling of burner valve open/close and ignitor insert/retract o. effected burner; could create explosion hazard; could also cause boiler trip because of timing errors.	8A, 11A
P.18	Boiler would be lit without purging when effected burner light-off initiated via burner on PB.	17A
P.19	Lose inhibit against starting a purge when a burner is being ignited.	17B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4B Burner Logic B Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.	
P.20	Lose boiler trip protection on flame-out of effected burner.	36A, 45B, 47B, 48A	
P.21	Lose burner trip protection for effected burner if ignitor command same as ignitor status.	18B, 19A, 35B	
P.22	Deleted.		
P.23	Lose burner trip protection if effected burner valve open/close command same as burner valve status.	49B	
P.24	Lose burner trip protection for effected burner if A/R open/close command same as A/R status.	55B	
P.25	Lose burner trip protection for effected burner against fan stop or drum level low-low condition if both "legs" of redundancy fail; redundancy as shown at right.		#21B redundant with #22A
P.26	Effected burner valve will not close on boiler safety trip if both "legs" of redundancy fail; redundancy as shown at right		#29A redundant with #53B, 54A, and 44A
P.27	Lose ignition sequence inhibit if effected burner not set up.	60A, 62A	
P.28	Effected ignitor would not retract and would be destroyed if both "legs" of redundancy fail; redundancy as shown at right.		#15B redundant with #14A, 20B, and 42A
P.29	Effected burner valve will close and stay closed following any burner valve close command to effected burner.	33A	

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.4B Burner Logic B Card

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.30	Effected burner valve will close and stay closed following any burner valve open command to effected burner.	33B
P.31	Boiler trip would not occur on flame-out; burner valves wo[illegible] still close is non-failed.	41A
P.32	Master F.O. valve de-energizes; boiler would shutdown.	41B
P.33	Burner fail logic enabled in manual mode; second failure could cause burner or boiler trip in manual mode.	36B, 37A
P.34	Burner fail trip and alarm occur when burner is shutdown (nuisance).	12B
P.35	Lose burner fail alarm and lamp for effected burner.	24A
P.36	Lose burner fail lamp for effected burner.	37B, 46B
P.37	Burner fail lamp for effected burner stays lit.	46A
P.38	No effect.	23B, 61B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.5 Burner Demand Sequencing

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Boiler	
P.1	Burner #1 could not be lit on demand increases.	8A, 9E
P.2	Burner #2 could not be lit on demand increases.	1A, 7C, 10E
P.3	Burner #3 could not be lit on demand increases.	1C
P.4	Burners #1 and/or #2 could not be lit on demand increases.	11B
P.5	Burner #1 could not be lit on demand increases when burner #2 selected as base burner.	3C
P.6	Burner #1 could not be lit on demand increases nor tripped on demand decreases when burner #2 selected as base burner.	3A, 5A
P.7	Burners #1 and #2 could not be lit on demand increases nor tripped on dereases when burner #3 selected as base burner.	2A, 4A
P.8	Burner #1 could not be tripped on demand decreases when burner #3 selected as base burner.	1E
P.9	Burner #2 could not be tripped on demand decreases when burner #3 selected as base burner.	1G
P.10	Burner #1 could not be tripped on demand decreases when burner #2 selected as base burner.	3E
P.11	Burner #1 could not be tripped on demand decreases.	6A, 9C

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.5 Burner Demand Sequencing

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.12	Burner #2 could not be tripped on demand decreases.	3G, 5C, 10C
P.13	Burners #1 and/or #2 could not be tripped on demand decreases.	11D
P.14	Burner #1 would light and stay lit.	8B
P.15	Burner #2 would light and stay lit.	7D
P.16	Burners #1 and/or #2 would light and stay lit.	11A
P.17	Burner #1 would trip and stay tripped.	9D
P.18	Burner #2 would trip and stay tripped.	10D
P.19	Burners #1, 2, or both would trip and stay tripped.	9B, 10B, 11C
P.20	Burners #1 and #2 would trip on demand decreases.	9A, 10A
P.21	No burner would light/trip on demand increases/decreases.	12
P.22	If burner #2 had lit on demand increase and demand continued to increase (or demand still not met), burner #1 would not light.	7A
P.23	A burner could be selected as the base burner when it was not lit; a subsequent light-off command to any other burner would allow the burner to light without purging.	4B, 5B
P.24	Burner #1 light commands could be generated when trip commands in effect.	6C, 9F

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.5 Burner Demand Sequencing

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.25	Burner #2 light commands could be generated when trip commands in effect.	10F
P.26	No effect.	1B, 1D, 1F, 1H, 2B, 3B, 3D, 3F, 3H, 5D, 6B, 7B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.6 Combustion Air Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Boiler	
P.1	Lose combustion air; boiler flame-out.	1A, 2A, 3A, 4A, 10
P.2	Increased air flow and decreased F.O. flow; boiler flame out.	5B, 6C, 8B
P.3	Boiler would not trip if FDB failed; master F.O. valve would remain open; Burner Logic B card should command burner valve to close or flame out should cause boiler trip.	14
P.4	Air preheater meltdown disables boiler.	19
P.5	Boiler trips and stays tripped.	12A, 13
P.6	High excess air; no effect during steaming; burners would blow out at low demand rates.	1B, 5A, 6A
P.7	Low air ratio; boiler would flame-out because of low air or start smoking and trip because flame scanners field of view obscured by smoke.	1C, 5C, 6B, 8A
P.8	Combustion air flow does not change with changed demand; would result in #6 or #7 above depending upon air flow at the time of failure and whether demand increased or decreased.	3B, 3C
P.9	Slow boiler response to demand increases.	4B
P.10	No "spurt" of excess air to level out boiler response to demand decreases	4C

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.6 Combustion Air Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	"False" purge during normal operation. No effect while steaming; burners would blow-out at low demand rates.	2B
P.12	Purge cycle fails and purge fails alarm occurs.	2C, 7
P.13	Lose capability for manually cross connecting air ducts so either boiler can be operated off either FDB.	12B
P.14	Lose FDB fail alarm.	15A
P.15	Continuous FDB fail alarm.	15B
P.16	Lose windbox pressure gauge or gauge reading incorrect.	16
P.17	Lose FDB discharge pressure gauge or gauge reading incorrect.	17
P.18	Lose boiler furnace pressure gauge or gauge reading incorrect.	18
P.19	No effect.	9, 11

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.7.1 F.O. Flow Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Boiler	
P.1	Lose F.O. supply to boiler; boiler flame-out.	2A, 5A, 8A
P.2	Insufficient F.O. flow for high demand rates. No effect at low demand rates; at high demand rates vessel speed could not be maintained.	1A, 4A, 4B, 5B
P.3	High excess air; no effect during steaming; burners would blow-out at low demand rates.	1C
P.4	Higher firing rate than desired; at low demand rates steam dump capabilities could be exceeded.	1B, 2B, 3, 6B
P.5	Low F.O. flow at low demand rates and no decrease in combustion air flow; probable boiler flame-out.	6A, 5C, 6C
P.6	Same as #4 above; also lose burner header pressure gauge reading.	7
P.7	Master F.O. valve stays open; boiler trips would still close burner valves if circuitry non-failed.	8B
P.8	Lose F.O. to burner header pressure low alarm.	9A
P.9	Continuous F.O. to burner header pressure low alarm.	9B
P.10	Lose burner header pressure gauge or gauge reading incorrect.	10
P.11	Lose F.O. flow meter or meter reading incorrect.	11

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SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.7.2 F.O. Temperature and Pressure Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required (total)	
P.1	F.O. too viscous to flow; both boilers would flame-out.	1A, 2A, 2C, 3A, 3C
P.2	F.O. continuously heated to maximum; inefficient combustion and smoke; flame scanners might not be able to "see" flame through the smoke and cause both boilers to trip; any leak of the hot F.O. could cause a fire.	1B, 2B, 3B
P.3	F.O. pressure could become too high at low demand rates.	5A, 6A, 7A, 7C
P.4	F.O. pressure would drop; both boilers would flame-out.	5B, 6B, 7B
P.5	Lose F.O. temperature high/low alarm.	4A
P.6	Continuous F.O. temperature high/low alarm.	4B
P.7	Lose F.O. service pressure low alarm.	8A
P.8	Continuous F.O. service pressure low alarm.	8B
P.9	Lose F.O. service pressure gauge or gauge reading incorrect.	9

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.7.3 F.O. Supply

F.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
NOTE.	There are two redundant F.O. service pumps (i.e., P and S). During normal operation, the "running" pump is set to run at high speed and the other pump is selected as the standby. If the running pump fails to maintain the proper F.O. pressure (e.g., due to failure of the running pump), the standby pump is automatically started. The "running" pump is set to run at slow speed only during periods of low steam demand (e.g., during in-port loading). One pump operating at slow speed can meet the F.O. requirements of only one boiler.	
P.1	P or S F.O. service pump cannot be operated at fast speed via ERC selection.	1(P), 5(S)
P.2	P or S F.O. service pump cannot be operated at slow speed via ERC selection.	2(P), 6(S)
P.3	P or S F.O. service pump cannot be selected as standby pump.	3(P), 7(S)
P.4	P or S F.O. service pump cannot be stopped from ERC.	4(P), 8(S)
P.5	Standby pump cannot be switched on automatically if running pump fails to maintain required pressure (lose redundant unit).	9
P.6	Lose P or S F.O. service pump fail alarm.	10A(P), 11A(S)
P.7	Continuous P or S F.O. service pump fail alarm.	10B(P), 11B(S)
P.8	Lose P or S F.O. service tank level high alarm.	13A(P), 14A(S)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.7.3 F.O. Supply

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.9	Continuous P or S F.O. service tank level high alarm.	13B(P), 14B(S)
P.10	Lose F.O. strainer differential pressure high alarm.	12B
P.11	Continuous F.O. strainer differential pressure high alarm.	12A
P.12	Lose low sulphur F.O. tank level high alarm.	15A
P.13	Continuous low sulphur F.O. tank level low alarm.	15B
P.14	Lose low sulphur F.O. tank level low alarm.	16A
P.15	Continuous low sulphur F.O. tank level low alarm.	16B

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SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.8 Feedwater/Drum Level Control

P.K	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
NOTE: There are two redundant feed pumps (FP's), either of which provides feedwater to BOTH boilers. The pumps are driven by their own steam turbines, and the normal procedure is for one to run while the other is on standby and starts if the running pump fails to maintain the required FW pressure. Each pump has its own controls and these are identified by the prefix P/S. In addition, there are some controls common to both pumps. Also, each boiler has its own feedwater controls and in addition there are some common controls. The term "effected boiler" implies that the failure effects are applicable to the boiler associated with the failure.		
P.1	Drum level rise in effected boiler; water carryover to turbine if drum level high-high trip does not occur.	1A, 2B, 3A, 3C, 5 (one per boiler)
P.2	Drum level would fall in effected boiler; explosion possible due to overheating of boiler surfaces if drum level low-low trip does not occur.	1B, 3B (one per boiler)
P.3	Main engine trip due to false drum level high-high trip from either boiler.	9A (one per boiler)
P.4	Lose drum level high-high trip from effected boiler.	9B (one per boiler)
P.5	Lose drum level high/low alarm, level high-high trip and drum level gauge for effected boiler.	6A (one per boiler)
P.6	Same as #3 above plus erroneous drum level high alarms and incorrect drum level gauge indications for effected boiler.	6B (one per boiler
P.7	Lose drum level high alarm, level high-high trip and drum level gauge for effected boiler.	6C (one per boiler)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.8 Feedwater/Drum Level Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.8	Both F.P.'s run at max. rate--would result in #1 above but for both boilers.	13 (one per boiler); 14A and 14B (common to both boilers)
P.9	Running F.P. runs at max. rate--would result in #1 above but for both boilers if recirculation system could not handle excess F.W. flow (e.g., at low demand rates).	15A, 15C (common to both F.P's)
P.10	Excessive F.W. flow at low demand rates; if no other control loop failures, loop would reduce flow; otherwise, same as #1 but for both boilers.	22B, 28B, 28D, 29B, 33F (all P/S)
P.11	Effected F.P. runs at max rate; otherwise, same as P.9 above.	16A, 16C, 18A (all P/S)
P.12	No effect if failure associated with running F.P.; otherwise both F.P.'s would run simultaneously and result would be same as #9 above.	39B, 39D, 44B (all P/S)
P.13	Same as #1 above if control air supply lost; no effect otherwise.	2A (one per boiler)
P.14	Effected F.P. would shutdown; if standby pump did not start, drum level in both boilers would fall; possible explosion, see #2 above.	18B, 19B, 24B, 33C, 34, 39A, 39C, 40A, 41A, 42, 43, 44A, 47, 48 (all P/S)
P.15	Speed reduction in running F.P. results the same as #14.	15B (common to both F.P.'s)
P.16	Effected F.P. runs at reduced rate; results the same as #14.	16B(P/S)
P.17	Decreased F.W. flow from effected F.P.--results the same as #14.	22A, 23B (both P.S)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.8 Feedwater/Drum Level Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.18	Effected recirculation valve stays open in auto. mode; decreased F.W. flow to both boilers; would result in #2 above but for both boilers.	28C, 29A, 31E, 49(all P/S)
P.19	Standby feedpump would not start.	17 (common to both F.P.'s); 36A, 36E, 36G, 37B, 46 (all
P.20	Effected F.P. would not start from standby mode.	36A, 36E, 36G, 37B, 46 (all P/S)
P.21	Lose swell/shrink compensation for effected boiler; slow system response to demand changes.	4 (one per boiler)
P.22	Aux. L.O. pump for effected F.P. would not start--could damage effected F.P. at start-up.	31C, 39E, 45A (all P/S)
P.23	Boiler would not trip on drum level low-low if both "legs" of redundancy incurred same failure mode.	11 (one per boiler)
P.24	Lose drum level high alarm for effected boiler.	7B (one per boiler)
P.25	Continuous drum level high alarm for effected boiler.	7A (one per boiler)
P.26	Lose drum level low alarm for effected boiler.	8B (one per boiler)
P 27	Continuous drum level low alarm for effected boiler.	8A (one per boiler)
P.28	Lose drum level gage or gage reading, incorrect for effeced boiler.	10 (one per boiler)
P.29	Drum level low-low lamp stays lit for effected boiler.	12A (one per boiler)
P.30	Lose drum level low-low lamp for effective boiler.	12B (one per boiler)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.8 Feedwater/Drum Level Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.31	Lose F.P. fail alarm for effected F.P.	30A, 39G, 50B (all P/S)
P.32	Continuous F.P. fail alarm for effected F.P.	30B, 39H, 50A (all P/S)
P.33	Lose F.P. discharge pressure low alarm for effected F.P.	20B (P/S)
P.34	Continuous F.P. discharge pressure low alarm for effected F.P.	20A (P/S)
P.35	Lose F.P. discharge pressure gauge or gauge reading incorrect for effected F.P.	21 (P/S)
P.36	Lose F.P. run lamp indication for effected F.P.	32B, 35 (both P/S)
P.37	Lose F.P. standby lamp indication for effected F.P.	36C (P/S)
P.38	F.P. standby lamp stays lit for effected F.P.	36D (P/S)
P.39	Lose F.W. recirculation valve open lamp indication for effected F.P. loop	38 (P/S)
P.40	Lose F.P. L.O cooler outlet temperature high alarm for effected F.P. loop.	27B (P/S)
P.41	Continuous F.P. L.O. cooler outlet temperature high alarm for effected F.P. loo.	27A (P/S)
P.42	Lose F.P. L.O. from cooler temperature gauge or gauge reading incorrect--both F.P.'s.	26 (common to both F.P.'s)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.8 Feedwater/Drum Level Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.43	Steam valve for affected F.P. stays open; if second failure caused F.P. throttle control valve to stay open, effected F.P. could not be shutdown.	19A, (P/S)
P.44	F.W. suction valve for effected F.P. stays open.	23A (P/S)
P.45	Exhaust valve for effected F.P. stays open.	24A (P/S)
P.46	Run/standby circuits for effected F.P. enabled without regard to whether F.P. steam valve powered. No effect unless power lost to steam valve, in which case F.P. would not start.	40B
P.47	Both aux. and main L.O. pumps for effected F.P. run simultaneously; no effect unless one of the L.O. pumps is damaged (e.g., by cavitation) in which case the associated F.P. would be disabled.	25, 31A, 31D, 32A, 33A, 45B (all P/S)
P.48	Run/standby circuits for effected F.P. enabled without regard to whether L.O. pump is powered. No effect unless power lost to L.O. pump, in which case effected F.P. would be damaged at start-up.	41B (P/S)
P.49	No effect.	28A, 31B, 31F, 33B, 33D, 33E, 36B, 36F, 36H, 37A, 39F (all P/S)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.9 Master Load Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	All but the base burners on both boilers would shutdown.	6A, 6C, 9A (common to both boilers)
P.2	All but the base burner on effected boiler would shutdown.	7A, 7C (one per boiler)
P.3	Higher firing rate than desired on both boilers; could exceed steam dump capacity at low demand rates.	3B, 6B (common to both boilers)
P.4	Same as #3 above except for effected boiler, and #7 below.	2B, 7B (one per boiler)
P.5	Deleted.	
P.6	Firing rate for both boilers based on steam pressure from only one boiler; no effect at high demand rates; vessel speed decrease if boiler being "sensed" was cut back.	8 (one per boiler); 9B (common to both boilers)
P.7	Lose steam flow gauge or gauge reading incorrect for effected boiler.	5 (one per boiler)
P.8	Deleted.	
P.9	Plant master controller response not accelerated with variations in steam flow; sluggish vessel response to speed change commands.	1, 2A, 2C (one per boiler); 3A, 3C (common to both boilers)
P.10	Effected recirculation valve stays open in auto mode; decreased F.W. flow to both boilers would result in drum level falling; explosion possible due to overheating of boiler surfaces if drum level low-low trip does not occur.	4A (common to both boilers)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.1.9 Master Load Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	Excessive F.W. flow at low demand rates; if no other control loop failures, loop would reduce flow; otherwise, drum level rise in both boilers; water carryover to turbine if drum level high-high trip does not occur.	4B (common to both boilers)

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.2 Boiler Local Panel

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
Note:	1 Required Per Boiler	
P.1	Boiler could not be operated from local panel or ERC.	1
P.2	Boiler could not be operated from ERC.	2A, 4A, 11B
P.3	Boiler could not be operated from local panel.	2B
P.4	Boiler would shutdown and could not be operated from ERC.	3A
P.5	Master F.O. valve could not be tripped automatically from ERC; lose auto, safety trip protection.	3D
P.6	Burner #1/#2/#3 would shutdown and could not be operated from ERC.	5A/6A/7A, 36A/37A/38A, 42B/43B/44B, 24B/25B/26B
P.7	Burners #2 and 3/1 and 3/1 and 2 could not be lit from local panel or ERC.	8A/9A/10A
P.8	Operation would not revert to manual mode if burner valve, master F.O. valve or F.O. recirculation valve jacked open/closed manually; ERC commands would still be active. If conditions warranted override, would be safety hazard.	11A
P.9	Master F.O. valve could not be tripped automatically from ERC; Lose auto. safety trip protection. Master F.O. valve stays open; could not be closed from ERC or local panel.	3D, 18A
P.9	Master F.O. valve stays open; could not be closed from ERC or local panel.	18A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.2 Boiler Local Panel

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.10	Burners #2 and #3/#1 and #3/#1 and #2 could not be lit from local panel or ERC.	8A/9A/10A
P.10	Master F.O. valve stays closed; could not be opened from ERC or local panel.	18B
P.11	Master F.O. valve could not be opened/closed from local panel.	3C
P.12	Effected burner valve stays open whenever no trips are present. If burner not lit, this would eventually cause a boiler trip.	48B/49B/50B
P.13	Light-off sequence not successful; effected burner could not be lit from burner-on PB or auto demand control.	48A/49A/50A, 30A/31A/32A, 45B/46B/ 47B
P.14	Lose burner trip protection for effected burner if ignitor command same as ignitor status.	51B/52B/53B
P.15	Deleted.	
P.16	Purge would not occur after boiler trip nor after activation of purge start PB or burner on PB.	27B/28B/29B, 20A
P.17	Effected burner valve stays open after flame-out; explosion hazard.	27A/28B/29B, 12B/13/14B
P.18	Ignitor could be inserted with effected burner valve open if second failure caused open burner valve.	30B/31B/32B
P.19	Deleted.	

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.2 Boiler Local Panel

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.20	Purge cycle terminates as though normal but without air-flow due to second failure (e.g., fan fail, A/R fail to open).	36B/37B/38B
P.21	Deleted.	
P.22	Deleted.	
P.23	Boiler could not b lit from ERC.	42A/43A/44A
P.24	Air register stays open; no effect during steaming; effected burner could be blown out at low demand rates. Air flow would be too high for light off. Lose local panel backup for failure effect.	33A/34A/35A; 39B/40B/41B
P.25	Flame-out of effected burner and boiler trip. Lose local panel for failure effect.	33B/34B/35B; 39A/40A/41A; 12E/13E/14E; 12A/13A/14A
P.26	Effected ignitor would not re-tract; would destroy ignitor.	45A/46A/47A
P.27	Deleted.	
P.28	Deleted.	
P.29	Effected burner valve stays open; cannot be closed auto-matically.	24A/25A/26A
1.30	Deleted.	
P.31	Deleted.	
P.32	Deleted.	
P 33	Deleted.	

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.2 Boiler Local Panel

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.34	Lose ignition sequence inhibit if effected burner not set up.	15B/16B/17B
P.35	Master F.O. valve stays closed	3A, 18B, 19A
P.36	Deleted.	
P.37	"False" purge when burner valves closed.	20B
P.38	Deleted.	
P.39	Master F.O. valve could not be opened manually for recirculation.	4C, 21B
P.40	F.O. recirculaiton valve stays open; F.O. header pressure decrease, flame out and trip.	21A
P.41	Deleted.	
P.42	Lose inhibit protection against manually opening the F.O. recirculation valve from the local panel in auto mode.	4D
P.43	Lose inhibit protection against manually operating air registers, ignitors and burner valves #1/#2/#3 from the local panel in auto mode.	5D/6D/7D
P.44	ERC master F.O. valve trip lamp never lights.	19C
P.45	ERC master F.O. valve trip lamp stays lit.	19D
P.46	ERC master F.O. valve reset lamp never lights.	20C
P.47	ERC master F.O. valve reset lamp stays lit.	20D

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.2 Boiler Local Panel

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.48	ERC burner valve #1/#2/#3 open lamp never lights.	27C/28C/29C
P.49	ERC burner valve #1/#2/#3 open lamp stays lit.	27D/28D/29D
P.50	ERC burner valve #1/#2/#3 close lamp never lights.	30C/31C/32C
P.51	ERC burner valve #1/#2/#3 close lamp stays lit.	30D/31D/32D
P.52	ERC air regulator #1/#2/#3 open lamp never lights.	36C/37C/38C
P.53	ERC air regulator #1/#2/#3 open lamp stays lit.	36D/37D/38D
P.54	ERC air regulator #1/#2/#3 close lamp never lights.	42C/43C/44C
P.55	ERC air regulator #1/#2/#3 close lamp stays lit.	42D/43D/44D
P.56	ERC ignitor #1/#2/#3 inserted lamp never lights.	48C/49C/50C
P.57	ERC ignitor #1/#2/#3 inserted lamp stays lit.	48D/49D/50D
P.58	ERC ignitor #1/#2/#3 retracted lamp never lights.	51C/52C/53C
P.59	ERC ignitor #1/#2/#3 retracted lamp stays lit.	41D/52D/53D
P.60	ERC F.O. recirculation valve open lamp never lights.	23A
P.61	ERC F.O. recirculation valve open lamp stays lit.	23B
P.62	ERC F.O. recirculaiton valve closed lamp never lights.	22A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
1.2 Boiler Local Panel

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.63	ERC F.O. recirculation valve closed lamp stays lit.	22B
P.64	Lose ERC flame intensity gauge #1/#2/#3 or reading incorrect.	12C/13C/14C
P.65	Lose local panel flame intensity gauge #1/#2/#3 or reading incorrect.	12D/13D/14D
P.66	No effect in auto mode.	3B, 4B, 5B, 5C, 6B, 6C, 7B, 7C, 8B, 9B, 10B, 19B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
2.0 Superheated Steam Temperature Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	Minimum or loss of S.H. steam cooling; temperature could get too high and possibly rupture S.H. tube or warp turbine blades.	1B, 4B
P.2	Maximum cooling of S.H. steam; low temperature would cause loss in efficiency and possibly condensation and moisture in turbine.	1A, 1C, 3, 4A
P.3	Lose S.H. steam temperature high alarm.	2A
P.4	Continuous S.H. temperature high alarm.	2B
P.5	Lose superheater outlet temperature gauge or gauge reading incorrect.	5

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
3.0 Desuperheated Steam Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	Lose atomizing steam; both boilers would flame-out. F.O. droplets could form and create an explosion hazard.	1B
P.2	Lose gland steam to main turbine and turbo-generator; would cause loss of vacuum and main engine trip.	2B
P.3	Atomizing steam pressure too high (same pressure as desuperheated steam pressure). If relief valve failure, could cause damage to burner nozzles or piping. Also, could extinguish burners.	1A
P.4	Gland steam pressure too high (same pressure as desuperheated steam pressure). If relief valve failure, could damage turbine or piping.	2A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
4 0 Exhaust and Bleed Steam Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	Difference in bleed steam pressure and turbine steam pressure during maneuvering causes backflow of steam into turbine and turbine damage.	1A
P.2	Difference in bleed steam pressure and turbine steam pressure during steaming cause backflow of steam into turbine and turbine damage.	1B, 2B, 3A
P.3	Excessive steam release to condenser and rise in condenser level resulting in loss of vacuum and damage to condenser if level rise not corrrected.	2A, 3B, 4A, 5A, 7B, 8D, 10A, 11B
P.4	Desuperheated steam never available to exhaust steam system; overpressure of desuperheated steam system. If not corrected, would damage piping and cause loss of atomizing steam and gland steam.	4B, 5B, 6A
P.5	Exhaust header pressure control always based on superheated steam pressure; lose ability to automatically correct for high exhaust header pressure.	6B, 7A
P.6	Exhaust header pressure control always based on exhaust header pressure; lose ability to automatically correct for high superheated steam header pressures--both boilers.	6C, 8A, 9A
P.7	Same as #6 above but for effected boiler.	9B
P.8	Exhaust steam never dumped to condensers; exhaust steam lines would overpressure and rupture; F.W. would become depleted and eventually cause boiler level low-low trip.	10B, 11A

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SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
5.0 L.P. Steam Generator Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	Max. Flow of desuperheated steam to L.P. steam generator; L.P. steam generator could become overpressured and rupture.	1A, 2B
P.2	F.O. too viscous to flow; both boilers would flame-out.	1B, 2A, 3B, 4A
P.3	Possible water carry over into contaminated steam supply; some loss of F.O. heating efficiency.	3A, 4B
P.4	Maximum condensate drainage to deaerator; probably not noticeable during normal operation.	5A, 6B
P.5	Lose condensate drainage to deaerator; drain cooler and L.P. steam generator could become overpressured and rupture.	5B, 6A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
6.0 3rd and 4th Stage Feed Heater Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	H.P. bleed steam always diverted into a feed heater; difference in bleed steam pressure and turbine steam pressure during maneuvering could cause backflow of steam into turbine and turbine damage.	1A, 4A
P.2	Third stage H.P. bleed steam never available to 4th stage feed heater; difference in bleed steam pressure and turbine steam pressure during steaming could cause backflow of steam into turbine and turbine damage.	1B, 4B
P.3	Decrease in feed heating; loss in efficiency.	2A, 3B, 5A, 6B
P.4	Third stage H.P. bleed line shut-off; 4th stage feed heater level would rise. Heater would be damaged if rise not corrected.	2B, 3A
P.5	Sixth stage H.P. bleed steam line shut-off; third stage feed heater level would rise; heater would be damaged if rise not corrected.	5B, 6A

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
7.0 Lube Oil Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
	NOTE: There are two redundant L.O. service pumps to circulate L.O. to the main engine. One pump is selected as the running unit and the other as the standby unit. If the running unit fails to maintain the required L.O. flow, the standby pump automatically starts. In the event that both pumps fail, a L.O. gravity tank prvides a 15-minute supply. If one the pumps is not functioning after that, the main engine would trip on L.O. pressure low-low. Engine damage would result if the trip did not occur.	
P.1	Lose L.O. cooling; high L.O. temp. could cause main engine to overheat and be damaged.	1A, 2A, 3B
P.2	Lose L.O. supply to main engine; engine would trip on L.O. pressure low-low if trip circuitry non-failed. Otherwise, engine damage.	1C
P.3	Max. L.O. cooling; no effect unless L.O. became too viscous to flow (remote possibility) in which case main engine could be damaged.	1B, 2B, 3A, 3C
P.4	L.O. pump associated with failure could not be selected as the "run" pump from the ERC (see note above).	4
P.5	L.O. pump associated with failure could not be selected as the "standby" pump from the ERC (see note above).	5
P.6	L.O. pump associated with failure could not be stopped from the ERC.	6

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
8.0 Condensate System Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	Depletion of feedwater to both boilers; explosion possible due to overheating of boiler surfaces if drum level low-low trips do not occur.	12B, 13A, 13B, 17A, 17C, 20A
P.2	Hotwell level would rise; if standby condensate pump failed to start to reduce level, water backup into L.P. turbine would occur.	1B, 4B,
P.3	Hotwell level would fall; condensate pumps could be damaged due to cavitation.	1A, 1C, 4A
P.4	Lose start signal to standby condensate pump; if both condensate pumps lost, hotwell level would rise; see #2 above. If both pumps lost, same as #1 above also.	2
P.5	Condensate pump associated with the failure could not be selected as the "running" pump (see #4 above).	6
P.6	Condensate pump associated with the failure could not be selected (remain) as the standby pump (see #4 above).	7
P.7	Lose deaerator high level control; level could rise above high limit and rupture deaerator and cause steam plant shutdown if relief valve failed to function.	17B
P.8	Condensate dump line stays closed; deaerator high level could not be corrected; same as #7 above if "dump" required.	20B
P.9	L.P. bleed steam always flows into condensate cooled distiller and 1st stage feed heater;	11A

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SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
8.0 Condensate System Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
	difference in bleed steam pressure and turbine steam pressure during maneuvering could cause backflow of steam into turbine and turbine damage.	
P.10	Lose L.P. bleed steam to condensate cooled distiller and first stage feed heater; loss in steam plant efficiency.	11B
P.11	Excessive F.W. flow into F.W. drain collecting tank; tank could overflow.	12A, 13C
P.12	Discharge from all drain pumps shutoff; F.W. drain collecting tank would overflow.	16B
P.13	Drain pump associated with failure could not be stopped or started; if more than one drain pump lost, same as #1 above.	14
P.14	All drain pump(s) discharge flows to deaerator or dump valve; no effect if drain pumps operating and cycling correctly.	16A
P.15	Condenser recirculation valve could not be opened manually from the ERC.	9
P.16	Condenser recirculation valve could not be closed manually from the ERC.	10
P.17	Lose condenser hotwell level high alarm.	3B
P.18	Continuous condenser hotwell level high alarm.	3A
P.19	Lose P or S condensate pump fail alarm.	8A
P.20	Continuous P or S condensate pump fail alarm.	8B

SUMMARY OF SHIP A SYSTEM FAILURE EFFECTS
8.0 Condensate System Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.21	Lose condensate pump discharge pressure gauge or gauge reading incorrect.	5
P.22	Lose F.W. drain collecting tank level high alarm.	15B
P.23	Continuous F.W. drain collecting tank level high alarm.	15A
P.24	Lose deaerator level high/low alarms and deaerator ("DC Heater") level gauge.	18A
P.25	Lose deaerator level high alarm.	18B
P.26	Lose deaerator level low alarm.	18C
P.27	Lose deaerator ("DC Heater") level gauge or gauge reading incorrect.	19
P.28	Lose condenser vacuum low alarm.	21B
P.29	Continuous condenser vacuum low alarm.	21A
P.30	Lose condenser vacuum gauge or gauge reading incorrect.	22
P.31	Lose standby vacuum pump; lose vacuum if both pumps lost. Main engine trip if trip circuitry non-failed.	23

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1	Console Power Supply #1 (redundant to unit #2 below)	Any.	Loss of or incorrect power output from unit.	No effect unless redundant unit failed. If both failed, control system would shut down and vessel would come to a stop.	9.2600	
2	Console Power Supply #2 (redundant to unit #1 above)	Any.	Same as #1.	Same as #1.	9.2600	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Purge Control Card Common Circuitry	Open.	Lose power or Power On reset to entire card; card would not function.	No auto or semi-auto purge; safety hazard.	0.9882	
1B	Purge Control Card Common Circuitry	Short.	Main 24 volt power shorted out on card.	Power to ALL cards and Local Panel shorted out--lose ERC and Local Panel.	0.7668	
2A	Burner Management in Auto* Input Circuit	Stays true.	Purge permissives never met.	Same as 1A.	0.0552	
2B	Burner Management in Auto* Input Circuit	Stays false.	Purge permissives could be met when Burner Management is in manual mode.	In manual operation, purges would occur automatically whenever Master F.O. valve and all burner valves closed. Not serious.	0.0552	
3A	Burner Management in Auto* Output Circuit	Stays true.	Lose Auto Enable signal to Burner Logic A and B.	Lose ability to trip burner valves if if flame out occurs. Also lose Burner Fail alarm. Safety hazard. Also burner could not be lit from ERC.	0.0853	
3B	Burner Management in Auto* Output Circuit	Stays false.	Auto mode always indicated on Burner Logic A and B.	Burner Fail Logic enabled in manual mode.	0.0853	
4A	Purge Start* Input Circuit	Stays true	Purge Start pushbutton inactivated.	Lose ability to initiate purge sequence from purge start pushbutton.	0.1950	
4B	Purge Start* Input Circuit	Stays false.	Purge Start pushbutton always appears activated--purge sequence would start and terminate in a purge fail.	In auto mode false purge start would occur and close Master F.O. Valve--Boiler Trip and no further purge possible. Boiler could not be restarted from ERC or Local Panel.	0.1950	
5A	Pre-Purge Cmd* Input Circuit	Stays true.	Pre-purge logic never activated.	No automatic purge following semi-auto (via pushbutton) burner start command at ERC. Safety hazard.	0.4924	
5B	Pre-Purge Cmd* Input Circuit	Stays false.	Pre-purge would always appear to be activated.	Same as 4B.	0.4924	
6A	Master F.O. Valve Closed Input Circuit	Stays true.	Purges could occur when Master F.O. valve was open; post-purge circuitry falsely enabled.	In auto mode, purges would occur when all burner valves closed. Not serious.	0.5963	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
6B	Master F.O. Valve Closed Input Circuit	Stays false.	Master F.O. valve would never appear to be closed. Purge latch could not be set.	Same as 1A.	0.5963	
7A	Any Burner Valve Open* Input Circuit	Stays true.	Post-purge enable latch could never be set.	Purge would not occur following a boiler safety shutdown of the Master F.O. valve. Safety hazard.	0.3024	
7B	Any Burner Valve Open* Input Circuit	Stays false.	Post-purge enable latch would stay set; therefore, post-purge always enabled.	Same as 4B.	0.3024	
8A	Purge Fail or Complete* Input	Stays true.	Post-purge enable latch and purge latch would be held in reset state.	Same as 1A.	0.6055	
8B	Purge Fail or Complete* Input	Stays false.	Purge and post-purge Enable latches would not be reset following a purge fail or complete.	Purges would not terminate and boiler could not be lit. There is no Purge Stop manual switch, so sequence could be terminated manually only by switching off console power or by turning off the fan or opening a burner valve (hazardous).	0.6055	
9A	Any Burner On*	Stays true.	Inhibits setting of purge latch and generation of purge start signal.	Same as 1A.	0.6055	
9B	Any Burner On*	Stays false.	Purge latch could be set when a burner was on if Purge Start or Burner On pushbutton depressed.	Purge could occur while a burner was on if Purge Start pushbutton depressed (human error or switch failure) or if Burner On pushbutton depressed. No effect at high demand rates except higher excess air than desired. At low demand rates, could blow out burner, where upon boiler would trip.	0.6055	
10A	Post-Purge Enable Latch and Output Gate	Stays true.	Erroneous start purge signal would continuously be generated.	Same as 4B.	0.2976	
10B	Post-Purge Enable Latch and Output Gate	Stays false.	Circuitry could not recognize the presence of a post-purge command.	Same as 7A.	0.2976	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
11A	Fan A Fast* Input Circuit and Fan On	Stays true.	Purge commands could be generated when fan was off (fan would always appear on).	Purges could occur without purge air available if the fans also failed (would require double failure)--safety hazard.	0.3625	
11B	Fan A Fast* Input Circuit and Fan On	Stays false.	Purge commands always inhibited.	Same as 1A.	0.3625	
12A	Fan A Stop* Signal	Stays True.	Fan Stop* signal to boiler safety stays true.	Same as Boiler Safety Item 18A	0.2609	
12B	Fan A Stop* Signal	Stays false.	Fan Stop* signal to boiler safety stays false.	Same as Boiler Safety Item 18B	0.2609	
13A	Fan A Slow*/Fan B Slow* and Fast* Circuits	Stays true.	Same as 11A.	Same as 11A.	0.4110	
13B	Fan A Slow*/Fan B Slow* and Fast* Circuits	Stays false.	No effect.	No effect.	0.4110	
14A	Fan B Stop* Circuit	Stays true.	Same as 12A.	Same as 12A.	0.1662	
14B	Fan B Stop* Circuit	Stays false.	No effect.	No effect.	0.1662	
15A	Purge Start Gates	Stays true.	Start Purge signal always present.	Same as 4B.	0.1578	
15B	Purge Start Gates	Stays false.	Purge Start signals never recognized.	Same as 1A	0.1578	
16A	Purge Latch Circuitry	Stays set.	Purge command constantly enabled whenever fan on and burner valves closed.	Purges would occur whenever fan on and burner valves closed. Not serious.	0.7665	
16B	Purge Latch Circuitry	Stays reset.	Purge command always disabled.	Same as 1A.	0.7665	
17A	Start Purge Output Signal	Stays true.	Start Purge signal to Prelight and Boiler Safety cards stay true.	Same as Boiler Safety Item 19A.	0.1410	
17B	Start Purge Output Signal	Stays false.	Start Purge signal to Prelight and Boiler Safety stays false.	Same as Boiler Safety Item 18B.	0.1410	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
18A	Purge Command Gate	Stays true.	Purge command and open. All A/R signals always inhibited.	Same as 1A.	0.4017	
18B	Purge Command Gate	Stays false.	Circuitry would command purge during normal operation.	No effect at high steam demand rates except possibly higher excess air than desirable. At low demand rates, could blow out burner which should cause boiler trip if trip circuitry non-failed.	0.4017	
19A	Purge Command Inverter	Stays true.	Purge timer would run continuously--finished purge signal would repeatedly occur.	Prelight card would generate erroneous purge finished signals--same as Prelight Item 14B.	0.0631	
19B	Purge Command Inverter	Stays false.	Purge timer would never trigger on-purge finished signal would stay false.	Prelight card would never generate purge finished signals--same as Prelight Item 1A/14A.	0.0631	
20A	Open All A/R Output Circuits	Stays true.	Purge* signal to Burner Logic B card stays true.	Same as Burner Logic B Card Item 2A.	0.0757	
20B	Open All A/R Output Circuits	Stays false.	Purge* signal to Burner Logic B card stays false.	Same as Burner Logic B Card Item 2B.	0.0757	
21A	Purge Air* Output Circuit	Stays true.	Signal to purge air demand solenoid valve always energized; purge air flow would occur during normal operation.	Same as 18B.	17.3425	
21B	Purge Air* Output Circuit	Stays false.	Signal to purge air demand solenoid valve never energized; purge air flow would not occur.	Same 25B.	17.3425	
22A	All Burner Valves Closed Input Circuit	Stays true.	Purge air could be commanded when a burner valve was open.	No effect unless a second failure caused a burner valve to open; explosion hazard in the case.	0.2924	
22B	All Burner Valves Closed Input Circuit	Stays false.	Failed signal would inhibit generation of a purge air command; purge sequence would fail.	Same as 1A.	0.2924	
23A	Combustion Air and Spare Input Circuits	Stays false.	Purge command gate would always inhibited--same as 22B.	Same as 1A.	0.7904	

SHIP: SHIP A SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
23B	Combustion Air and Spare Input Circuits	Stays true.	No effect.	No effect.	0.7904	
24A	Purge Stop Circuit	Stays true.	Purge latch would stay reset--same as 16B.	Same as 1A.	0.2451	
24B	Purge Stop Circuit	Stays false.	No effect.	No effect.	0.2451	
25A	All A/R Open Input Circuit	Stays true.	Purge timers could be started when A/R' were closed.	If A/R's failed to open, purge cycle would time out with no airflow nor purge fail alarm. Would take two failures for safety hazard.	0.2924	
25B	All A/R Open Input Circuit	Stays false.	Purge timers would not start; purge fail latch would be set.	Purge cycle would stop and purge fail alarm would occur.	0.2924	
26A	Purge Air Flow Adeq* Input Circuit	Stays true.	Purge timers could be started when purge airflow was not adequate.	If failure caused inadequate airflow, purge cycle would time out as though normal. There would be no purge fail alarm. Would take two failures for safety hazard.	0.2577	
26B	Purge Air Flow Adeq* Input Circuit	Stays false.	Same as 25B.	Same as 25 B.	0.2577	
27A	Spare Input Circuit	Stays true.	No effect.	No effect.	0.2789	
27B	Spare Input Circuit	Stays false.	Same as 25B.	Same as 25B.	0.2789	
28A	Purge Permissives Met* Gate	Stays true.	Timers could be started when purge permissives had not been met.	If second failure caused A/R's not to open or inadequate airflow, purge cycle would time out as though normal. There would be no purge fail alarm. Would take two failures for safety hazard.	0.4017	
28B	Purge Permissives Met* Gate	Stays false.	Same as 25A.	Same as 25A.	0.4017	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.1 PURGE CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
29A	Purge Permissives Met* Timer	Stays true.	Purge fail latch would be set and purge fail signal generated, causing prelight control to generate and send back the Purge Fail or Complete signal. This would inhibit further purges. Purge Fail alarm would occur.	Same as 1A.	0.2727	
29B	Purge Permissives Met* Timer	Stays false.	Same as 28A.	Same as 28A.	0.2727	
30A	Purge Timer	Stays true.	Finished purge signal would always be true and prelight control would always generate and send back purge fail or complete signal, keeping the purge latch reset, and thus inhibiting purge commands.	Same as 1A.	0.7552	
30B	Purge Timer	Stays false.	Finished purge signal would never be generated. Purge fail latch would be set, purge fail alarm would occur, and purge sequence would be inhibited.	Same as 1A.	0.7552	
31A	Start Purge Annunciator	Stays true.	Start Purge lamp always stays lit.	False alarm--possible crew confusion. No impact on system operation unless failure causes crew to take incorrect action.	7.1231	
31B	Start Purge Annunciator	Stays false.	Start Purge lamp will not light.	Crew confusion during purges, i.e., no indication that purge was in progress. Best crew approach would be to purge as in 1A.	28.4926	
32A	Reset* Input Circuit	Stays true.	Purge fail latch would stay reset--same as 34B.	Same as 28A.	0.2687	
32B	Reset* Input Circuit	Stays false.	Purge fail latch would not reset--same as 34A.	Same as 1A.	0.2687	
33A	Minimum Purge Timer	Stays false.	Minimum purge timer would appear never to time out, thus causing purge timer to set the purge fail latch, thus inhibiting purge sequence. Purge Fail alarm would	Same as 1A.	0.5924	

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
33B	Minimum Purge Timer	Stays true.	Minimum purge timer would always appear to have timed out. Finished purge signal could be erroneously generated, (i.e., before purge was complete) by purge timer if its timing was incorrect.	No effect if Purge Timer (item 30) non-failed. If purge timer failed, same as item 1A.	0.5924	
34A	Purge Fail Latch	Stays set.	Purge Fail signal stays true; purge would be inhibited and Purge Fail alarm would occur.	Same as 1A.	0.5272	
34B	Purge Fail Latch	Stays reset.	Conditions that should cause a purge fail would not be detected.	Same as 28A.	0.5272	
35A	Purge Fail* Output Circuit	Stays true.	Purge latch would stay reset--same as item 16B.	Same as 1A.	0.0757	
35B	Purge Fail* Output Circuit	Stays false.	Same as 34B.	Same as 28A.	0.0757	
36A	Prelight Fail Input Circuit	Stays true.	Purge Fail latch would stay set--same as item 34A.	Same as 1A.	0.3487	
36B	Prelight Fail Input Circuit	Stays false.	Purge Fail latch would not set if prelight max period timed out without A/R's closing.	Purge sequence would terminate as though normal without checking to see if A/R's closed at end of sequence. No effect if A/R's did close. Airflow would be too high for light off if A/R's did not close.	0.3487	
37A	Spare Input Circuit	Stays true.	Same as 36A.	Same as 1A.	0.2798	
37B	Spare Input Circuit	Stays false.	No effect.	No effect.	0.2798	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.2 PRELIGHT CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Prelight Control Card Common Circuitry	Open.	Lose power or power on reset signal to entire card--card would not function.	Boiler could not be lit from ERC.	1.1433	
1B	Prelight Control Card Common Circuitry	Short.	Main 24 volt power shorted out on card.	Power to ALL cards and Local Panel shorted out--lose ERC and Local Panel.	0.9444	
2A	Atomizing Steam Pressure OK* Input Circuit	Stays true.	Boiler Ready signal would not be inhibited if atomizing steam pressure inadequate.	If second failure caused inadequate atomizing steam pressure, boiler would not light but F.O. would flow--safety hazard. Boiler trip would occur via burner valve open and no flame.	0.3082	
2B	Atomizing Steam Pressure OK* Input Circuit	Stays false.	Boiler Ready signal would stays inhibited.	Same as 1A.	0.3082	
3A	F.O. Hdr. Pressure OK* Input Circuit	Stays true.	Boiler Ready signal would not be inhibited if F.O. hdr. pressure not adequate.	If second failure caused inadequate F.O. hdr. pressure, boiler would not light. There could still be F.O. flow and safety hazard even at low F.O. pressure.	0.3398	
3B	F.O. Hdr. Pressure OK* Input Circuit	Stays false.	Same as 2B.	Same as 1A.	0.3398	
4A	F.O. Hdr. Temperature OK* Input Circuit	Stays true.	Boiler Ready signal would not be inhibited if F.O. Hdr. temperature too high or too low.	If second failure caused high F.O. temperature, smoke and inefficient combustion would result. Flame scanner could not "see" flame through the smoke and boiler trip would result. If second failure caused low F.O. temperature, F.O. would not flow and boiler would not light. Boiler trip would occur via burner valver open and no flame.	0.3398	
4B	F.O. Hdr. Temperature OK* Input Circuit	Stays false.	Same as 2B.	Same as 1A.	0.3398	
5A	Master F.O. Valve Open* Input Circuit	Stays true.	Boiler Ready signal would not be inhibited if master F.O. valve were closed.	If second failure caused Master F.O. valve to remain shut, boiler would not light anyway--no effect.	0.3487	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A — SUBSYSTEM: 1.1.2 PRELIGHT CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	COMMENT INDEX
5B	Master F.O. Valve Open* Input Circuit	Stays false.	Same as 2B.	Same as 1A.	0.3487	
6A	Boiler Trip Input Circuit	Stays true.	Boiler Ready signal could be generated when boiler trip condition exists.	Same as Boiler Safety FMECA, item 32A.	0.2556	
6B	Boiler Trip Input Circuit	Stays false.	Same as 2B.	Same as 1A.	0.2556	
7A	Permissive Circuit	Stays true.	Boiler Ready circuit would not be inhibited if permissive absent.	Boiler could be lit when permissive not met.	0.5812	
7B	Permissive Circuit	Stays false.	Same as 2B.	Same as 1A.	0.5812	
8A	Permissive Circuit	Stays true.	Same as 7A.	Same as 7A.	0.1368	
8B	Permissive Circuit	Stays false.	Same as 7A.	Same as 7A.	0.1368	
9A	Boiler Ready to Light Lamp Driver Circuit	Stays true.	Boiler Ready lamp would stay lit--absence of boiler light-up permissive would not inhibit lamp signal.	During boiler light-off, boiler could be lit when a second failure had occurred if crew not alerted to second failure via other alarms or meter readings.	2.7516	
9B	Boiler Ready to Light Lamp Driver Circuit	Stays false.	Boiler Ready lamp would stay dark.	Crew would think they could not proceed with light-up from ERC.	2.7516	
10A	Prelight Conditions Check Gate U2	Stays true.	Boiler Ready signal could be generated when prelight conditions not met.	If second failure occurred, would cause same effect as 2A, 3A, 4A, 5A, or 7A, depending on effect of second failure.	0.4017	
10B	Prelight Conditions Check Gate U2	Stays false.	Same as 2B.	Same as 1A.	0.4017	
11A	Prelight Conditions Check Gate U5	Stays true.	Boiler Ready signal always generated--even when boiler trip condition exists or when prelight conditions not met.	If second failure occurred, would cause same effect as 2A, 3A, 4A, 5A, 6A, or 7A, depending on effect of second failure. Also, Boiler Ready lamp would stay on.	0.0885	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
11B	Prelight Conditions Check Gate U5	Stays false.	Same as 2B.	Same as 1A.	0.0885	
12A	Boiler Ready* Output Circuit	Stays true.	Same as 11A.	Same as 11A, except Boiler Ready lamp would function normally.	0.1446	
12B	Boiler Ready* Output Circuit	Stays false.	Boiler Ready signal to Burner Logic A would stay inhibited.	Same as Burner Logic A FMECA, item 6A.	0 [illegible]46	
13A	Spare Circuit 2	Stays false.	Same as 2B.	Same as 1A.	0.1446	
13B	Spare Circuit 2	Stays true.	No effect.	No effect.	0.1446	
14A	Finished Purge* Input Circuit	Stays true.	Purge Complete latch would never set (i.e., stay reset); purge sequence would never appear to be finished.	Same as 1A.	0.2856	
14B	Finished Purge* Input Circuit	Stays false.	Purge Complete latch would "try" to stay set but the presence of any reset signal would reset it. It could stay set long enough to generate an erroneous purge complete signal.	Purge Sequence could be terminated before complete--safety hazard.	0.2856	
15A	Purge Complete Latch	Stays set.	Purge would always appear to be complete--would inhibit generation of purge commands on purge control card.	No auto or semi-auto purge; safety hazard.	0.5337	
15B	Purge Complete Latch	Stays reset.	Purge would never appear to be complete--prelight sequence could not continue.	Boiler could not be lit from ERC without manual intervention to interrupt purge cycle.	0.5337	
16A	Start Purge* Input Circuit	Stays true.	Purge Complete latch held reset.	Same as 15B.	0.2924	
16B	Start Purge* Input Circuit	Stays false.	Purge Complete latch would not be reset at beginning of purge; same as 15A.	Same as 15A.	0.2924	
17A	All Burner Valves Closed Input Circuit	Stays true.	Same as 16A.	Same as 15A.	0.2924	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.2 PRELIGHT CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
17B	All Burner Valves Closed Input	Stays false.	Purge Complete latch would not be reset if a burner valve opened	Purge could occur with burner valve open--safety hazard.	0.2924	
18A	Any Burner Valve Open* Input Circuit	Stays true.	Same as 16A.	Same as 15B.	0.2924	
18B	Any Burner Valve Open* Input Circuit	Stays false.	Same as 17B.	Same as 17B.	0.2924	
19A	Purge Complete Latch Reset Gate	Stays true.	Purge Complete latch held reset.	Same as 15B.	0.2009	
19B	Purge Complete Latch Reset Gate	Stays false.	Purge Complete Latch would not be reset at start of purge cycle or if burner valve opened.	Same as 15A.	0.2009	
2C	Purge Fail or Complete Output Circuit	Stays true.	Same as item 8A, Purge Control card FMECA.	Same as item 1A, Purge Control card FMECA.	0.1779	
20B	Purge Fail or Complete Output Circuit	Stays false.	Same as item 8B, Purge Control card FMECA.	Same as item 8B, Purge Control card FMECA.	0.1779	
21A	Purge Complete Lamp Driver Circuit	Stays true.	Purge Complete lamp would stay lit--absence of Boiler Ready signal would not inhibit lamp signal.	Same as 9A.	2.6769	
21B	Purge Complete Lamp Driver Circuit	Stays false.	Purge Complete lamp would stay dark.	Same as 9B.	2.6769	
22A	Purge Complete Signal to Prelight Gate	Stays true.	Prelight signal would occur whenever A/R's were closed. (purge cycle would appear complete).	Same as 15A.	0.2202	
22B	Purge Complete Signal to Prelight Gate	Stays false.	Prelight signal would stay inhibited.	Same as 1A.	0.2202	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.2 PRELIGHT CONTROL

REF. NO.	ITEM NOMENCLATURE & FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
23A	Prelight Circuit	Stays true.	Prelight and Boiler Ready signals would occur without consideration of purge status.	Boiler could be lit without purging--safety hazard.	0.2678	
23B	Prelight Circuit	Stays false.	Same as 22B.	Same as 1A.	0.2678	
24A	Spare Circuits 3 and 4	Stays false.	Same as 22B.	Same as 1A.	0.6353	
24B	Spare Circuits 3 and 4	Stays true.	No effect.	No effect.	0.6353	
25A	Purge Fail Input Circuit	Stays true.	Purge Fail or Complete signal always generated--same as item 35A, Purge Control card FMECA.	Same as item 1A, Purge Control card FMECA.	0.2924	
25B	Purge Fail Input	Stays false.	Same as item 34B, Purge Control card FMECA.	Same as item 28A, Purge Control card FMECA.	0.2924	
26A	All A/R Closed Input Circuit	Stays true.	Prelight and Boiler Ready signals would not be inhibited if air regs open.	Boiler could be lit with A/R's open--fuel safety problem (F.O. would flow, flame would be blown out) if flame-out not detected.	0.3928	
26B	All A/R Closed Input Circuit	Stays false.	Same as item 22B.	Same as item 1A.	0.3928	
27A	Prelight Timer	Stays true.	Purge Complete latch would stay reset--same as item 15B.	Same as item 15B.	1.0468	
27B	Prelight Timer	Stays false.	Time-out reset of purge control latch would not occur; Boiler Ready signal would stay true past alloted time period.	Boiler could be lit too long after purge--safety hazard.	1.0468	
28A	Maximum Prelight Timer	Stays true.	Prelight Fail signal stays false--same as item 36B, Purge Control FMECA.	Same as item 36B, Purge Control FMECA.	1.2171	
28B	Maximum Prelight Timer	Stays false.	Prelight Fail signal stays true--same as item 36A, Purge Control FMECA.	Same as item 1A, Purge Control FMECA.	1.2171	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.3 BOILER SAFETY | PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Common Circuitry	Open.	Lose power or Power On reset to entire card--card would not tion.	Master fuel oil valve would de-energize--boiler would shutdown.	1.3942	
1B	Common Circuitry	Short.	Main 24 volt power shorted on card.	Power to ALL cards and Local Panel shorted out--lose ERC and Local Panel.	0.5234	
2A	Master Fuel Valve Solenoid Driver Circuit	Stays true.	Master Fuel valve would stay energized (i.e., open).	Boiler could not be tripped via Master Fuel Valve automatically. Trips would still shutdown burner valves.	1.5894	
2B	Master Fuel Valve Solenoid Driver Circuit	Stays false.	Master Fuel valve de-energizes (i.e., closed).	Boiler flame-out; boiler trip would also occur if trip circuitry non-failed.	1.5894	
3A	Manual Trip Latch	Stays set.	Same as 2B (logic "thinks" it received manual trip signal).	Same as 2B.	0.2894	
3B	Manual Trip Latch	Stays reset.	Master F.O. valve could not be tripped via manual trip switch.	Lose backup manual boiler trip capability.	0.2894	
4A	Master F.O. Valve Trip PB Input Circuit	Stays true.	Same as 2B (same as 3A).	Same as 2B.	0.1950	
4B	Master F.O. Valve Trip PB Input Circuit	Stays false.	Same as 3B.	Same as 3B.	0.1950	
5A	Master F.O. Valve Reset PB Input Circuit	Stays true.	Manual trip latch stays reset and recirculation latch stays set. Master F.O. valve will stay open.	Same as 2A.	0.1950	
5B	Master F.O. Valve Reset PB Input Circuit	Stays false.	Lose switch function (i.e., F.O. recirculation).	Master F.O. valve could not be opened manually via reset switch for F.O. recirculation.	0.1950	
6A	All Burner Valves Closed Input Circuit	Stays true.	All burner valves would appear closed; recirculation latch would stay reset; lose Master F.O. Valve Reset PB function--same as 5B.	Same as 5B.	0.3497	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A SUBSYSTEM: 1.1.3 BOILER SAFETY PAGE: 2

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
6B	All Burner Valves Closed Input Circuit	Stays false.	Recirculation latch would not reset if any burner valve opened; Master F.O. valve reset PB would not be inhibited if a burner valve opened.	Recirculation could be manually commanded with a burner valve open--safety hazard. There is a redundant signal that protects against this--see item 13.	0.3497	
7A	Recirculation Latch	Stays set.	Master F.O. valve will always receive open command--same as 2A.	Same as 2A.	0.5972	
7B	Recirculation Latch	Stays reset.	Lose Master F.O. Valve Reset PB function--same as 5B.	Same as 5B.	0.5972	
8A	Master F.O. Valve Open Limit SW Input Circuit	Stays true.	Master F.O. valve always appears open--same as Prelight Control FMECA item 5A.	Same as Prelight Control FMECA item 5A.	0.2564	
8B	Master F.O. Valve Open Limit SW Input Circuit	Stays false.	Master F.O. Valve Open Command would be inhibited--same as 2B.	Same as 2B.	0.2564	
9A	Master F.O. Valve Open Output Circuit	Stays true.	Master F.O. valve always appears to be open; closed status would not inhibit Master F.O. Valve Open command.	Boiler trip alarm could occur when boiler was shutdown--nuisance only.	0.1464	
9B	Master F.O. Valve Open Output Circuit	Stays false.	Same as 8B/2B.	Same as 2B.	0.1464	
10A	Master F.O. Valve Open* Output Circuit	Stays true.	Same as Prelight Control FMECA item 5A.	Same as Prelight Control FMECA item 5A.	0.0795	
10B	Master F.O. Valve Open* Output Circuit	Stays false.	Same as Prelight Control FMECA item 2B.	Same as Prelight Control FMECA item 1A.	0.0795	
11A	Master F.O. Valve Closed Limit SW Circuit	Stays true.	Master F.O. valve would appear closed in "OK to Lightoff B" circuit and on purge control card--same as Purge Control card item 6A.	Same as Purge Control card FMECA item 6A.	'0.2563	
11b	Master F.O. Valve Closed Limit SW Circuit.	Stays false.	Same as Purge Control card FMECA item 6B.	Same as Purge Control card FMECA item 6B.	0.2563	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A SUBSYSTEM: 1.1.3 BOILER SAFETY

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
12A	Master F.O. Valve Closed* Output Circuit	Stays true.	Same as Purge Control card FMECA item 6A.	Same as Purge Control card FMECA item 6A.	0.1464	
12B	Master F.O. Valve Closed* Output Circuit	Stays false.	Same as Purge Control card FMECA item 6B.	Same as Purge Control card FMECA item 6B.	0.1464	
13A	Any Burner Valve Open* Input Circuit	Stays true.	F.O. recirculation valve open. Command would be inhibited.	F.O. could not be recirculated--would be a problem if boiler was down and recirculation needed to keep F.O. temperature adequate.	0.3593	
13B	Any Burner Valve Open* Input Circuit	Stays false.	F.O. recirculation would not be inhibited if a burner valve was open.	Safety hazard if F.O. was being recirculated and a burner valve was open.	0.3593	
14A	F.O. Recirculation Valve Solenoid Driver Circuit	Stays true.	F.O. recirculation valve would stay open.	Would divert F.O. from burner valves, with subsequent flame-out.	1.3931	
14B	F.O. Recirculation Valve Solenoid Driver Circuit	Stays false.	F.O. recirculation valve could not be opened.	Same as 13A.	1.3931	
15A	Any Burner On* Input Circuit	Stays true.	OK to Lite Off A signal would stay true whenever Master F.O. Valve was closed.	Boiler could be lit without purging--safety hazard.	0.2924	
15B	Any Burner On* Input Circuit	Stays false.	OK to Lite Off A signal would go false after prelight and trial for ignition.	Boiler trip would occur if redundant counterpart incurred same failure mode.	0.2924	
16A	Prelight* Input Circuit	Stays true.	OK to Lite Off A signal would stay true.	Same as 15A.	0.3777	
16B	Prelight* Input Circuit	Stays false.	OK to Lite Off A signal would stays false at beginning of lite off sequence.	Boiler could not be lit if redundant counterpart incurred same failure mode.	0.3777	
17A	Trial for Igniting Any Burner* Input Circuit	Stays true.	Same as item 16A.	Same as item 15A.	0.3777	
17B	Trial for Igniting Any Burner* Input Circuit	Stays false.	OK to Lite Off A signal would go false after prelight period.	Same as 16B.	0.3777	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.3 BOILER SAFETY

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
18A	Fan On* Input Circuit	Stays true.	Lose fan stauts check in one redundant leg of boiler trip circuit.	Boiler trip would not occur if fan stopped if redundant counterpart incurred same failure mode.	0.3777	
18B	Fan On* Input Circuit	Stays false.	Boiler trip signal would be generated.	Boiler would shutdown.	0.3777	
19A	Start Purge* Input Circuit	Stays true.	Master F.O. valve close signal would not be generated for purge.	Purge would occur with Master F.O. valve open--safety hazard.	0.2924	
19B	Start Purge* Input Circuit	Stays false.	Same as 18B.	Same as 18B.	0.2924	
20A	Start Purge* Inverter	Stays true.	Recirculation latch could not be set--same as 7B.	Same as 5B.	0.0669	
20B	Start Purge* Inverter	Stays false.	Recirculation latch could be set while purge in progress.	Master F.O. valve could be opened manually during purge--human error/safety hazard.	0.0669	
21A	Any Burner Off and BV Not Closed* Input Circuit	Stays true.	Boiler trip signal would not be generated if burner valve open and flame out.	Lose boiler trip protection on burner flame out--safety hazard.	0.3777	
21B	Any Burner Off and BV Not Closed* Input Circuit	Stays false.	Same as 18B.	Same as 18B.	0.3777	
22A	Drum Level Below Lo-Lo Input Circuit	Stays true.	Boiler Trip signal would not be generated if boiler drum level fell below low-low limit if redundant counterpart failed in same mode.	Lose boiler trip protection on boiler level lo-lo condition if redundant counterpart incurred same failure mode--if lo-lo level occurred, lose cooling of boiler surfaces and possible boiler explosion.	0.5275	
22B	Drum Level Below Lo-Lo Input Circuit	Stays false.	Same as 18B.	Same as 18B.	0.5275	
23A	Drum Level Below Lo-Lo Input Circuit	Stays true.	Same as 18B.	Same as 18B.	0.1768	
23B	Drum Level Below Lo-Lo Input Circuit	Stays false.	No effect.	No effect.	0.1768	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.3 BOILER SAFETY

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
24A	OK to Lite Off A Gate U16	Stays true.	Master F.O. valve appears closed and burner valves appear off--OK to Lite Off A signal always true.	Same as 15A.	0.1004	
24B	OK to Lite Off A Gate U16	Stays false.	Same as 15B.	Same as 15B.	0.1004	
25A	OK to Lite Off U7	Stays true.	OK to Lite Off A signal always true.	Same as 15A.	0.1339	
25B	OK to Lite Off U7	Stays false.	Lose OK to Lite Off A signal--Boiler Trip signal would stay true.	Same as 18B.	0.1339	
26A	Spare Input Circuits	Stays false.	Same as item 18B.	Same as item 18B.	1.1941	
26B	Spare Input Circuits	Stays true.	No effect.	No effect.	1.1941	
27A	Boiler Trip 1* Logic Circuits	Stays true.	Boiler Trip signal never generated from this leg of the redundancy.	Lose boiler trip protection if redundant counterpart incurs same failure mode--safety hazard, i.e.: - Boiler could be lit without purging - Boiler would not trip if fan stopped - Purge could occur with Master F.O. valve open - Boiler would not trip on level lo-lo condition.	0.8101	
27B	Boiler Trip 1*	Stays false.	Same as #18B.	Same as #18B.	0.8101	
28A	Boiler Trip 1* Output Circuit	Stays true.	Boiler Trip signal to Burner Logic B never generated from this leg of the redundancy; Burner Logic B would not shutdown burner valves if trip condition occurred.	Same as 27A.	0.0921	
28B	Boiler Trip 1* Output Circuit	Stays false.	Burner Logic B would shutdown burner valves--same as 18B.	Same as 18B.	0.0921	
29A	Boiler Trip* Circuit	Stays true.	Same as 27A.	Same as 27A.	0.1338	
29B	Boiler Trip* Circuit	Stays false.	Same as 18B.	Same as 18B.	0.1338	

SHIP: SHIP A

SUBSYSTEM: 1.1.3 BOILER SAFETY

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
30A	Boiler Trip 1 Logic Circuits	Stays true.	Same as 27A.	Same as 27A.	0.2442	
30B	Boiler Trip 1 Logic Circuits	Stays false.	Same as 18B.	Same as 18B.	0.2442	
31A	Boiler Trip 1 Output Circuit	Stays true.	Same as 28A.	Same as 27A.	0.2183	
31B	Boiler Trip 1 Output Circuit	Stays false.	Same as 28B/18B.	Same as 18B.	0.2183	
32A	Boiler Trip Output Circuit	Stays true.	Boiler Ready signal on Prelight Card would be generated when boiler trip condition exists. Burner Logic A card pre-purge latch would set.	Boiler could be lit when trip condition exists, i.e., fan stopped; if fan boiler level lo-lo. Safety hazard. Fuel safety trip alarm/lamp would not activate.	0.2720	
32B	Boiler Trip Output Circuit	Stays false.	Boiler Ready signal on Pre-light card would stay inhibited.	Boiler could not be lit from ERC. Fuel safety trip alarm/lamp would stay activated.	0.2720	
33A	Master F.O. Valve Input Circuit	Stays true.	Master F.O. valve open command would not be inhibited by master F.O. valve closed status.	False alarms when boiler is in shutdown state--nuisance only.	0.2798	
33B	Master F.O. Valve Input Circuit	Stays false.	Master F.O. valve open command would false and valve solenoid would de-energize.	Same as 2B.	0.2798	
34A	Open Master F.O. Valve Signal	Stays true.	Master F.O. valve solenoid would stay energized--same as 2A.	Same as 2A.	0.1130	
34B	Open Master F.O. Valve Signal	Stays false.	Same as 2B.	Same as 2B.	0.1130	
35A	Fan Stop* Input Circuit	Stays true.	Same as 18A.	Same as 18A.	0.2856	
35B	Fan Stop* Input Circuit	Stays false.	Same as 18B.	Same as 18B.	0.2856	
36A	Spare Input Circuit	Stays true.	No effect.	No effect.	0.2798	

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
36B	Spare Input Circuit	Stays false.	Same as 18B.	Same as 18B.	0.2798	
37A	All Burners Off Input Circuit	Stays true.	OK to Lite Off B signal would stay true whenever Master F.O. valve was closed.	Same as 15A.	0.3593	
37B	All Burners Off Input Circuit	Stays false.	OK to Lite Off B signal would go false after pre-light period had timed out.	Same as 15B.	0.3593	
38A	OK to Lite Off B Gate U15	Stays true.	Same as 24A except for OK to Lite Off B signal.	Same as 15A.	0.1004	
38B	OK to Lite Off B Gate U15	Stays false.	Same as 37B.	Same as 15B.	0.1004	
39A	OK to Lite Off B Gate	Stays true.	OK to Lite Off B signal always true.	Same as 15A.	0.1465	
39B	OK to Lite Off B Gate	Stays false.	Same as 25B except for B signal.	Same as 18B.	0.1465	
40A	Prelight Time Delay Circuit	Stays true.	Same as 39A.	Same as 15A.	1.0149	
40B	Prelight Time Delay Circuit	Stays false.	OK to Lite Off B signal would stay false through lightoff period.	Same as 16B.	1.0149	
41A	Actual Drum Level Circuit	Stays true.	Same as 22A.	Same as 22A.	1.4359	
41B	Actual Drum Level Circuit	Stays false.	Same as 18B.	Same as 18B.	1.4359	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4A BURNER LOGIC A |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Burner Logic A Card Common Circuity	Open.	Lose power to card or Power On reset fail--lose all functions on card.	Effected burner could not be lit.	0.8093	
1B	Burner Logic A Card Common Circuitry	Short.	Main 24 volt power shorted out on card.	Power to ALL cards and Local Panel shorted out--lose ERC and local panel.	0.5071	
2A	Burner on PB* Input Circuit	Stays true.	In auto mode, start sequence and purge sequence would stay initiated.	Same as Purge Control FMECA item 5B/4B.	0.2609	
2B	Burner on PB* Input Circuit	Stays false.	Lose burner on pushbutton function.	Burner could not be lit from ERC.	0.2609	
3A	BM Auto* Input Circuit	Stays false.	Auto mode logic would always be enabled; burner on/off pushbuttons could be activated in manual mode.	If PB's erroneously pushed, burner would lite/shutdown without purge--safety hazard.	0.3467	
3B	BM Auto* Input Circuit	Stays true.	Lose Burner On and Burner Off pushbutton functions.	Burner could not be lit or shut off from ERC.	0.3467	
4A	Burner On PB AND Gate	Stays true.	Start sequence and purge sequence would stay initiated--manual or auto mode.	Same as Purge Control FMECA item 5B/4B.	0.1004	
4B	Burner On PB AND Gate	Stays false.	Same as 2B.	Same as 2B.	0.1004	
5A	Pre-Purge Command* Input Circuit	Stays true.	Pre-purge latch could be set when another burner is commanding pre-purge.	Lose inhibit protection against starting a purge when one is already in progress.	0.2846	
5B	Pre-Purge Command* Input Circuit	Stays false.	Pre-purge latch could not be set via Burner On PB; would inhibit start sequence.	Same as 2B.	0.2846	
6A	Boiler Ready* Input Circuit	Stays true.	Pre-purge latch could be set when another burner is already ready to light. Another purge would be initiated.	Lose inhibit protection against starting a lite-off sequence when one is already in progress.	0.2924	
6B	Boiler Ready* Input Circuit	Stays false.	Same as 5B.	Same as 2B.	0.2924	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.4A BURNER LOGIC A

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
7A	Trial for Ignition*--Input Circuit	Stays true.	Pre-purge latch could be set when another burner is in its trial for ignition period.	Same as 6A.	0.2924	
7B	Trial for Ignition*--Input Circuit	Stays false.	Same as 5B.	Same as 2B.	0.2924	
8A	Any Burner On* Input Circuit	Stays true.	Pre-purge latch could be set when another burner is already on.	Lose protection against starting a purge when a burner is already lit.	0.2924	
8B	Any Burner On* Input Circuit	Stays false.	Same as 5B.	Same as 2B.	0.2924	
9A	Inhibit Gate	Stays true.	Pre-purge latch could be set when any inhibit condition	Any of items 5A, 6A, 7A, or 8A could occur.	0.2004	
9B	Inhibit Gate	Stays false.	Same as 5B.	Same as 2B	0.2004	
10A	Unused Input Circuits	Stays true.	No effect.	No effect.	0.5265	
10B	Unused Input Circuits	Stays false.	Same as 5B.	Same as 2B.	0.5265	
11A	OK to Light* Output Circuit	Stays false.	Burner Logic B card could proceed with light-up when permissives not met.	Same as Burner Logic B card item 9B.	0.2677	
11B	OK to Light* Output Circuit	Stays true.	Inhibits Burner Logic B card from lighting burner.	Same as Burner Logic B card Item #8B.	0.2677	
12A	Pre-purge Latch	Stays set.	Pre-purge comamnd would stay "false"; same as Purge Control card item 5B.	Same as Purge Control card FMECA item 4B.	0.6434	
12B	Pre-purge Latch	Stays reset.	Same as item 5B.	Same as item 2B.	0.6434	
13A	Pre-purge Timer	Stays true.	Pre-purge latch would stay reset--same as item 12B.	Same as item 2B.	1.7773	
13B	Pre-purge Timer	Stays false.	Pre-purge latch would not reset folowing activation of Burner On PB switch; coud be reset by Purge Fail. Pre-Purge Command* to Purge Control would stay active.	Same as Purge Control card FMECA item 5B.	1.7773	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.4A BURNER LOGIC A

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
14A	Purge Fail Input Circuit	Stays true.	Pre-purge latch would stay reset--same as item 5B.	Same as item 2B.	0.2924	
14B	Purge Fail Input Circuit	Stays false.	Pre-purge latch would not be reset following failure of purge cycle.	Same as Purge Control card item 28A.	0.2924	
15A	Trip Pulse Input--Not Used	Stays true.	Same as item 14A.	Same as 2B.	0.2924	
15B	Trip Pulse Input--Not Used	Stays false.	No effect.	No effect.	0.2924	
16A	Insert Ignition Input--Not Used	Stays true.	Same as item 14A.	Same as 2B.	0.7135	
16B	Insert Ignition Input--Not Used	Stays false.	No effect.	No effect.	0.7135	
17A	Burner Off PB Input Circuit	Stays true.	Burner Off PB would always appear activated--Off Command* would stay true.	Burner would trip off and stay off.	0.3966	
17B	Burner Off PB Input Circuit	Stays false.	Lose Burner Off pushbutton function.	Burner shutdown not possible from ERC.	0.3966	
18A	Off Input Circuits--Not Used	Stays true.	Same as item 17A.	Same as item 17A.	0.5570	
18B	Off Input Circuits--Not Used	Stays false.	No effect.	No effect.	0.5570	
19A	Pre-Purge Command* Output	Stays false.	Purge would stay activated--same as Purge Control card FMECA item 5B.	Same as Purge Control card FMECA item 4B.	0.1590	
19B	Pre-Purge Command* Output	Stays true.	Purge control card pre-purge logic never activated--same as Purge Control card FMECA item 5A.	Same as Purge Control card FMECA item 5A.	0.1590	
20A	Start Sequence* Output	Stays true.	Same as Burner Logic B card item 8A.	Same as Burner Logic B card item 8A.	0.1673	
20B	Start Sequence* Output	Stays false.	Same as Burner Logic B card item 8B.	Same as Burner Logic B card item 8B.	0.1673	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4A BURNER LOGIC A | PAGE: 4

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
21A	Burner Off Lamp Driver	Stays true.	Burner Off lamp would stay on.	Crew should realise this was erroneous indication. Also, backup available via flame intensity indications.	0.7660	
21B	Burner Off Lamp Driver	Stays false.	Burner Off lamp would never light.	Backup indication available via Burner Off alarm (item 23); also from flame intensity indicators.	0.7660	
22A	Burner On Lamp and Relay Driver	Stays true.	Burner On lamp stays on and Burner Sequencing Relay would stay energized (A2-K4, K5 or K6 for Burners #3, #2, #1, respectively).	Lamp staying on would not be too important. Relay staying energised would prevent effected burner being sequenced on to meet increases in load demand (i.e., relay logic would "think" burner was already on).	0.8934	
22B	Burner On Lamp and Relay Driver	Stays false.	Burner On lamp would never light and sequencing relay would never energize.	Lamp staying off would not be too important. Relay staying de-energised would prevent effected burner from being sequenced on to meet increases in load demand in this case because relay could not be energised.	0.8934	
23A	Burner Off Alarm Circuit	Stays true.	Burner Off Alarm goes off continuously.	False alarm	0.1673	
23B	Burner Off Alarm Circuit	Stays false.	Lose Burner Off Alarm.	No automatic indication available if burner goes out.	0.1673	
24A	Burner Valve Off Latch	Stays set.	Burner Off lamp and Burner Off alarm continuously energized.	Same as 21A and 23A--not serious.	1.2524	
24B	Burner Valve Off Latch	Stays reset.	Lose Burner Off lamp and burner Off alarm.	Same as 23B.	1.2524	
25A	Ignition Inserted Input/Output	Stays true.	Ignitor Inserted signal to Burner Logic B always active--same as Burner Logic B FMECA item 25B.	Same as Burner Logic B FMECA item 25B.	0.4294	
25B	Ignition Inserted Input/Output	Stays false.	Lose Ignitor Inserted signal to Burner Logic B--same as Burner Logic B FMECA item 25A.	Same as Burner Logic B FMECA item 25A.	0.4294	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.4A BURNER LOGIC A

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
26A	Ignitor Retracted Input/Output	Stays true.	Ignitor Retracted signal to Burner Logic B always active--same as Burner Logic B FMECA item 18B.	Same as Burner Logic B FMECA item 18B.	0.4294	
26B	Ignitor Retracted Input/Output	Stays false.	Lose Ignitor Retracted signal to Burner Logic B--same as Burner Logic B FMECA item 19A.	Same as Burner Logic B FMECA item 19A.	0.4294	
27A	Burner Valve Open Input	Stays true.	Burner valve appears open to all boiler control logic. Same as: Purge Control card 7A and 9A; Prelight card 18A; Boiler Safety 13A and 15A; Burner Logic A 49A.	Boiler could be lit without purging and no purge following boiler safety trip--safety hazard (several other effects possible but this is most critical).	0.2563	
27B	Burner Valve Open Input	Stays false.	Burner valve appears closed to all boiler control logic; same as: Purge Control card 7B and 9B; Prelight card 18B; Boiler Safety 13B and 15B; Burner Logic B 49B.	Purge could occur with burner valve open; burner trip would not be generated if flame-out (several other effects possible but this is most critical).	0.2563	
28A	Burner Valve Closed Input	Stays true.	Burner valve appears to be closed to all boiler control logic. Same as: Purge Control card 22A; Prelight card 17A; Boiler Safety 6A; Burner Logic 10B.	Ignitor could be inserted while a burner valve was open--safety hazard (most critical of several).	0.2563	
28B	Burner Valve Closed Input	Stays false.	Burner valve appears to be open to all boiler control logic. Same as: Purge Control card 22B; Prelight card 17B; Boiler Safety 6B; Burner Logic B 10A.	Light-off sequence would hang-up--same as 2B.	0.2563	
29A	A/R Open Input Circuit	Stays true.	Air Register always appears open--same as: Purge Control card 25A; Burner Logic B card 55B.	Same as Purge Control card item 25A and Burner Logic B card item 55B.	0.1225	
29B	A/R Open Input Circuit	Stays false.	Same as Purge Control card item 25B and Burner Logic B item 55A.	Same as Purge Control card item 25B and Burner Logic B item 55A.	0.1225	
30A	A/R Closed Input Circuit	Stays true.	Air Register always appears closed--same as: Prelight card 26A; Burner Logic B card 55A.	Same as Prelight card 26A and Burner Logic B card item 55A.	0.1225	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.4A BURNER LOGIC A

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
30B	A/R Closed Input Circuit	Stays false.	Same as Prelight card 26B and Burner Logic B item 55B.	Same as Prelight card 26B and Burner Logic B item 55B.	0.1225	
31A	BV Open* Output Circuit	Stays true.	Burner valve appears closed--same as: Purge Control card 7A; Prelight card 17B; Boiler Safety card 13A.	Same as: Purge Control card 7A; Boiler Safety card 13B; Prelight card 17B.	0.0795	
31B	BV Open* Output Circuit	Stays false.	Burner valve never appears closed. Same as: Purge Control card 7B; Prelight card 17B; Boiler Safety card 13A.	Same as: Purge Control card 7B; Boiler Safety card 13A; Prelight card 17B.	0.0795	
32A	BV Open* Output Circuit	Stays true.	Burner valve appears closed--same as Burner Logic B card item 49A.	Same as Burner Logic B card item 49A.	0.0795	
32B	BV Open* Output Circuit	Stays false.	Burner valve never appears closed. Same as: Burner Logic B card item 49B.	Same as Burner Logic B card item 49B.	0.0795	
33A	BV Closed* Output Circuit	Stays true.	Burner valve appears open--same as Burner Logic B card item 10A.	Same as Burner Logic B card item 8B.	0.0795	
33B	BV Closed* Output Circuit	Stays false.	Burner valve never appears open--same as Burner Logic B card item 10B.	Same as Burner Logic B card item 10B.	0.0795	
34A	BV Closed Output Circuit	Stays true.	Burner valve always appears closed--same as: Purge Control card 22A; Prelight card 16A; Boiler Safety card 6B.	Same as: Purge Control card 9B; Prelight card 15B; Boiler Safety card 6B.	0.1464	
34B	BV Closed Output Circuit	Stays false.	Burner valve never appears closed--same as: Purge Control card 22B; Prelight card 17B; Boiler Safety card 6A.	Same as: Purge Control card 1A; Prelight card 17B; Boiler Safety card 6A.	0.1464	
35A	A/R Open* Output Circuit	Stays true.	Same as Burner Logic B card item 55A.	Same as Burner Logic B card item 55A.	0.2019	
35B	A/R Open* Output Circuit	Stays false.	Same as Burner Logic B card item 55B.	Same as Burner Logic B card item 55B.	0.2019	
36A	A/R Open Output Circuit	Stays true	Same as Purge Control card item 25A.	Same as Purge Control card item 25A.	0.0795	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

REP. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
36B	A/R Open Output Circuit	Stays false.	Same as Purge Control card item 25B.	Same as Purge Control card item 25B.	0.0795	
37A	A/R Closed* Output Circuit	Stays true.	Same as Burner Logic B card item 55B.	Same as Burner Logic B card item 55B.	0.2019	
37B	A/R Closed* Output Circuit	Stays false.	Same as Burner Logic B card item 55A.	Same as Burner Logic B card item 55A.	0.2019	
38A	A/R Closed Output	Stays true.	Same as Prelight card item 26A.	Same as Prelight card item 26A.	0.0795	
38B	A/R Closed Output	Stays false.	Same as Prelight card item 22B.	Same as Prelight card item 1A.	0.0795	
39A	Flame Scanner On Circuit	Stays true.	Flame always appears on to all boiler control logic. Same as: 8A above; Purge Control card 9A; Burner Logic B item 38B.	Same as: 8A above; Purge control card 1A; Burner Logic B item 38B.	0.9285	
39B	Flame Scanner On Circuit	Stays false.	Flame never appears on to boiler control logic. Same as: 5B above; Purge Control card 9B; Boiler Logic B item 38A.	Same as: 2B above; Purge Control card 9B; Burner Logic B item 38A.	0.9285	
40A	Flame On* Output Circuit	Stays true.	Same as Burner Logic B item 38A.	Same as Burner Logic B item 38A.	0.0795	
40B	Flame On* Output Circuit	Stays false.	Same as Burner Logic B item 38B.	Same as Burner Logic B item 38B.	0.0795	
41A	Burner On Gates	Stays true.	Same as: Purge Control card item 9A; Boiler Safety 15A; Burner Logic B 26A; 8A above.	Same as: Purge Control Card 1A; Boiler Safety 15A; Burner Logic B 26A; 8A above.	0.3012	
41B	Burner On Gates	Stays false.	Same as: Purge Control card 9B; Boiler Safety 15B; Burner Logic B 26B; 5B above.	Same as: Purge Control card 9B; Boiler Safety 15B; Burner Logic B 34A; 2B above.	0.3012	13
42A	Burner On 2* Output Circuit	Stays true.	Same as: 8A above; Boiler Safety 15A; Purge Control 9A.	Same as: 8A above; Boiler Safety 15A; Purge Control 1A.	0.0795	
42B	Burner On 2* Output Circuit	Stays false.	Same as: 5B above; Boiler Safety 15A; Purge Control 9B.	Same as: 2B above; Boiler Safety 15A; Purge Control 9B.	0.0795	
43A	Burner Off 1 Output Circuit	Stays true.	Same as Boiler Safety 37A.	Same as Boiler Safety 37A.	0.0795	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A SUBSYSTEM: 1.1.4A BURNER LOGIC A

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
43B	Burner Off 1 Output Circuit	Stays false.	Same as Boiler Safety 37B.	Same as Boiler Safety 37B.	0.0795	
44A	Burner Off 2 Output Circuit	Stays true.	Same as Burner Logic B item 26A.	Same as Burner Logic B item 26A.	0.0795	
44B	Burner Off 2 Output Circuit	Stays false.	Same as Burner Logic B item 26B.	Same as Burner Logic B item 26B.	0.0795	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A SUBSYSTEM: 1.1.4B BURNER LOGIC B PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Common Power Circuitry	Open.	Lose power to entire card--card would not function.	Burner would shutdown.	0.9730	
1B	Common Power Circuitry	Short.	Main 24 volt power shorted out on card.	Power to ALL cards and Local Panel shorted out--lose ERC and Local Panel.	0.5937	
2A	Purge* Input Circuit	Stays true.	A/R would stay open.	No effect at high steam demand rates except possibly higher excess air than desired. Could blow burner out at low demand rates, where upon boiler would trip and purge if protection circuits non-failed. At light-off, airflow would be too high.	0.2924	
2B	Purge* Input Circuit	Stays false.	A/R would stay closed during purge cycle. Purge cycle would stop.	Purge would be unsuccessful because purge air would not be available.	0.2924	
3A	BV Closed* Time Delay	Stays false.	A/R would open for purge cycle and then remain closed during all other operations.	Burner would flame-out, boiler would trip and could not be re-lit.	1.4843	
3B	BV Closed* Time Delay	Stays true.	Same as 2A.	Same as 2A.	1.4843	
4A	Open A/R* Gate	Stays true.	Same as 2A.	Same as 2A.	0.1673	
4B	Open A/R* Gate	Stays false.	A/R would stay closed.	Same as 3A.	0.1673	
5A	Open A/R Solenoid Driver	Stays true.	Open A/R solenoid would stay energized (i.e., open)--A/R would stay open.	Same as 2A.	1.4902	
5B	Open A/R Solenoid Driver	Stays false.	Same as 4B.	Same as 3A.	1.4902	
6A	Close A/R* Circuit	Stays true.	A/R fail circuit would generate fail signal anytime A/R is open; burner valve would then close.	Same as 3A.	0.1338	
6B	Close A/R* Circuit	Stays false.	A/R fail circuit would not generate a fail signal if A/R was commanded to close and did not.	No auto protection if A/R does not close on command.	0.1338	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.4B BURNER LOGIC B

REP. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
7A	Close A/R Solenoid Driver	Stays true.	Close A/R solenoid would stay energized--A/R would stay closed.	Same as 3A.	1.4902	
7B	Close A/R Solenoid Driver	Stays false.	Close A/R solenoid would not energize--A/R would stay open.	Same as 2A.	1.4902	
8A	Start Sequence* Input	Stays true.	Insert Ignitor latch would cycle on and off continuously; burner valve would receive alternate open/close commands.	Ignitor would be inserted and retracted continuously and burner valve would be opened/closed continuously. Boiler would even-tually trip because timing messed up, but explosion hazard prior to trip.	0.2924	
8B	Start Sequence* Input	Stays false.	Insert Ignitor latch would not set to initiate ignition sequence.	Light Off sequence would fail--burner could not be lit.	0.2924	
9A	OK* to Light Input	Stays true.	Would inhibit start sequence--same as 8B.	Same as 8B.	0.2924	
9B	OK* to Light Input	Stays false.	Start sequence could be initi-ated out of sequence if Burner Logic A card pre-purge latch inhibit protection circuit failed such that inhibit protec-tion lost.	Burner valve would be opened and ignitor inserted before purge com-plete if Burner Logic A item 9A failure occurred.	0.2924	
10A	Burner Valve Closed* Input	Stays true.	Same as 9A/8B.	Same as 8B.	0.2924	
10B	Burner Valve Closed* Input	Stays false.	Burner valve appear closed; start sequence could be initi-ated when burner valve actually open.	Ignitor would be inserted when burner valve open if another failure caused burner valve to open erroneously--safety hazard.	0.2924	
11A	Ignitor Latch Input Logic	Stays true.	Same as 8A.	Same as 8A.	0.4686	
11B	Ignitor Latch Input Logic	Stays false.	Ignitor latch could not be set--same as 8B.	Same as 8B.	0.4686	
12A	BV Close Signal	Stays true.	BV would always appear closed in BV Fail check circuit; Fail signal womuld be generated when-ever BV commanded to open.	Same as #18A. operation.	0.0669	

SHIP: SHIP A

SUBSYSTEM: 1.1.4B BURNER LOGIC B

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
12B	BV Close Signal	Stays false.	BV would always appear open in BV fail check circuit; fail signal would be generated whenever BV commanded to close.	BV Fail signal/trip/alarm would be generated at shutdown--nuisance.	0.0669	
13A	Ignitor Latch	Stays set.	Insert ignitor and Open Burner Valve commands continuously generated.	No effect during steady state operation except that ignitor would probably burn-up. Probable explosion during start up because ignition and fuel flow would be present prior to purge.	0.2791	
13B	Ignitor Latch	Stays reset.	Same as 8B.	Same as 8B.	0.2791	
14A	Safety Latch	Stays set.	Lose back-up ignitor retraction capability.	No effect if 15B does not occur. If this failure and 15B occur, ignitor would not be retracted.	0.4338	
14B	Safety Latch	Stays reset.	Time Up* signal would be generated whenever ignitor inserted, in turn generating trip signal.	Same as 8B.	0.4338	
15A	Ignitor Timer	Stays true.	Ignitor latch held reset--same as 8B.	Same as 8B.	1.6516	
15B	Ignitor Timer	Stays false.	Lose primary means for ignitor retraction.	No effect if 14A does not occur. If this failure and 14A occur, ignitor would not be retracted.	1.6516	
16A	Insert Ignitor Solenoid Driver	Stays true.	Insert ignitor solenoid would stay energized--i.e., ignitor would stay inserted.	No effect during steady state operation except that ignitor would probably burn-up. Safety hazard during lite-off since ignition source would be present prior to purge.	1.4902	
16B	Insert Ignitor Solenoid Driver	Stays false.	Insert ignitor solenoid would never energize--i.e., ignitor would stay retracted.	Burner could not be lit.	1.4902	
17A	Trial for Ignition Output Circuit	Stays true.	OK to Light-Off A signal on Boiler Safety card would stay true. Pre-purge latch on Burner Logic A card would stay inhibited from setting.	Boiler could be lit without purging--safety hazard.	0.0795	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4B BURNER LOGIC B |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
17B	Trial for Ignition Output Circuit	Stays false.	Same as Burner Logic A card 7A and Boiler Safety card 17B.	Purge sequence could be initiated while a burner was being ignited.	0.0795	
18A	Insert Ignitor Inverter	Stays true.	Ignitor fail signal would be generated whenever ignitor in retracted state.	Burner fail signal would be generated and boiler would trip.	0.0669	
18B	Insert Ignitor Inverter	Stays false.	Ignitor retract command status check always appears valid.	No auto protection if ignitor commanded to retract when it is already retracted.	0.0669	
19A	Ignitor Out* Input Circuit	Stays true.	Same as #18B.	Same as #18B.	0.2924	
19B	Ignitor Out* Input Circuit	Stays false.	Ignitor fail signal would be generated whenever ignitor retract command given.	Same as #18A.	0.2924	
20A	Safety Timer	Stays true.	Safety latch would be held reset--same as #14B.	Same as #8B.	1.7237	
20B	Safety Timer	Stays false.	Safety latch would never reset, i.e., stay set--same as #14A.	Same as #14A.	1.7237	
21A	Fuel Safety Trip Input	Stays true.	Trip signal always appears present--burner valve solenoid would de-energize.	Same as #18A.	0.2798	
21B	Fuel Safety Trip Input	Stays false.	Lose one leg of redundant trip protection from Boiler Safety Card.	If both items #21B and #22A occur, burner valves would not be shutdown if fan stopped or drum level below lo-lo nor for purge--safety hazard.	0.2798	
22A	Fuel Safety Trip* Input	Stays true.	Same as #21B.	Same as #21B.	0.3467	
22B	Fuel Safety Trip* Input	Stays false.	Same as #21A.	Same as #18A.	0.3467	
23A	Spare Input Circuit on Pin 17	Stays true.	Same as #21A.	Same as #18A.	0.3467	
23B	Spare Input Circuit on Pin 17	Stays false.	No effect.	No effect.	0.3467	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.4B BURNER LOGIC B

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
24A	Trip Summary Gate	Stays true.	Trip signals from Boiler Safety card never generate Fail* signal.	Lose Burner Fail alarm and indicator on Boiler Trip condition.	0.1004	
24B	Trip Summary Gate	Stays false.	Fail* signal would be generated whenever burner valve is open.	Same as #18A.	0.1004	
25A	Ignitor Inserted* Input	Stays true.	Ignitor would never appear inserted.	On light-off, burner valve would not open and light-off sequence would halt.	0.2856	
25B	Ignitor Inserted* Input	Stays false.	Ignitor always appears inserted.	Burner valve would open anytime trips present from Boiler Safety card. Could open when it was supposed to be closed--safety hazard.	0.2856	
26A	Burner On* Input	Stays true.	Burner would never appear lit--burner valve solenoid would de-energize following ignition.	Burner valve would close following ignition.	0.2856	
26B	Burner On* Input	Stays false.	Burner would always appear lit--burner valve solenoid would stay energized.	Same as #34A.	0.2856	
27A	Off Command* Input	Stays true.	Manual Off pushbutton input and off commands from boiler load demand management would never appear present.	(1) Burner could not be shutdown via pushbutton or (2) when load demands decreased. Safety hazard--(1) Lose manual shutdown protection, (2) steam generation rate could exceed steam dump capacity--possible boiler overpressure.	0.2856	
27B	Off Command* Input	Stays false.	Off command always appears present and burner off latch would set.	Same as #34R.	0.2856	
28A	Burner Off Latch	Stays set.	Burner Trip signal would be generated--burner valve solenoid would de-energize.	Same as #27B.	0.2784	
28B	Burner Off Latch	Stays reset.	Burner valve could not be closed by off command or burner fail condition.	Same as #27A plus: burner would not shutdown when: A/R or ignitor command and status disagree; when BV command and status disagree.	0.2784	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4B BURNER LOGIC B | PAGE: 6

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
29A	Trip* Gate	Stays true.	Same as #53B.	Same as #53B.	0.2009	
29B	Trip* Gate	Stays false.	Trip condition would always appear present.	Same as #27B.	0.2009	
30A	Open BV Gate U15-3	Stays true.	Ignition conditions will always appear present--burner valve solenoids will stay energized if no trips present.	Same as #25B.	0.1004	
30B	Open BV Gate U15-3	Stays false.	Ignition conditions never appear appear present--burner valve solenoid would not energize for light off.	Same as 25A.	0.1004	
31A	Open BV Gate U7-11	Stays true.	Flame or ignition conditions always appear present--burner valve solenoid will stay energized if no trips present.	Same as #25B.	0.1004	
31B	Open BV Gate U7-11	Stays false.	Flame or ignition conditions never appear present--BV solenoid stays de-energized.	Same as #27B.	0.1004	
32A	Open BV Gate U4-10	Stays true.	Burner valve solenoid stays energized--same as #34A.	Same as #34A.	0.1004	
32B	Open BV Gate U4-10	Stays false.	Burner valve solenoid stays de-energized--same as #34B.	Same as #34B.	0.1004	
33A	Open BV* Signal	Stays true.	Burner valve would appear closed in check circuit--Fail* signal would be generated anytime a burner valve close command given.	Burner would shutdown and could not be relighted after close command--would occur if burner shutdown due to decrease in steam demand.	0.2037	
33B	Open BV* Signal	Stays false.	Burner valve would appear open in check circuit--Fail* signal would be generated anytime a burner valve open command given.	Burner would shutdown and could not be relighted after open command--would occur if open command given on light-off or due to increase in steam demand.	0.2037	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.4B BURNER LOGIC B

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
34A	Burner Valve Solenoid Driver	Stays true.	Burner valve solenoid would stay energized--burner valve would stay open and could not be closed from ERC.	(1) Fuel safety hazard due to open burner valve during light-off or shutdown. (2) Burner would not shutdown if steam demand decreased--steam dump capacity could be exceeded with possible overpressure conditions.	1.3456	
34B	Burner Valve Solenoid Driver	Stays false.	Burner valve solenoid would stay de-energized. Burner valve would stay closed and could not be opened from ERC.	Burner would go out and stay out--reduced steam production from boiler.	1.3456	
35A	Ignitor Command/ Status Check Circuit	Stays true.	Ignitor fail signal would stay true--BV solenoid driver would de-energize.	Same as #34B.	0.4397	
35B	Ignitor Command/ Status Check Circuit	Stays false.	Lose status check on ignitor commands--ignitor could be commanded to the state it was already in.	No effect if ignitor insert/ retract sequence normal. If sequence not normal, lose check protection.	0.4397	
36A	BM Auto* Input Circuit	Stays true.	Signal would never indicate auto mode.	Status/command checks for ignitor, A/R and BV would be disabled--lose burner fail protection in auto mode Lose flameout and burner valve open trip--safety hazard.		
36B	BM Auto* Input Circuit	Stays false.	Auto mode always indicated.	Burner fail logic would be enabled in manual mode.		
37A	BM Auto Gate	Stays true.	Same as #36B.	Same as #36B.	0.1004	
37B	BM Auto Gate	Stays false.	Same as #36A	Lose Burner Fail lamp.	0.1004	
38A	Flame On* Input Circuit	Stays true.	Flame would never appear on; BV trip would be generated whenever BV open.	Burner valve would close and boiler would trip.	0.2856	
38B	Flame On* Input	Stays false.	Flame would always appear on.	If flameout occurred, BV would stay open--safety hazard.	0.2856	
39A	Flame On Gate	Stays true.	Flameout condition always indicated.	Same as #38A.	0.1004	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4B BURNER LOGIC B | PAGE: 8

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
39B	Flame On Gate	Stays false.	Flameout would never be indicated.	Same as #38B.	0.1004	
40A	BV Trip Logic	Stays true.	BV Trip condition always indicated.	Same as #38A.	0.2507	
40B	BV Trip Logic	Stays false.	Same as #39B.	Same as #38B.	0.2507	
41A	BV Trip* Output Circuit	Stays true.	Flameout condition never indicated to Boiler Safety card--same as Boiler Safety card #21A.	Same as Boiler Safety card #21A.	0.0727	
41B	BV Trip* Output Circuit	Stays false.	Same as Boiler Safety card #18B.	Same as Boiler Safety card #18B.	0.0727	
42A	Burner Set Up Gate	Stays true.	Lose timing check of burner set up via safety timer.	Redundant with ignitor timer signal. If ignitor timer failed false--item #15B--ignitor would not be retracted.	0.0947	
42B	Burner Set Up Gate	Stays false.	Time out always appears to occur without BV being set up--Burner Fail signal would be generated--BV solenoid would de-energize.	Same as #34B.	0.0947	
43A	BV Trip* Gate	Stays true.	Same as #39B and #42A.	Same as #38B and #42A.	0.0947	
43B	BV Trip* Gate	Stays false.	Same as #39A and #42B.	Same as #38A.	0.0947	
44A	BV Fail Time Delay	Stays true.	Lose BV Fail* signal--same as Circuit	Same as #53B.	0.2154	#53B.
44B	BV Fail Time Delay Circuit	Stays false.	Burner valve always appears to have failed.	Same as #34B.	0.2154	
45A	Burner Fail Combining Logic	Stays true.	Burner Fail signal always generated.	Same as #34B	0.1635	
45B	Burner Fail Combining Logic	Stays false.	Burner Fail signal would never be generated.	Same as #36A	0.1635	
46A	Burner Fail Lamp Driver	Stays true.	Burner Fail lamp would stay illuminated.	Nuisance.	0.6029	
46B	Burner Fail Lamp Driver	Stays false.	Burner Fail lamp would never illuminate.	Lose Burner Fail visual indication.	0.6029	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4B BURNER LOGIC B |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
47A	Burner Fail Output Gate	Stays true.	Same as #45A.	Same as #34B.	0.1004	
47B	Burner Fail Output	Stays false.	Same as #45B.	Same as #36A.	0.1004	
48A	Burner Fail* Inverter	Stays true.	Burner valve could not be closed by burner fail condition.	Same as #36A.	0.0669	
48B	Burner Fail* Inverter	Stays false.	Burner valve close signal would always be generated.	Same as #34B.	0.0669	
49A	BV Command/Status Check Circuit	Stays true.	Fail* signal would always be generated--same as #44B.	Same as #34B.	0.5911	
49B	BV Command/Status Check Circuit	Stays false.	Lose status check on BV commands--BV could be commanded to the state it was already in.	No effect if burner valve command sequence normal. If sequence not normal, lose check protection.	0.5911	
50	Combined with item 49--part of same function.					
51	Combined with item 49--part of same function.					
52	Combined with item 49--part of same function.					
53A	Trip Sum/BV Close Gate	Stays true.	Same as #49A.	Same as #49A.	0.1004	
53B	Trip Sum/BV Close Gate	Stays false.	Lose ability to close burner valve in event of fuel safety trip from Boiler Control card. Could still be closed via redundant trip signal if it is non-failed.	No effect if redundant trip gate non-failed (item 29). If both failed, burner valve could not be closed by a fuel safety trip--safety hazard.	0.1004	
54A	Fail* Circuit	Stays true.	Same as #53B.	Same as #53B.	0.2342	
54B	Fail* Circuit	Stays false.	Same as #44B.	Same as #34B.	0.2342	
55A	A/R Command Status Check Circuit	Stays true.	A/R Fail signal would always be generated--BV solenoid driver would de-energize.	Same as #34B.	1.0107	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.4B BURNER LOGIC B |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
55B	A/R Command/Status Check Circuit	Stays false.	Lose status check on A/R commands--A/R could be commanded to the state it was already in.	No effect if A/R command sequence normal. If sequence not normal, lose check protection.	1.0107	
56	Combined with item 55--part of same function.					
57	Combined with item 55--part of same function.					
58	Combined with item 55--part of same function.					
59	Combined with item 55--part of same functions.					
60A	Burner Set Up Input Circuit	Stays true.	Burner would always appear "set up," i.e., burner gun in place, etc.	Ignition sequence would not be halted if burner not set up.	0.1022	
60B	Burner Set Up Input Circuit	Stays false.	Burner would never appear set-up; ignition sequence would halt.	Same as #25A.	0.1022	
61A	Program Input Circuit	Stays true.	Same as #60B.	Same as #25A.	0.2856	
61B	Program Input Circuit	Stays false.	No effect.	No effect.	0.2856	
62A	Burner Set-Up Gate	Stays true.	Same as #60A.	Same as #60A.	0.1026	
62B	Burner Set-Up Gare	Stays false.	Same as #60B.	Same as #25A.	0.1026	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.5 BURNER DEMAND SEQUENCING   PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	#3 Base Burner A2-K1; 4PST	#1 NO Contact Sticks open.	Relay A2-K8 could not energize.	#2 Burner could not be lit on demand increases.	0.5480	
1B	#3 Base Burner A2-K1; 4PST	#1 NO Contact Sticks closed.	Relay A2-K8 would energize on demand increases whenever Burner #2 was selected as base.	No effect--if #2 selected as base it would already be lit anyway.	0.5480	
1C	#3 Base Burner A2-K1; 4PST	#2 NO Contact Sticks open.	Relay A2-K9 could not energize on demand increases when Burner #3 selected as base.	#3 Burner could not be lit on demand increases.	0.5480	
1D	#3 Base Burner A2-K1; 4PST	#2 NO Contact Sticks closed.	Relay A2-K9 would energize on demand increases when Burner #2 in manual and #1 in auto.	No effect--normal operation.	0.5480	
1E	#3 Base Burner A2-K1; 4PST	#3 NO Contact Sticks open.	Relay A2-K10 would not energize on demand decreases when Burner #3 selected as base.	Burner #1 would not trip on demand decreases when Burner #3 selected as base.	0.5480	
1F	#3 Base Burner A2-K1; 4PST	#3 NO Contact Sticks closed.	Relay A2-K10 would energize when Burner #1 in auto and demand decreased.	No effect--normal operation.	0.5480	
1G	#3 Base Burner A2-K1; 4PST	#4 NO Contact Sticks open.	Relay A2-K11 would not energize on demand decreases when Burner #3 selected as base.	Burner #2 would not trip on demand decreases when Burner #3 selected as base.	0.5480	
1H	#3 Base Burner A2-K1; 4PST	#4 NO Contact Stick closed.	Relay A2-K11 would energize when demand decreased and Burner #1 in manual.	No effect--normal operation.	0.5480	
2A	#3 Base Burner Relay, A2-K2, SPST	Contact Sticks open.	Relays A2-K1 and A2-K2 would not stay energized when Burner #2 in auto or manual; Burner #3 could not be selected as base burner.	If Burner #3 selected as base burner, Burners #1 and #2 would not light on demand increases or trip on demand decreases.	0.8768	
2B	#3 Base Burner Relay, A2-K2, SPST	Contact Sticks closed.	Relays A2-K1 and A2-K2 would stay energized whenever Burner #3 selected as auto or base.	No effect--normal operation.	0.8768	
3A	#2 Base Burner Relay, A2-K3, 4PST	#1 NO Contact Sticks open.	Relay A2-K3 would not stay energized; Burner #2 could not be selected as base burner.	If Burner #2 selected as base burner, Burner #1 would not light on demand increases or trip on demand decreases.	0.5480	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A　　SUBSYSTEM: 1.1.5 BURNER DEMAND SEQUENCING　　

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
3B	#2 Base Burner Relay, A2-K3, 4PST	#1 NO Contact Sticks closed.	Relay A2-K3 would stay energized whenever Burner #2 selected as auto or base.	No effect--normal operation.	0.5480	
3C	#2 Base Burner Relay, A2-K3, 4PST	#2 NO Contact Sticks open.	Relay A2-K9 would not energize when #2 Burner selected as base.	If Burner #2 selected as base, Burner #1 would not light on demand increases.	0.5480	
3D	#2 Base Burner Relay, A2-K3, 4PST	#2 NO Contact Sticks closed.	Relay A2-K9 would energize on demand increases whenever #1 Burner in auto mode.	No effect--normal operation.	0.5480	
3E	#2 Base Burner Relay, A2-K3, 4PST	#3 NO Contact Sticks open.	Relay A2-K10 would not energize on demand decreases when Burner #2 selected as base.	If Burner #2 selected as base, Burner #1 would not trip on demand decreases.	0.5480	
3F	#2 Base Burner Relay, A2-K3, 4PST	#3 No Contact Sticks closed.	Relay A2-K10 would energize on demand decrease whenever Burner #1 in auto.	No effect-normal operation.	0.5480	
3G	#2 Base Burner Relay, A2-K3, 4PST	#4 NC Contact Sticks open.	Relay A2-K11 could never energize.	Burner #2 would not trip on demand decreases.	0.5480	
3H	#2 Base Burner Relay, A2-K3, 4PST	#4 NC Contact Stick closed.	Relay A2-K11 would energize on demand decreases whenever Burner #3 selected as base.	No effect--normal operations.	0.5480	
4A	Burner #3 On Relay A2-K4; SPST	Contact Sticks open.	Relays A2-K1 and A2-K2 would not energize when Burner #3 selected as base.	Same as #2A.	0.8768	
4B	Burner #3 On Relay A2-K4; SPST	Contact Sticks closed.	Burner #3 could be selected as base burner when the burner was off.	If Burner #3 was off when selected as base, Burners #1 or #2 could be lit without purging--safety hazard.	0.8768	
5A	Burner #2 On Relay A2-K5, DPST	#1 NO Contact stays open.	Relay A2-A3 would not energize when Burner #2 selected as base.	Same as #3A.	0.6576	
5B	Burner #2 On Relay A2-K5, DPST	#1 NO Contact stays closed.	Same as #4B except for Burner #2.	Same as #4B except different permutation of burners.	0.6576	
5C	Burner #2 On Relay A2-K5, DPST	#2 NO Contact stays open.	Relay A2-K11 would never energize--same as #3G.	Same as #3G.	0.6576	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.5 BURNER DEMAND SEQUENCING |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
5D	Burner #2 On Relay A2-K5, DPST	#2 NO Contact stays closed.	Trip commands could be generated for Burner #2 when Burner #2 not light.	No effect.	0.6576	
6A	Burner #1 On Relay A2-K6, DPST	#1 NO Contact stays open.	Relay A2-K10 could never be energized.	Burner #1 would not trip on demand decreases.	0.6576	
6B	Burner #1 On Relay A2-K6, DPST	#1 NO Contact stays closed.	Same as #5D except for Burner #1.	No effect.	0.6576	
6C	Burner #1 On Relay A2-K6, DPST	#2 NC Contact--any.	Lose Burner On interlock protection on Burner On commands.	Would take second failure cause an effect.	1.3153	
7A	Light Burner #2 Relay A2-K8, DPST	#1 NO Contact stays open.	Relay A2-K9 could not be energized if Fuel Demand greater than 40%.	If Burner #2 lit on increasing demand, and demand continued to increase, Burner #1 could not be lit.	0.6576	
7B	Light Burner #2 Relay A2-K8, DPST	#1 NO Contact stays closed.	Relay A2-K9 would energize if Fuel Demand greater than 40%.	No effect--normal operation.	0.6576	
7C	Light Burner #2 Relay A2-K8, DPST	#2 NO Contact stays open.	Burner #2 On commands to Burner Logic for demand increases would not occur.	Same as #1A.	0.6576	
7D	Light Burner #2 Relay A2-K8, DPST	#2 NO Contact stays closed.	Burner #2 On command to Burner Logic stays active.	Burner #2 would be lit erroneously.	0.6576	
8A	Light Burner #1 A2-K9, SPST	NO Contact stays open.	Same as #7C except for Burner #1.	Same as #1A except for Burner #1.	0.8768	
8B	Light Burner #1 A2-K9, SPST	NO Contact stays closed.	Same as #7D except for Burner #1.	Same as #7D except for Burner #1.	0.8768	
9A	Trip Burner #1 Relay A2-K10, 3PST	#1 NO Contact stays open.	Reduce Firing Rate signal would stay active after Burner #1 had been tripped.	On demand decreases, Burner #1 and #2 trip.	0.5857	
9B	Trip Burner #1 Relay A2-K10, 3PST	#1 NO Contact stays closed.	Reduce Firing Rate signal would always look active.	Burner #1, #2, or both would trip.	0.5857	
9C	Trip Burner #1 Relay A2-K10, 3PST	#2 NC Contact stays open.	Burner #1 Off commands to burner logic would not be generated.	Same as #6A.	0.5857	
9D	Trip Burner #1 Relay A2-K10, 3PST	#2 NC Contact stays closed.	Burner #1 Off command to burner logic stays active.	Burner #1 would shut off and stay off.	0.5857	

SHIP: SHIP A

SUBSYSTEM: 1.1.5 BURNER DEMAND SEQUENCING

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
9E	Trip Burner #1 Relay A2-K10, 3PST	#3 NC Contact stays open.	Relay A2-K9 could never energize.	Same as #1A except for Burner #1.	0.5857	
9F	Trip Burner #1 Relay A2-K10, 3PST	#3 NC Contact stays closed.	Burner #1 light commands could be generated when burner #1 trip command in effect.	Same as #6C.	0.5857	
10A thru 10F	Trip Burner #2 Relay A2-K10, 3PST	Same as #9A-9F except for Burner #2.			0.5857	
11A	Increase/Decrease Firing Rate Circuitry	Increase Firing Rate signal stays active.	Light Burners #1 and/or #2 relay(s) would stay energized.	Burners #1 and/or #2 would be lit erroneously.	1.9666	
11B	Increase/Decrease Firing Rate Circuitry	Lose Increase Firing Rate signal.	Light Burners #1 and/or #2 relay(s) would not energize.	Burners #1 and/or #2 would not light in response to increased demand.	1.9666	
11C	Increase/Decrease Firing Rate Circuitry	Decrease Firing Rate signal stays active.	Trip Burners #1 and/or #2 relays would stay energized.	Burners #1 and/or #2 would shut down erroneously--same as #9B.	1.9666	
11D	Increase/Decrease Firing Rate Circuitry	Lose Decrease Firing Rate signal.	Trip Burner #1 and/or #2 relays would not energize.	Burners #1 end/or #2 would not trip in response to decreased demand.	1.9666	
12	Burner Base/Auto/ Manual Selector Switches	Any.	Base/auto/manual mode selection for burners would be erroneous.	System would not respond to increases and/or decreases in demand.	2.8104	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.6 COMBUSTION AIR CONTROL |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Air Flow Controller PIC144 (pneumatic)	Complete loss of instrument.	Loss pneumatic signal to solenoid valve AZ1 and thence to vane actuator CV144.	FDB vanes would close--lose combustion air; flame-cut and boiler trip.	12	
1B	Air Flow Controller PIC144 (pneumatic)	Output too high.	Vane would be opened more than desired.	High excess air; flame could be blown out causing boiler trip; boiler would start smoking, if excessive flame scanners might not "see" the flame through the smoke and cause boiler trip.	4	
1C	Air Flow Controller PIC144 (pneumatic)	Output too low.	Vanes would not open as widely as desired.	Low air ratio--could cause flame-out and boiler trip. Boiler would start smoking--same as #1B for smoking.	4	
2A	Purge/Combustion Solenoid Valve A21, 3-way valve	Lose output.	Lose pneumatic signal to vane actuator CV144.	Same as #1A.	24	
2B	Purge/Combustion Solenoid Valve A21, 3-way valve	Purge position stays energized.	Purge air flow would occur during normal operation.	Same as Purge Control card #18B.	18	
2C	Purge/Combustion Solenoid Valve A21, 3-way valve	Combustion air position stays energized.	Lose purge air.	Same as Purge Control card #25B.	18	
3A	Vane Actuator CV144, pneumatically operated actuator	Input signal blocked.	Vanes would close.	Same as #1A.	3.3	
3B	Vane Actuator CV144, pneumatically operated actuator	Control air input blocked.	Vanes retained in existing position.	Combustion air flow would not be increased or decreased with changing demand conditions. Depending on demand could result in #1B or #1C or vessel speed decrease.	3.3	
3C	Vane Actuator CV144, pneumatically operated actuator	Incomplete actuation.	Vanes would not be opened/ closed the desired amount.	Inadequate response to changing demand condition could cause vessel speed decrease. Also, could result in inadequate purge air and purge fail.	4.4	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.6 COMBUSTION AIR CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
4A	High Select Pneumatic Unit HSS139	Lose output.	Lose desired valve signal to PIC144 Air Flow Controller; PIC144 output signal would be lost.	Same sa #1A.	16	
4B	High Select Pneumatic Unit HSS139	Demand Input signal blocked.	Air flow controller would always adjust air flow to match F.O. Flow system.	Slow system response on demand increases; slow vessel response to commands for increased speed.	4.5	
4C	High Select Pneumatic Unit HSS139	F.O. Flow Input signal blocked.	Air flow controller would always adjust air flow to match Demand Input signal.	Excess air would not be available on demand decreases.	4.5	
5A	Air/Fuel Ratio Station RY144 and Ratio Relay A17 (both pneumatic)	Lose output.	Lose measured valve signal to PIC144 air flow controller; PIC 144 output signal would always command full vane opening.	Same as #1B.	20.8	
5B	Air/Fuel Ratio Station RY144 and Ratio Relay A17 (both pneumatic)	Output too low.	Measure valve signal to PIC144 too low; PIC144 would command increased vane opening. LSS139 would cause fuel flow controller to decrease F.O. flow rate.	The combustion air increase and F.O. flow decrease would cause the burners to go out and the boiler to trip.	2.6	
5C	Air/Fuel Ratio Station RY144 and Ratio Relay A17 (both pneumatic)	Output too high.	Measured valve signal to PIC144 too high; PIC144 would command decreased vane opening.	Same as #1C.	2.6	
6A	Square Root Extractor (pneumatic) SQ144	Lose output.	Air/fuel ratio would show no air flow, PIC144 would command full vane opening.	Same as #1B.	12	
6B	Square Root Extractor (pneumatic) SQ144	Output too high.	Air/fuel ratio would show too much air flow. PIC144 would command decreased vane opening.	Same as #1C.	1.5	
6C	Square Root Extractor (pneumatic) SQ144	Output too low.	Air/fuel ratio would show too little airflow. Same as #5B.	Same as #5B.	1.5	
7	Purge Air Adequate Pressure Switch, P57	Lose output.	Same as Purge Control card, item #25B.	Same as Purge Control card, item #25B.	13	
8A	Measured Air Flow Temperature Correction	"Output" too high.	SQ144 output would be too high--same as #6B.	Same as #1C.	39.7299	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.6 COMBUSTION AIR CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
8B	Measured Air Flow Temperature Correction	"Output" too low.	SQ144 output would be too low--same as #6C.	Same as #5B.	39.7299	
9	FDB Fast Switch, Pushbutton, SPST	Stays open.	FDB could not be operated at fast speed.	No effect; normal operation is at slow speed.	0.1703	
10	FDB Slow Switch, Pushbutton, SPST	Stays open.	FDB could not be operated at slow speed.	Same as #1A.	0.1703	
11	FDB Stop Switch	Stays open.	FDB could not be stopped.	Generally no effect. FDB could not be taken out of service for maintenance.	10	
12A	FDB Normal/Fail Switch, Rotary Switch, 4 decks, 3 contacts per deck	"Normal" contacts stay open.	FDB would appear to be stopped.	Boiler trip.	0.4684	
12B	FDB Normal/Fail Switch, Rotary Switch, 4 decks, 3 contacts per deck	"Fail" contacts stay open.	Lose ability to operate either boiler with either FDB.	FDB could not be cross connected to other boiler.	0.4684	
13	FDB "On" Limit Switch, SPST	Stays open.	Same as #12A.	Same as #12A.	10	
14	FDB "Off" Limit Switch, SPST	Stays open.	FDB would never appear off.	Boiler would not trip if FDB failed--F.O. would continue to flow--safety hazard.	10	
15A	FDB Failure Alarm	Stays false.	Lose FDB Fail alarm.	Same as subsystem effect.	8.8027	
15B	FDB Failure Alarm	Stays true.	Continuous FDB Fail alarm.	False alarm.	8.8027	
16	Windbox Pressure Gauge (1 meter)	Any.	Lose manual windbox pressure indication or indication incorrect.	Same as subsystem effect.	10	
17	FDB Discharge Pressure Gauge (1 meter)	Any.	Lose manual FDB discharge pressure indication or indication incorrect.	Same as subsystem effect.	10	
18	Boiler Furnace Pressure Gauge (1 meter)	Any.	Lose manual boiler furnace pressure indication or indication incorrect.	Same as subsystem effect.	10	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.7.1 F.O. FLOW CONTROL | PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Fuel Flow Controller, PIC139 (2D3-C11) Pneumatic Controller	Complete loss of instrument.	Fuel flow controller would no longer control flow; fuel flow would be controlled by Pressure Controller PIC110 of minimum setting.	Insufficient fuel flow for high steam demand rates; vessel speed limited and/or slowdown.	12	
1B	Fuel Flow Controller, PIC139 (2D3-C11) Pneumatic Controller	Output too high.	Flow control valve CV139 would allow more flow than desired; air flow would be increased in an attempt to meet apparent increased demand.	Higher firing rate than desired. Correction attempts would be unsuccessful. Steam dump system capacity could be exceeded at low demand rates.	4	
1C	Fuel Flow Controller, PIC139 (2D3-C11) Pneumatic Controller	Output too low.	Flow control valve CV139 would decrease flow rate; air flow would not be decreased.	High excess air; same as Combustion Air Control #1B.	4	
2A	Flow Control Valve CV139; pneumatically controlled valve	Fails closed.	Fuel supply to boiler shut off.	Boiler flame-out and shutdown.	12	
2B	Flow Control Valve CV139; pneumatically controlled valve	Fails open.	Fuel flow to boiler could not be controlled; flow would stay constant at max. rate; air flow would be increased in an attempt to meet apparent increased demand.	Same as #1B.	8	
3	Fuel Flow Transmitter, FT138	Lose output.	Lose fuel flow measured valve to Fuel Flow Controller PIC139 and Combustion Air High Select Unit HSS139. PIC139 would continuously increase fuel flow up to max. rate.	Same as #1B.	20	
4A	Low Select Pneumatic Unit LSS-139	Lose output.	Lose desired valve signal to fuel flow controller PIC139; output signal from PIC139 would be lost. Same as #1A.	Same as #1A.	6	
4B	Low Select Pneumatic Unit LSS-139	Lose either input.	Desired valve signal to fuel flow controller PIC139 would be lost--same as #1A.	Same as #1A.	9	
5A	High Select Pneumatic Unit HSS-110	Lose output.	Lose signal to control valve CV139--valve would close.	Same as #2A.	6	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.7.1 F.O. FLOW CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
5B	High Select Pneumatic Unit HSS-110	PIC139 input signal blocked.	Lose signal from fuel flow controller--same as #1A.	Same as #1A.	4.5	
5C	High Select Pneumatic Unit HSS-110	PIC110 input signal blocked.	Lose signal from Pressure Controller PIC-110; same as #6A.	Same as #6A.	4.5	
6A	Pressure Controller PIC-110 (2D3-C3)	Complete loss of instrument.	Pressure Controller PIC110 would no longer control minimum fuel flow rate. Flow rate would always be controlled by Fuel Flow Controller.	At low demand rates, fuel flow would drop below minimum rates Air flow would not be decreased. Probable flame-out.	12	
6B	Pressure Controller PIC-110 (2D3-C3)	Output too high.	Minimum fuel flow rate "commanded" by PIC110 would be too high.	Same as #1B.	4	
6C	Pressure Controller PIC-110 (2D3-C3)	Output too low.	Minimum fuel flow rate "commanded" by PIC110 would be too low.	Same as #6A.	4	
7	Pressure Transmitter, PT110	Lose output.	Lose Burner Header Pressure signal to gauge and PIC110. PIC110 output will increase--same as #6B.	Same as #1B plus lose burner header pressure gauge.	20	
8A	Master Fuel Oil Shut Off Valve, CV152, Solenoid Valve	Fails closed.	Same as #2A.	Same as #2A.	36	
8B	Master Fuel Oil Shut Off Valve, CV152, Solenoid Valve	Fails open.	Valve could not be tripped if trip condition occurred.	Same as Boiler Safety card item #2A.	14	
9A	Fuel Oil to Burner Pressure Low Alarm	Stays false.	Lose F.O. to Burner Pressure Low alarm.	Same as subsystem effect.	15.3027	
9B	Fuel Oil to Burner Pressure Low Alarm	Stays true.	Continuous F.O. to Burner Pressure Low alarm.	False alarm.	15.3027	
10	Burner Header Pressure Gauge (1 meter)	Any.	Lose Burner Header Pressure Gauge reading or reading incorrect.	Same as subsystem effect.	10	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.7.1 F.O. FLOW CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
11	F.O. Flow Meter (1 meter)	Any.	Lose F.O. flow meter reading or reading incorrect.	Same as subsystem effect.	10	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.7.2 F.O. TEMPERATURE AND PRESSURE CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	F.O. Heater Temp. Control Valve C57, pneumatically controlled valve	Fails closed.	Would shut off heating steam supply to F.O. Heaters; F.O. temperature would drop.	F.O. would eventually become too viscous to flow; both boilers would flame-out and shutdown.	12	
1B	F.O. Heater Temp. Control Valve C57, pneumatically controlled valve	Fails open.	Heating steam would constantly circulate through the F.O. Heaters. F.O. temperature control would be lost; continuous max. heating.	F.O. temperature would increase to max. Inefficient combustion; smoke, flame scanners might not "see" flame through the smoke and cause a boiler trip. Any leak of the hot F.O. could cause a fire.	8	
2A	F.O. Heating Steam Pressure Controller, pneumatic	Complete loss of instrument	Lose pneumatic signal to control valve C57; C5-7 would close.	Same as #1A.	12	
2B	F.O. Heating Steam Pressure Controller, pneumatic	Output too high.	C5-7 would open sooner or stay open wider/longer that required. F.O. temperature would rise.	Same as #1B.	4	
2C	F.O. Heating Steam Pressure Controller, pneumatic	Output too low.	C5-7 would close sooner or stay closed longer than required. F.O. temperature would drop.	Same as #1A.	4	
3A	F.O. to Boilers Temperature Sensor/Controller, pneumatic (RTP-2)	Complete loss of instrument.	Loss of control signal to F.O. Heating Steam Pressure Controller.	Same as #1A.	12	
3B	F.O to Boilers Temperature Sensor/Controller, pneumatic (RTP-2)	Output too high.	F.O. Heating Steam Pressure Controller would signal for more steam flow.	Same as #1B.	4	
3C	F.O. to Boilers Temperature Sensor/Controller, pneumatic (RTP-2)	Output too low.	F.O. Heating Steam Pressure Controller would signal for less steam flow.	Same as #1A.	4	
4A	F.O. Temperature Hi/Lo Alarm	Stays false.	Lose F.O. Temperature Hi/Lo alarm.	Same as subsystem effect.	15.3027	
4B	F.O. Temperature Hi/Lo Alarm	Stays true.	F.O. Temperature Hi/Lo alarm occurs continuously.	False alarm.	15.3027	
5A	F.O. Pressure Control, Constant Pressure Regulator F014	Fails closed.	F.O. could not be circulated around F.O. Service Pumps if F.O. pressure is too high.	F.O. pressure could become too high at low demand rates.	12	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.7.2 F.O. TEMPERATURE AND PRESSURE CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
5B	F.O. Pressure Control, Constant Pressure Regulator FO14	Fails open.	F.O. would always be circulated around F.O. service pumps.	F.O. pressure would drop--boilers would flame out and shut-down.	8	
6A	F.O. Pressure Control Volume Boost Relay	Fails closed.	Lose pneumatic signal to FO14; FO14 would close--same as #5A.	Same as #5A.	2.6	
6B	F.O. Pressure Control Volume Boost Relay	Fails open.	Max. pneumatic signal would always be applied to FO14--same s #5B.	Same as #5B.	10.4	
7A	F.O. Pressure Control Pressure Controller (PDAP-1), pneumatic	Complete loss of instrument.	Same as #6A.	Same as #5A.	12	
7B	F.O. Pressure Control Pressure Controller (PDAP-1), pneumatic	Output too high.	Pneumatic signal to FO14 would be too high--excessive F.O. circulation around service pumps.	Same as #5B.	4	
7C	F.O. Pressure Control Pressure Controller (PDAP-1), pneumatic	Output too low.	Pneumatic signal to FO14 would be too low--not enough F.O. circulation around F.O. pumps.	Same as #5A.	4	
8A	F.O. Pressure Lo Alarm	Stays false.	Lose F.O. Service Pressure Low alarm.	Same as subsystem effect.	15.3027	
8B	F.O. Pressure Lo Alarm	Stays true.	F.O. Service Pressure Low alarm occurs continuously.	False alarm.	15.3027	
9	F.O. Service Pres. Gage	Any.	Lose F.O. Service Pressure gauge reading or reading incorrect.	Same as subsystem effect.	10	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.7.3 F.O. SUPPLY

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1	Port F.O. Service Pump Fast Switch (SPST)	Fails open.	Port F.O. service pump could not be operated at fast speed via ERC manual selection.	No effect is starboard F.O. service pump non-failed. Otherwise, port F.O. service pump would have to be operated at slow speed; would be sufficient only for operation on 1 boiler.	0.1703	
2	Port F.O. Service Pump Slow Switch (SPST)	Fails open.	Port F.O. service pump could not be operated at slow speed via ERC manual selection.	No effect if starboard F.O. service pump non-failed. Otherwise, port F.O. service pump could be operated at fast speed to maintain F.O. flow.	0.1703	
3	Port F.O. Service Pump Slow Switch (SPST)	Fails open.	Port F.O. service pump could not be manually selected as the standby pump.	Same as #2.	0.1703	
4	Port F.O. Service Pump Stop Switch (SPST)	Fails open.	Port F.O. service pump could not be stopped via ERC stop switch.	Same as subsystem effect.	0.1703	
5-8	Starboard F.O. Service Pump Fast/Slow/ Standby Stop Switch	Same as #1 - #4 except for Starboard F.O. Service Pump.				
9	Pressure Switch, PS742	Fails open.	Lose ability to switch on standby F.O. service pump automatically if other pump cannot maintain required F.O. pressure.	At periods of high demand or in event of failure of running pump, F.O. pressure would not be adequate. Vessel slowdown at high demand periods; both boilers would flame-out if running pump failed.	13	
10A	Port F.O. Service Pump Failure Alarm	Fails false.	Lose alarm.	Lose auto indication that port F.O. service pump had failed.	8.8027	
10B	Port F.O. Service Pump Failure Alarm	Stays true.	False alarm.	No effect on operation unless crew took wrong action.	8.8878	
11A 11B	Starboard F.O. Service Pump Failure Alarm	Same as #10A/B.			17.7756	
12A	F.O. Strainer AP High Alarm	Stays true.	False alarm.	Same as #10B.	15.3027	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.7.3 F.O. SUPPLY

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
12B	F.O. Strainer AP High Alarm	Stays false.	Lose alarm.	Lose auto indication that F.O. strainer differential pressure high--no effect unless strainer blocked, then F.O. flow could be blocked and shutdown both boilers without previous warning.	15.3027	
13A	Port F.O. Service Tank Level High Alarm	Stays false.	Lose alarm.	Lose auto indication if port F.O. service tank leve is high.	8.8871	
13B	Port F.O. Service Tank Level High Alarm	Stays true.	Port F.O. Service Tank Level High alarm womuld occur continuously.	Same as #10B.	8.8871	
14A, 14B	Starboard F.O. Tank Level High Alarm	Same as #13A/B except for Starboard Tank.			17.7742	
15A	Low Sulphur F.O. Tank Level High Alarm	Stays false.	Lose alarm.	Lose auto indication if low sulphur F.O. tank level is high.	17.7742	
15B	Low Sulphur F.O. Tank Level High Alarm	Stays true.	Low Sulphur F.O. Service Level High alarm occurs continuously.	Same as #10B.	17.7742	
16A, 16B	Low Sulphur F.O. Tank Level Low Alarm	Same as #15A/B except for Level Low alarm.			17.7742	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Boiler F.W. Control Valve CV124, pneumatically operated (1 required for each boiler)	Stays open.	Lose feedwater control to effected boiler--flow would be at max rate.	Drum level would rise; level high alarm would occur followed by turbine trip if level reaches high-high. If alarm/trip also failed, water carry over to turbine and turbine damage.	16	
1B	Boiler F.W. Control Valve CV125, pneumatically operated (1 required for each boiler)	Stays closed.	F.W. to effected boiler would shutdown.	Drum level would fall; level low alarm would occur followed by boiler trip if level dropped to low-low. If alarm/trip also failed, boiler surfaces would overheat; boiler explosion likely.	24	
2A	Lock-up Relay, A28, pneumatic relay, 1 required for each boiler	Fails open.	A28 could not maintain position of CV124 if air supply lost.	No effect during normal operation. If control air supply lost, CV124 would not be held in proper position; would open-same as #1A.	20.8	
2B	Lock-up Relay, A28, pneumatic relay, 1 required for each boiler	Fails closed.	Control signal to CV124 blocked; CV124 would open fully.	Same as #1A.	5.2	
3A	Drum Level Controller, PIC124; pneumatic; 1 required for each boiler	Complete loss of instrument	Lose control signal to CV124; CV124 would open fully.	Same as #1A.	24	
3B	Drum Level Controller, PIC124; pneumatic; 1 required for each boiler	Output too high.	CV124 would decrease F.W. flow to drum.	Same as #1B.	8	
3C	Drum Level Controller, PIC124; pneumatic; 1 required for each boiler	Output too low.	CV124 would increase F.W. flow to drum.	Same as #1A.	8	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
4	Trim Signal to Drum Level Controller, 1 required for each boiler.	Lose signal or signal incorrect.	Drum level controller would not receive proper signal for accelerating its response to steam flow variations to account for effects of swell or shrinkage.	Slow steam flow rate changes in response to demand rate changes; vessel response to speed change commands would be sluggish.	100	
5	Differential Pressure Transmitter, pneumatic, DPT-124; 1 required for each boiler	Lose output.	Lose measured valve signal to drum level controller, CV124 would open fully.	Same as #1A.	40	
6A	Drum Level High/ Low Alarm; Level High-High Trip; 1 required for each boiler	Lose Drum Level Output signal.	Lose signal to Drum Level High/ Low alarm, meter, and trip circuitry.	Lose Boiler Drum Level High/Low alarms, drum level high-high trip and drum level indication on drum level gauge.	33.1624	
6B	Drum Level High/ Low Alarm; Level High-High Trip; 1 required for each boiler	Signal too high.	Drum level would "appear" higher than it actually was.	Erroneous drum level high alarms and high-high trips; gauge reading incorrect.	3.0542	
6C	Drum Level High/ Low Alarm; Level High-High Trip; 1 required for each boiler	Signal too low.	Drum level would "appear" lower than it actually was.	Lose Drum Level High alarm and high-high trip; gauge reading incorrect.	3.0542	
7A	Drum Level High High Alarm; 1 required for each boiler	Stays true.	Drum Level High alarm would occur continuously.	False alarm--no effect unless crew took wrong action.	25.2406	
7B	Drum Level High High Alarm; 1 required for each boiler	Stays false.	Lose Drum Level High alarm.	Same as subsystem effect.	25.2406	
8A	Drum Level Low Alarm; 1 required for each boiler	Stays true.	Drum Level Low alarm would occur continuously.	Same as #7A.	25.2406	
8B	Drum Level Low Alarm; 1 required for each boiler	Stays false.	Lose Drum Level Low alarm.	Same as subsystem effect.	25.2406	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
9A	Drum Level High-High Trip; 1 required for each boiler	Stays true.	False drum level high-high trip.	Turbine would trip--lose propulsion.	13.0018	
9B	Drum Level High-High Trip; 1 required for each boiler	Stays false.	Lose drum level high-high trip.	If drum level did reach high-high, trip would not occur; water carryover to turbine and turbine damage.	30.3376	
10	Drum Level Gauge, 1 required for each boiler	Any.	Lose gauge reading or gauge reading incorrect.	Lose backup drum level visual indication.	20	
11	Drum Level Low-Low Trip, 1 required for each boiler	Contacts fail open.	Lose drum level lo-lo trip.	Same as Boiler Safy ycard, item #22A.	0.5110	
12A	Drum Level Lo-Lo Indicator, 1 required for each boiler	Stays true.	Drum level lo-lo indicator stays lit.	Same as #7A.	17.6054	
12B	Drum Level Lo-Lo Indicator, 1 required for each boiler	Stays false.	Lose Drum Level Lo-Lo indication.	Same as subsystem effect.	17.6054	
13	Feedwater Control Valve Differential Pressure Transmitter, DPT-105; 1 required for each boiler	Lose output.	Lose measured valve signal from effected boiler to LSS105; CV124 would appear full open.	Both F.P. throttle valves would be held full open; F.P. would run at max rate; stand-by F.P. would start. Effects described in #1A would occur.	40	
14A	Low Select Pneumatic Unit, LSS-105; 1 required for each boiler	Lose output.	Lose measured valve signal from both boilers to Master Pressure Controller PIC105.	Same as #13.	6	
14B	Low Select Pneumatic Unit, LSS-105; 1 required for each boiler	Lose either input.	Same as #13.	Same as #13.	9	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS.	COMMENTS INDEX
15A	Master Pressure Controller, pneumatic, PIC105; 1 required total (i.e., per ship)	Complete loss of instrument.	Lose signal to P/S F.P. throttle controllers.	Throttle valve of running F.P. would be held full open; F.P. would run at max rate. Could overload recirculation system.	12	
15B	Master Pressure Controller, pneumatic, PIC105; 1 required total (i.e., per ship)	Output too high.	P/S F.P. throttle controllers would signal for decreased throttle valve opening.	Speed reduction in running F.P. Standby pump, if non-failed, would start in order to maintain F.W. flow. If standby failed, effects of #1B would occur.	4	
15C	Master Pressure Controller, pneumatic, PIC105; 1 required total (i.e., per ship)	Output too low.	Low signal to P/S F.P. throttle controllers.	Same as #15A.	4	
16A	P/S Feed Pump Throttle Controller, HA105	Complete loss of instrument.	Lose signal to throttle control valve; valve would be held full open.	F.P. associated with failure would run at max. rate; could overload recirculation system.	24	
16B	P/S Feed Pump Throttle Controller, HA105	Output too high.	Signal to throttle control valve too high; valve would close in amount proportioned to signal.	F.P. associated with failure would run at reduced speed. Standby pump, if non-failed, would start in order to maintain F.W. flow. If standby failed, effects of #1B would occur.	8	
16C	P/S Feed Pump Throttle Controller, HA105	Output too low.	Signal to throttle control valve would call for increased opening.	Same as #16A.	8	
17	Low Differential Pressure Pressure Switch, PS155; 1 required total (i.e., per ship)	Lose output.	Lose signal for starting standby feedpump.	In event of failure of running feedpump, standby pump would not start. Subsequently, same as #1B.	13	
18A	P/S Throttle Control Valve, pneumatically operated	Stays open.	Max. steam input to F.P. associated with failure.	Same as #16A.	24	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
18B	P/S Throttle Control Valve, pneumatically operated	Stays closed.	No steam flow to F.P. associated with failure.	F.P. associated with failure would shutdown. Standby pump, if non-failed, would start. Otherwise, same as #1B.	16	
19A	P/S F.P. Steam Valve; Motor operated, with motor controller (electrical)	Stays open.	Steam would always he available at throttle valve suction.	No effect if throttle valve non-failed. Otherwise, F.P. associated with failure could not be shut off.	16	
19B	P/S F.P. Steam Valve; Motor operated, with motor controller (electrical)	Stays closed.	Same as #18B.	Same as #18B	24	
20A	P/S F.P. Discharge Pressure Low Alarm	Stays true.	F.P. Discharge Pressure Low alarm would occur continuously.	Same as #7A.	30.6054	
20B	P/S F.P. Discharge Pressure Low Alarm	Stays false.	F.P. Discharge Pressure Low alarm would never occur.	Lose F.P. Discharge Pressure Low alarm.	30.6054	
21	P/S F.P. Discharge Pressure Gauge (1 meter)	Any.	Lose gauge reading or gauge reading incorrect.	Lose Backup F.P. Discharge Pressure visual indication.	20	
22A	P/S Recirculation Valve, solenoid operated	Stays open.	Recirculation from F.P. to deaerator would always occur. F.W. to boilers pressure would drop.	Standby F.P., if non-failed, would start in order to maintain F.W. pressure. If standby failed--same as #1B.	72	
22B	P/S Recirculation Valve, solenoid operated	Stays closed.	Recirculation from F.P. to deaerator not possible.	Excessive F.W. flow to boilers at low demand rates. Control loop would eventually slow down F.P.	48	
23A	P/S Feedpump Suction Valve, solenoid operated	Stays open.	F.W. would always be avaiable at F.P. suction.	No effect during normal operation.	72	
23B	P/S Feedpum Suction Valve, solenoid operated	Stays closed.	No F.W. available at suction of F.D.	Same as #22A.	48	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
24A	P/S Feedpump Exhaust Valve, solenoid operated	Stays open.	F.P. exhaust valve always open.	No effect during normal operation.	72	
24B	P/S Feedpump Exhaust Valve, solenoid operated	Stays closed.	Exhaust from pump turbine blocked.	Same as #18B. Also, possible damage to pump.	48	
25	P/S Auxiliary L.O. Pump Pressure Switch, PS818	Lose output.	Auxiliary L.O. pump would not receive stop signal after F.P. main L.O. pump had started (part of start-up proceure).	Both auxiliary and main L.O. pumps would run simultaneously. No effect unless this damages one or the other of the pumps, in which case F.P. would be disabled.	26	
26	Feedpump L.O. from Cooler Temperature Gauge	Any.	Lose F.P. L.O. from cooler temperature indication or indication incorrect.	Same as subsystem effect	10.1703	
27A	P/S Feedpump L.O. Cooler Outlet Temperature High Alarm	Stays true.	Feedpump L.O. Cooler Outlet Temperature High alarm occurs continuously.	False alarm.	15.3027	
27B	P/S Feedpump L.O. Cooler Outlet Temperature High Alarm	Stays false.	Lose Feedpump L.O. Cooler Outlet Temperature High alarm.	Same as subsystem effect.	15.3027	
28A	P/S Close Recirculation Valve Relay (2G1-K7): DPST	#1 Contact Sticks open.	Relay 2G1-K7 would not stay energized when F.W. demand fell below 30 %.	F.W. recirculation valve would stay open at low F.W. demand rates No effect; normal operation.	1.3152	
28B	P/S Close Recirculation Valve Relay (2G1-K7): DPST	#1 Contact Sticks closed.	Relay 2G1-K7 would stay energized when F.W. demand fell below 20%.	F.W. recirculation valve would stay closed at low F.W. demand rates--F.W. would not recirculate--same as #22B.	1.3152	
28C	P/S Close Recirculation Valve Relay (2G1-K7): DPST	#2 Contact Sticks open.	Lose recirculation valve close signal in auto mode.	Recirculation valve would stay open in auto mode--F.W. recirculation would always occur, causing decrease F.W. flow to boilers. Control loop would try to compensate, but eventually drum level in both boilers would fall. See #1B.	1.3152	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
28D	P/S Close Recirculation Valve Relay (2G1-K7); DPST	#2 Contact Sticks closed.	Recirculation valve close signal would always be active in auto mode.	F.W. recirculation valve would stay closed in auto mode. F.W. would not recirculate; same as #22B.	1.3152	
29A	P/S Feed Flow >20%/30% Pressure Switch, PS135; DPDT	#1 Contact stays open.	Relay 2G1-K7 would not energize when F.W. demand rose above 30%.	Same as #28C.	0.4110	
29B	P/S Feed Flow >20%/30% Pressure Switch, PS135; DPDT	#2 Contact stays open.	Relay 2G1-K7 would not energize at low demand rates.	Same as #28B.	0.4110	
30A	P/S Feed Valve Differential Pressure Low Relay (2G1-K8); SPST	Contact Sticks open.	P/S Main Feed Pump Fail alarm circuit stays open in feed valve differential pressure leg.	Lose Feed Pump Fail alarm.	1.7536	
30B	P/S Feed Valve Differential Pressure Low Relay (2G1-K8); SPST	Contact Sticks closed.	P/S Main Feed Pump Fail alarm circuit stays "mode."	False Feed Pump Fail alarm	1.7536	
31A	P/S Feed Pump L.O. Pressure OK Relay (2G1-K9); 3PST	#1 Contact Sticks open.	Relay 2G1-K9 would not stay energized when F.P. running.	Auxiliary L.O. pump would stay turned on when F.P. running--same as #25.	1.1714	
31B	P/S Feed Pump L.O. Pressure OK Relay (2G1-K9); 3PST	#1 Contact Sticks closed.	Relay 2G1-K9 would stay energized whenever F.P. running.	No effect--normal operation.	1.1714	
31C	P/S Feed Pump L.O. Pressure OK Relay (2G1-K9); 3PST	#2 Contact Sticks open.	Circuit to auxiliary L.O. pump would stay open.	Auxiliary L.O. pump would not come on. Lack of L.O. could damage F.P. at start-up.	1.1714	
31D	P/S Feed Pump L.O. Pressure OK Relay (2G1-K9); 3PST	#2 Contact Sticks closed.	Run L.O. pump relay 2G1-K20 would stay energized whatever F.P. running.	Same as #31A.	1.1714	
31E	P/S Feed Pump L.O. Pressure OK Relay (2G1-K9); 3PST	#3 Contact Sticks open.	Close recirculation valve signal would not go active at high F.W. demand rates.	Same as #28C.	1.1714	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL | PAGE: 8

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
31F	P/S Feed Pump L.O. Pressure OK Relay (2G1-K9); 3PST	#3 Contact Sticks closed.	Close recirculation valve signal would go active at high F.W. demand rates.	No effect--normal operation.	1.1714	
32A	P/S F.P. L.O. Pressure >25 PSI Pressure Switch, PS820, DPST	#1 Contact stays open.	Relay 2G1-K9 could not be energized.	Same as #31A.	0.2554	
32B	P/S F.P. L.O. Pressure >25 PSI Pressure Switch, PS820, DPST	#2 Contact stays open.	F.P. run light circuit stays open.	Lose F.P. Run Visual indication.	0.2554	
33A	P/S F.P. Steam Valve Closed Relay (2G1-K10), 3PST	#1 Contact Sticks open.	Relay 2G1-K9 would not stay energized when F.P. running.	Same as #31A.	1.1714	
33B	P/S F.P. Steam Valve Closed Relay (2G1-K10), 3PST	#1 Contact Sticks closed.	Relay 2G1-K9 would stay energized.	Same as #31B.	1.1714	
33C	P/S F.P. Steam Valve Closed Relay (2G1-K10), 3PST	#2 Contact Sticks open.	Open steam valve relay 2G1-K19 could not be energized.	Same as #18B.	1.1714	
33D	P/S F.P. Steam Valve Closed Relay (2G1-K10), 3PST	#2 Contact Sticks closed.	Open steam valve relay 2G1-K19 would energize whenever F.P. running.	No effect-normal operation.	1.1714	
33E	P/S F.P. Steam Valve Closed Relay (2G1-K10), 3PST	#3 Contact Sticks open.	Close Recirculation Valve signal would not go active when F.P. not running.	Recirculation valve would stay open when F.P. not running.	1.1714	
33F	P/S F.P. Steam Valve Closed Relay (2G1-K10), 3PST	#3 Contact Sticks closed.	Same as #28D.	Same as #28D.	1.1714	
34	P/S F.P. Steam Valve Closed Limit Switch, SPST	Contact stays open.	Steam valve closed relay 2G1-K10 would not energize; open steam valve relay would not energize.	Same as #18B.	0.3406	
35	P/S F.P. Steam Valve Open Limit Switch, SPST	Contact stays open.	Same as #32B.	Same as #32B.	0.3406	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
36A	P/S F.P. Standby Relay (2G1-K11), 4PST	#1 Contact Sticks open.	Time delay relay 2G1-K22 would not energize.	Same as #17.	1.0960	
36B	P/S F.P. Standby Relay (2G1-K11), 4PST	#1 Contact Sticks closed.	Time delay relay 2G1-K22 would energize whenever feed valve differential pressure low.	No effect; normal operation for standby pump; running pump would receive an extra run signal.	1.0960	
36C	P/S F.P. Standby Relay (2G1-K11), 4PST	#2 Contact Sticks open.	Lose signal to standby indicator lamp.	Standby indicator lamp would not light.	1.0960	
36D	P/S F.P. Standby Relay (2G1-K11), 4PST	#2 Contact Sticks closed.	Signal to standby indicator lamp always active.	Standby indicator lamp stays lit.	1.0960	
36E	P/S F.P. Standby Relay (2G1-K11), 4PST	#3 Contact Sticks open	F.P. standby relay 2G1-K11 would not stay energized.	Same as #17.	1.0960	
36F	P/S F.P. Standby Relay (2G1-K11), 4PST	#3 Contact Sticks closed.	F.P. standby relay 2G1-K11 would stay energized whenever standby permissives met.	Same as #36B.	1.0960	
36G	P/S F.P. Standby Relay (2G1-K11), 4PST	#4 Contact Sticks open.	F.P. run relay 2G1-K12 would not energize from standby signal.	Same as #17.	1.0960	
36H	P/S F.P. Standby Relay (2G1-K11), 4PST	#4 Contact Sticks closed.	F.P. run relay 2G1-K11 would energize whenever run permissives met.	Same as #36B.	1.0960	
37A	P/S Time Delay Relay (2G1-K22), SPST	Contact Sticks closed.	Same as #36H.	Same as #36B.	1.7536	
37B	P/S Time Delay Relay (2G1-K22), SPST	Contact Sticks open.	Same as #36G.	Same as #17.	1.7536	
38	P/S F.W. Recirculation Valve Open Limit Switch, SPST	Contact stays open.	Lose signal to Recirculation Valve Open indicator lamp.	Recirculation Valve Open indicator lamp would not light.	0.3406	
39A	P/S F.P. Run Relay (2G1-K12), 4PST	#1 Contact Sticks open.	Run relay 2G1-K12 would not stay energized.	Same as #18B.	1.0960	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
39B	P/S F.P. Run Relay (2G1-K12), 4PST	#1 Contact Sticks closed.	Run relay 2G1-K12 would stay energized whenever run permissives met.	No effect if failure associated with running F.P. otherwise, both feed pumps would run, then same as #1A if control loop could not handle excessive F.W. flow rate.	1.0960	
39C	P/S F.P. Run Relay (2G1-K12), 4PST	#2 Contact Sticks open.	Open steam valve relay 2G1-K19 would not energize.	Same as #18B.	1.0960	
39D	P/S F.P. Run Relay (2G1-K12), 4PST	#2 Contact Sticks closed.	Open steam valve relay 2G1-K19 would energize; steam valve would open.	Same as #39B.	1.0960	
39E	P/S F.P. Run Relay (2G1-K12), 4PST	#3 Contact Sticks open.	Same as #31C.	Same as #31C.	1.0960	
39F	P/S F.P. Run Relay (2G1-K12), 4PST	#3 Contact Sticks closed.	Run lube oil pump relay 2G1-K20 would energize whenever L.O. pressure below 25 psi.	No effect if failure associated with running F.P. Otherwise, same as #25.	1.0960	
39G	P/S F.P. Run Relay (2G1-K12), 4PST	#4 Contact Sticks open.	Same as #30A.	Same as #30A.	1.0960	
39H	P/S F.P. Run Relay (2G1-K12), 4PST	#4 Contact Sticks closed.	Same as #30B.	Same as #30B.	1.0960	
40A	P/S Steam Valve Powered Relay (2G1-K15), SPST (120VAC relay)	Contact Sticks open.	Relays 2G1-K11, K12, K19 and K-20 could not be energized.	Same as #18B.	1.7536	
40B	P/S Steam Valve Powered Relay (2G1-K15), SPST (120VAC relay)	Contact Sticks closed.	Run/standby circuits would be enabled without regard to steam valve powered status.	No effect if steam valve is powered. Otherwise attempts to start the F.P. could be made when the steam valve was closed.	1.7536	
41A	P/S L.O. Pump Powered Relay (2G1-K16), SPST (120VAC relay)	Contact Sticks open.	Same as #40A.	Same as #18B.	1.7536	
41B	P/S L.O. Pump Powered Relay (2G1-K16), SPST (120VAC relay)	Contact Sticks closed.	Run/standby circuits would be enabled without regard to L.O. pump powered status.	No effect if L.O. pump is powered. Otherwise, lack of L.O. could damage F.P. at start-up.	1.7536	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL | PAGE: 11

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
42	P/S Suction Valve Open Limit Switch, SPST	Contact stays open.	Same as #40A.	Same as #18B.	0.3406	
43	P/S Exhaust Valve Open Limit Switch, SPST	Contact stays open.	Same as #40A.	Same s #18B.	0.3406	
44A	P/S Open Steam Valve Relay (2G1-K19), SPST	Contact Sticks open.	Lose open signal to steam valve.	Same as #18B.	1.7536	
44B	P/S Open Steam Valve Relay (2G1-K19), SPST	Contact Sticks closed.	Open signal to steam valve always active.	Same as #39B.	1.7536	
45A	P/S Run L.O. Pump Relay (2G1-K20) SPST	Contact Sticks open.	Same as #31C.	Same as #31C.	1.7536	
45B	P/S Run L.O. Pump Relay (2G1-K20) SPST	Contact Sticks closed.	Run L.O. pump signal always active.	Same as #25.	1.7536	
46	P/S F.P. Standby P.B. Switch, 2PST (2D1-53)	Contacts fail open.	Same as #36E.	Same as #17.	0.3406	
47	P/S F.P. Stop P.B. Switch, 3PST (2D1-55)	Contacts fail open.	Standby relay 2G1-K11 and run relay 2G1-K12 would not stay energized.	Same as #18B.	0.6812	
48	F/S F.P. Run P.B. Switch, DPST, (2D1-51)	Contacts fail open.	Same as #47.	Same as #18B.	0.5110	
49	P/S F.P. Recirculation Valve Mode Selector Switch, 2D1-56, 2 decks, 3 positions per deck	Contacts fail open.	Same as #28C.	Same as #28C.	1.8736	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A　　SUBSYSTEM: 1.1.8 FEEDWATER/DRUM LEVEL CONTROL　　PAGE: 12

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
50A	P/S F.P. Fail Alarm	Fails true.	Same as #30B.	Same as #30B.	17.6054	
50B	P/S F.P. Fail Alarm	Fails false.	Same as #30A.	Same as #30A.	17.6054	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A　　　SUBSYSTEM: 1.1.9 MASTER LOAD CONTROL　　　PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1	P/S Differential Pressure Transmitter DPT128 (pneumatic)	Lose output.	Lose drum discharge pressure signal to P/S SQ128; trim signal to plant master controll would not "consider" steam flow variations from boiler associated with failures.	Plant master controller response would not be accelerated when there are variations in steam flow. Sluggish vessel response to speed increase commands.	40	
2A	P/S Square Root Extractor (pneumatic) SQ128	Lose output.	Lose drum discharge pressure signal to HSS128.	Same as #1. Also lose P/S steam flow gauge reading.	24	
2B	P/S Square Root Extractor (pneumatic) SQ128	Output too high.	Drum discharge presure signal to HSS128 and steam flow gauge too high. Plant master controller would call for increased fuel and air flow.	Higher firing rate that desired; also, P/S steam flow gauge reading too high.	3	
2C	P/S Square Root Extractor (pneumatic) SQ128	Output too low.	Drum discharge pressure signal to HSS128 and steam flow gauge too low.	Same as #1; also, P/S steam flow gauge reading too low.	3	
3A	Trim Signal	Lose output signal.	Lose trim signal to plant master controller.	Same as #1.	6	
3B	Trim Signal	Output too high.	Trim signal to plant master controller too high.	Higher firing rate than desired on both boilers.	4.5	
3C	Trim Signal	Output too low.	Trim signal to plant master controller too low.	Same as #1.	4.5	
4A	Pneumatic Summer A34	Lose output.	Lose signal to F.P. recirculation control pressure switch PS135.	Same as Feedwater/Drum Level Control item #28C.	7.5	
4B	Pneumatic Summer A34	Output too high.	Signal to F.P. recirculation control pressure switch PS135 too high.	Same as Feedwater/Drum Level Control item #28B.	7.5	
5	P/S Steam Flow Gauges, 2D3-C4/C5	Any.	Lose gauge reading or reading incorrect.	Same as subsystem effect.	20	
6A	Plant Master Controller PIC100 (2D3-C13)	Complete loss of instrument.	Lose control signal to both P/S boiler master controller; demand signals to P and S F.O. and C.A. control would be lost.	All but the base burners on both boilers would shutdown; vessel speed decrease.	12	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.1.9 MASTER LOAD CONTROL | PAGE: 2

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
6B	Plant Master Controller PIC100 (2D3-C13)	Output too high.	Control signal to both P/S boiler master controllers too high; demand signals to P and S F.O. and C.A. control too high.	Higher firing rate than desired on both boilers.	4	
6C	Plant Master Controller PIC100 (2D3-C13)	Output too low.	Control signal to both P/S boiler master controllers too low; demand signals to P and S F.O. and C.A. control too low.	Same as #6A.	4	
7A	P/S Boiler Master Controller HA101 (2D3-C12/C14)	Complete loss of instrument.	Lose demand signal to F.O. and C.A. control for boiler associ-ated with failure.	All but the base burner would shutdown--vessel speed decrease.	24	
7B	P/S Boiler Master Controller, HA101 (2D3-C12/C14)	Output too high.	Demand signal to F.O. and C.A. control too high for boiler associated with failure.	Higher firing rate than desired on boiler associated with failure.	8	
7C	P/S Boiler Master Controller, HA101 (2D3-C12/C14)	Output too low.	Demand signal to F.O. and C.A. control too low for boiler associated with failure.	Same as #7A.	8	
8	P/S Pressure Transmitter PT100	Lose output.	Lose superheater outlet pressure signal to HSS-100; HSS-100 would base measured valve signal on input from non-failed sensor.	Demand rate would be based steam pressure from only 1 boiler. No effect normally. Vessel speed decrease if the boiler being "sensed" were cut back.	30	
9A	High Select Pneumatic Unit HSS-100	Lose output.	Lose measured valve signal to plant master controller.	Same as #6A.	6	
9B	High Select Pneumatic Unit HSS-100	Lose either input.	Lose signal from P or S pressure transmitter PT100.	Same as #8.	9	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1	Power Distribution for Local Panel	Any.	Lose power to 1 or more local panel functions; relays would de-energize, lose power to actuators.	Not possible to operate from local panel or ERC.	1.3	
2A	Local/ERC Control Mode Selector Switch	Lose ERC position.	Relays 3A1-K3, K6, and K10 would de-energize--system would stay in local mode.	Boiler could not be operated from ERC.	0.4684	
2B	Local/ERC Control Mode Selector Switch	Lose local position.	Relays 3A1-K3, K6, and K10 would stay energized--system would stay in ERC mode.	Boiler could not be operated from local panel--no effect in auto mode.	0.4684	
3A	Local/ERC Control Mode Relay 3A1-K3	NO contact sticks open.	Opens circuit from ERC to master F.O. valve actuator.	In auto mode, master F.O. valve would trip. Boiler would shutdown and could not be operated from ERC.	0.4384	
3B	Local/ERC Control Mode Relay 3A1-K3	NO contact sticks closed.	Circuit from ERC to master F.O. valve actuator stays closed.	No effect in auto mode.	0.4384	
3C	Local/ERC Control Mode Relay 3A1-K3	NC contact sticks open.	Local panel master F.O. valve control circuit stays open.	Master F.O. valve could not be opened/closed from local panel.	0.4384	
3D	Local/ERC Control Mode Relay 3A1-K3	NC contact sticks closed.	Local panel circuit to master F.O. valve stays closed in auto mode.	Master F.O. valve could not be tripped automatically from ERC--lose auto safety trip protection.	0.4384	
4A	Local/ERC Control Mode Relay 3A1-K6	NO contacts stick open.	ERC-F.O. recirculation valve circuit stays open. Also, 3A1-K10, K13 and K14 would not energize to close ERC burner circuits.	Same as #2A.	2.4114	
4B	Local/ERC Control Mode Relay 3A1-K6	NO contacts stick closed.	ERC circuits stay closed.	No effect in auto mode.	2.4114	
4C	Local/ERC Control Mode Relay 3A1-K6	NC contacts stick open.	Local panel circuit to F.O. recirculation valve stays open.	Recirculation valve could not be operated from local panel.	2.4114	
4D	Local/ERC Control Mode Relay 3A1-K6	NC contacts stick closed.	Local panel circuit to F.O. recirculation valve stays enabled.	F.O. recirculation valve could be opened from local panel in auto mode.	2.4114	
5A	Local/ERC Control Mode Relay 3A1-K6	NO contacts stick open.	ERC circuits to Burner #1 stay open.	Burner #1 would shutdown and could not be operated from ERC.	2.4114	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
5B	Local/ERC Control Mode Relay 3A1-K6	NO contacts stick closed.	ERC circuits to Burner #1 stay closed.	Same as #4B.	2.4114	
5C	Local/ERC Control Mode Relay 3A1-K6	NC contacts stick open.	Local panel circuits to Burner #1 stay open.	Same as #4B.	2.4114	
5D	Local/ERC Control Mode Relay 3A1-K6	NC contacts stick closed.	Local panel circuits to Burner #1 stay closed.	A/R, ignitors, or burner valves could be operated manually from local panel in auto mode.	2.4114	
6A	Local/ERC Control Mode Relay 3A1-K13	NO contacts stick open.	ERC circuits to Burner #2 stay open.	Burner #2 would shutdown and could not be operated from ERC.	2.4114	
6B	Local/ERC Control Mode Relay 3A1-K13	NO contacts stick closed.	ERC circuits to Burner #2 stay closed.	Same as #4B.	2.4114	
6C	Local/ERC Control Mode Relay 3A1-13	NC contacts stick open.	Local panel circuits to Burner #2 stay open.	Same as #4B.	2.4114	
6D	Local/ERC Control Mode Relay 3A1-K13	NC contacts stick closed.	Local panel circuits to Burner #2 stay closed.	A/R, ignitors, or burner valves could be operated manually from local panel in auto mode.	2.4114	
7A	Local/ERC Control Mode Relay 3A1-K14	NO contacts stick open.	ERC circuits to Burner #3 stay open.	Burner #3 would shutdown and could not be operated from ERC.	2.4114	
7B	Local/ERC Control Mode Relay 3A1-K14	NO contacts stick closed.	ERC circuits to Burner #3 stay closed.	Same as #4B.	2.4114	
7C	Local/ERC Control Mode Relay 3A1-K14	NC contacts stick open.	Local panel circuits to Burner #3 stay open.	Same as #4B.	2.4114	
7D	Local/ERC Control Mode Relay 3A1-K14	NC contacts stick closed.	Local panel circuits to Burner #3 stay closed.	A/R, ignitors, or burner valves could be operated manually from local panel in auto mode.	2.4114	
8A	Ignitor #1 Inserted Relay 3A1-K5	Contacts stick open.	Circuit to Ignitors #2 and #3 stay open in local and ERC modes.	Burners #2 and #3 could not be lit from local panel or ERC.	1.3153	
8B	Ignitor #1 Inserted Relay 3A1-K5	Contacts stick closed.	Ignitors #2 or #3 could be inserted when Ignitor #1 already inserted.	Same as #4B.	1.3153	
9A	Ignitor #2 Inserted Relay 3A1-K11	Contacts stick open.	Circuit to Ignitors #2 and #3 stay open in local and ERC modes.	Burners #2 and #3 could not be lit from local panel or ERC.	1.3153	
9B	Ignitor #2 Inserted Relay 3A1-K11	Contacts stick closed.	Ignitors #2 or #3 could be inserted when Ignitor #1 already inserted.	Same as #4B	1.3153	

SHIP: SHIP A

SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
10A	Ignitor #3 Inserted Relay 3A1-K12	Contacts stick open.	Circuit to Ignitors #2 and #3 stay open in local and ERC modes.	Burners #2 and #3 could not be lit from local panel or ERC.	1.3153	
10B	Ignitor #3 Inserted Relay 3A1-K12	Contacts stick closed.	Ignitors #2 or #3 could be inserted when Ignitor #1 already inserted.	Same as #4B.	1.3153	
11A	Manual Override Circuit	Relay K4 stays energized/contacts stick closed/limit switches stick closed.	Operation would not revert to manual mode if burner valve, master F.O. valve or F.O. recirculation valve jacked open/closed manually.	ERC commands would still be active when valve manually overridden. If conditions warranted override, would be safety hazard.	10	
11B	Manual Override Circuit	Relay K4 stays de-energized/contacts stick open/limit switches stick open.	Manual override would erroneously take effect.	Same as #2A.	40	
12A	Flame Scanner and Signal Conditioner--Burner #1	Lose flame on output and meter output.	Lose flame-on signal to Burner Logic A and flame intensity signal to ERC flame gauge.	Same as Burner Logic B item #38A; plus, lose back-up manual flame indication at ERC.	35	
12B	Flame Scanner and Signal Conditioner--Burner #1	Flame on output stays "true."	Same as Burner Logic B, item #38B.	Same as Burner Logic B, item #38B.	5	
12C	Flame Scanner and Signal Conditioner--Burner #1	Lose meter output.	Lose ERC flame intensity meter reading or reading incorrectly.	Lose manual back-up flame indication at ERC.	2.5	
12D	Flame Scanner and Signal Conditioner--Burner #1	Lose boiler panel outputs.	Lose local panel flame intensity indicators.	Lose back-up flame indication at local panel.	5	
12E	Flame Scanner and Signal Conditioner--Burner #1	Lose flame on output.	Lose flame on signal to Burner Logic A.	Same as Burner Logic B, item #38A.	2.5	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
13A	Flame Scanner and Signal Conditioner--Burner #2	Lose flame on output and meter output.	Lose flame-on signal to Burner Logic and flame intensity signal to ERC flame gauge.	Same as Burner Logic B item #38A; plus, lose back-up manual flame indication at ERC.	35	
13B	Flame Scanner and Signal Conditioner--Burner #2	Flame on output stays "true."	Same as Burner Logic B, item #38B.	Same as Burner Logic B, item #38B.	5	
13C	Flame Scanner and Signal Conditioner--Burner #2	Lose meter output.	Lose ERC flame intensity meter reading or reading incorrectly.	Lose manual back-up flame indication at ERC.	2.5	
13D	Flame Scanner and Signal Conditioner--Burner #2	Lose boiler panel outputs.	Lose local panel flame intensity indicators.	Lose back-up flame indication at local panel.	5	
13E	Flame Scanner and Signal Conditioner--Burner #2	Lose flame on output.	Lose flame on signal to Burner Logic A.	Same as Burner Logic B, item #38A.	2.5	
14A thru 14E	Same as #12A-#12E except for Burner #3.					
15A	#1 Burner Set-Up Limit Switch	Stays open.	Same as Burner Logic B item #60B.	Same as Burner Logic B, item #25A.	5	
15B	#1 Burner Set-Up Limit Switch	Stays closed.	Same as Burner Logic B item #60A.	Same as Burner Logic B item #60A.	5	
16A, 16B	Same as #15A and B except for Burner #2.				5	
17A, 17B	Same as #15A and B except for Burner #3.				5	
18A	Master F.O. Valve Actuating Solenoid	Stays energized.	Master F.O. valve would stay open.	Same as Boiler Safety item #2A; also, lose back-up from local panel.	30	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
18B	Master F.O. Valve Actuating Solenoid	Stays de-energized.	Master F.O. valve would stay closed.	Same as Boiler Safety item #2B; also, lose back-up from local panel.	30	
19A	Master F.O. Valve Open Limit Switch SPDT	NO contact stays open.	Same as Boiler Safety item #8B.	Same as Boiler Safety item #2B.	2.5	
19B	Master F.O. Valve Open Limit Switch SPDT	NO contact stays closed.	Same as Boiler Safety item #8A.	Same as Boiler Safety item #8A.	2.5	
19C	Master F.O. Valve Open Limit Switch SPDT	NC contact stays open.	ERC master F.O. valve trip lamp never illuminates.	Same as subsystem effect.	2.5	
19D	Master F.O. Valve Open Limit Switch SPDT	NC contact stays closed.	Master F.O. valve trip lamp on ERC stays lit.	Same as subsystem effect.	2.5	
20A	Master F.O. Valve Close Limit Switch SPDT	NO contact stays open.	Same as Boiler Safety item #11B.	Same as Boiler Safety item #11B.	2.5	
20B	Master F.O. Valve Close Limit Switch SPDT	NO contact stays closed	Same as Boiler Safety item #11A.	Same as Boiler Safety item #11A.	2.5	
20C	Master F.O. Valve Close Limit Switch SPDT	NC contact stays open.	ERC master F.O. valve reset lamp never illuminates.	Same as subsystem effect.	2.5	
20D	Master F.O. Valve Close Limit Switch SPDT	NC contact stays closed.	Master F.O. valve reset lamp on ERC stays lit.	Same as subsystem effect.	2.5	
21A	F.O. Recirculation Valve Actuating Solenoid	Stays energized.	F.O. recirculation valve would stay open.	Same as Boiler Safety item #14A; also lose back-up from local panel.	30	
21B	F.O. Recirculation Valve Actuating Solenoid	Stays de-energized.	F.O. recirculation valve would stay closed.	Same as Boiler Safety item #13A; also lose back-up from local panel.	30	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A　　　SUBSYSTEM: 1.2 BOILER LOCAL PANEL　　　

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
22A	F.O. Recirculation Valve Closed Limit Switch, SPST	Contact stays open.	ERC F.O. Recirculation Valve Closed lamp never illuminates.	Same as subsystem effect.	5	
22B	F.O. Recirculation Valve Closed Limit Switch, SPST	Contact stays closed.	ERC F.O. Recirculation Valve Closed lamp stays illuminated.	Same as subsystem effect.	5	
23A	F.O. Recirculation Valve Open Limit Switch, SPST	Contact stays open.	ERC F.O. Recirculation Valve Open lamp never illuminates.	Same as subsystem effect.	5	
23B	F.O. Recirculation Valve Open Limit Switch, SPST	Contact stays closed.	ERC F.O. Recirculation Valve Open lamp stays illuminated.	Same as subsystem effect.	5	
24A	Burner Valve #1 Actuating Solenoid	Stays energized.	Same as Burner Logic B item #34A.	Same as Burner Logic B item #34A; also lose back-up from local panel.	30	
24B	Burner Valve #1 Actuating Solenoid	Stays de-energized.	Same as Burner Logic B item #34B.	Same as Burner Logic B item #34B; also lose back-up from local panel.	30	
25A, 25B	Same as #24A/B except for Burner #2.				30	
26A, 26B	Same as #24A/B except for Burner #3.				30	
27A	Burner Valve #1 Open Limit Switch, SPDT	NO contact stays open.	Same as Burner Logic A item #27B.	Same as Burner Logic A item #27B.	2.5	
27B	Burner Valve #1 Open Limit Switch, SPDT	NO contact stays closed.	Same as Burner Logic A item #27A.	Same as Burner Logic A item #27A.	2.5	
27C	Burner Valve #1 Open Limit Switch, SPDT	NC contact stays open.	ERC Burner Valve #1 open lamp never illuminates.	Same as subsystem effect.	2.5	
27D	Burner Valve #1 Open Limit Switch, SPDT	NC contact stays closed.	ERC Burner Valve #1 open lamp stays illuminated.	Same as subsystem effect.	2.5	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A　　SUBSYSTEM: 1.2 BOILER LOCAL PANEL　　

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
28A thru 28D	Same as #27A-D except for Burner Valve #2.				2.5	
29A thru 29D	Same as #27A-D except for Burner Valve #3.					
30A	Burner Valve #2 Closed Limit, SPDT	NO contact stays open.	Same as Burner Logic A item #28B.	Same as Burner Logic A item #28B.	2.5	
30B	Burner Valve #2 Closed Limit, SPDT	NO contact stays closed.	Same as Burner Logic A item #28A.	Same as Burner Logic A item #28A.	2.5	
30C	Burner Valve #2 Closed Limit, SPDT	NC contact stays open.	ERC Burner Valve #1 closed lamp never illuminates.	Same as subsystem effect.	2.5	
30D	Burner Valve #2 Closed Limit,	NC contact stays closed.	ERC Burner Valve #1 closed lamp stays illuminated.	Same as subsystem effect.	2.5	
31A thru 31D	Same as #30A-D except for Burner Valve #2.				10	
32A thru 32D	Same as #30A-D except for Burner Valve #3.				10	
33A	A/R #1 Open Actuator	Stays energized.	Same as Burner Logic B item #5A.	Same as Burner Logic B item #2A; also, lose back-up from local panel.	5.5	
33B	A/R #1 Open Actuator	Stays de-energized.	Same as Burner Logic B item #4B.	Same as Burner Logic B item #3A; also, lose back-up from local panel.	5.5	
34A, 34B	Same as 33A/B except for A/R #2.				11	
35A, 35B	Same as 33A/B except for A/R #3.				11	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 1.2 BOILER LOCAL PANEL |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
36A	A/R #1 Open Limit Switch, SPDT	NO contact stays open.	Same as Burner Logic A item #29B.	Same as Burner Logic A item #29B.	2.5	
36B	A/R #1 Open Limit Switch, SPDT	NO contact stays closed.	Same as Burner Logic A item #29A.	Same as Burner Logic A item #29A.	2.5	
36C	A/R #1 Open Limit Switch, SPDT	NC contact stays open.	A/R #1 open lamp on ERC never illuminates.	Same as subsystem effect.	2.5	
36D	A/R #1 Open Limit Switch, SPDT	NC contact stays closed.	A/R #1 open lamp on ERC stays illuminated.	Same as subsystem effect.	2.5	
37A thru 37D	Same as #36A-D except A/R #2.				10	
38A thru 38D	Same as #37A-D except A/R #3.				10	
39A	A/R #1 Close Actuator	Stays energized.	Same as Burner Logic B item #7A.	Same as Burner Logic B item #3A; also, lose back-up from local panel.	5.5	
39B	A/R #1 Close Actuator	Stays de-energized.	Same as Burner Logic B item #7B.	Same as Burner Logic B item #2A; also, lose back-up from local panel.	5.5	
40A, 40B	Same as #39A/B except for A/R #2.					
41A, 41B	Same as #39A/B except for A/R #3.					
42A	A/P #1 Close Limit Switch, SPDT	NO contact stays open.	Same as Burner Logic A item #30B.	Same as Burner Logic A item #303.	2.5	
42B	A/R #1 Close Limit Switch, SPDT	NO contact stays closed.	Same as Burner Logic A item #30A.	Same as Burner Logic A item #30A.	2.5	
42C	A/R #1 Close Limit Switch, SPDT	NC contact stays open.	A/R #1 closed lamp on ERC never illuminates.	Same as subsystem effect.	2.5	
42D	A/R #1 Close Limit Switch, SPDT	NC contact stays closed.	A/R #1 closed lamp on ERC stays illuminated.	Same as subsystem effect.	2.5	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
43A thru 43D	Same as #42A-D except for A/R #2.				10	
44A thru 44D	Same as #42A-D except for A/R #2.				10	
45A	Ignitor #1 Actuator	Stays energized.	Same as Burner Logic B item #16A.	Same as Burner Logic B item #16A; also, lose back-up from local panel.	5.5	
45B	Ignitor #1 Actuator	Stays de-energized.	Same as Burner Logic B item #16B.	Same as Burner Logic B item #16B; also, lose back-up from local panel.	5.5	
46A, 46B	Same as #45A/B except for Ignitor #2.				11	
47A, 47B	Same as #45A/B except for Ignitor #3.				11	
48A	Ignitor #1 In Limit Switch, SPDT	NO contact stays open.	Same as Burner Logic A item #25B.	Same as Burner Logic A item #25B.	2.5	
48B	Ignitor #1 In Limit Switch, SPDT	NO contact stays closed.	Same as Burner Logic A item #25A.	Same as Burner Logic A item #25A.	2.5	
48C	Ignitor #1 In Limit Switch, SPDT	NC contact stays open.	Ignitor In #1 lamp never illuminates.	Same as subsystem effect.	2.5	
48D	Ignitor #1 In Limit Switch, SPDT	NC contact stays closed.	Ignitor In #1 lamp never illuminated.	Same as subsystem effect.	2.5	
49A thru 49D	Same as #48A-D except for Ignitor #2.				10	
50A thru 50B	Same as #48A-D except for Ignitor #3.				10	
51A	Ignitor #1 Out Limit Switch, SPDT	NO contact stays open.	Same as Burner Logic A item #26B.	Same as Burner Logic A item #26B.	2.5	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.2 BOILER LOCAL PANEL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
51B	Ignitor #1 Out Limit Switch, SPDT	NO contact stays closed.	Same as Burner Logic A item #26A.	Same as Burner Logic A item #26A.	2.5	
51C	Ignitor #1 Out Limit Switch, SPDT	NC contact stays open.	Ignitor Out #1 lamp never illuminates.	Same as subsystem effect.	2.5	
51D	Ignitor #1 Out Limit Switch, SPDT	NC contact stays closed.	Ignitor Out #1 lamp stays	Same as subsystem effect.	2.5	
52A thru 52D	Same as #51A-D except for Ignition #2.				10	
53A thru 53D	Same as #51A-D except for Ignition #3.				10	
54	Smoke Detection	Lose signal.	Lose smoke alarm.	Same as subsystem effect.		

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 2.0 SUPERHEATER STEAM TEMPERATURE CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENT INDEX
1A	Superheater Outlet Temperature Controller, TIC116	Complete loss of instrument.	Lose signal to control valve CV117--valve would open fully.	Max steam flow through desuperheater--S.H. steam temperature would drop--loss in efficiency and possibly condensation and moisture in turbine.	12	
1B	Superheater Outlet Temperature Controller, TIC116	Outlet too high.	Signal to CV117 too high--CV117 would close partially/fully.	Min. steam flow through desuperheater therefore min. cooling of S.H. steam. Temperature could get too high and possibly rupture S.H. tube or warp turbine blades.	4	
1C	Superheater Outlet Temperature Controller, TIC116	Outlet too low.	Signal to CV117 too low--CV117 would open partially/fully.	Same as #1A.	4	
2A	S.H. Steam Temperature High Alarm	Output stays false	Lose S.H. Steam Temperature High alarm.	Same as subsystem effect.	15.3027	
2B	S.H. Steam Temperature High Alarm	Output stays true.	S.H. Steam Temperature High alarm occurs continuously.	False alarm.	15.3027	
3	Temperature Transmitter, TT116	Lose output.	Lose measured valve signal to temperature controller, TIC116; CV117 would open fully.	Same as #1A.	20	
4A	Temperature Control Valve CV117 (pneumatically operated)	Fails open.	Temperature control valve would stay open.	Same as #1A.	12	
4B	Temperature Control Valve CV117 (pneumatically operated)	Fails closed.	Temperature control valve would stay closed.	No steam flow through desuperheater--no cooling of S.H. steam temperature could get too high and rupture S.H. tube or warp turbine blades.	8	
5	Superheater Outlet Temperature Gauge (2B3-M6/M13)	Any.	Lose reading or reading incorrect.	Same as subsystem effect.	10	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 3.0 DESUPERHEATED STEAM CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	Atomizing Steam Control Valve, D543, locking screw set point type reducing valve	Stays open.	No pressure reduction in desuperheated steam flow to atomizing steam header.	Atomizing steam pressure would rise. If non-failed, relief valve should open to lower pressure.	10	
1B	Atomizing Steam Control Valve, D543, locking screw set point type reducing valve	Stays closed.	Lose steam flow to atomizing steam header.	Both boilers would flame out and shutdown F.O. droplets could form and create explosion hazard.	10	
2A	Gland Steam Control Valve, D512, same type as above	Stays open.	No pressure reduction in desuperheated steam flow to gland steam header.	Gland steam pressure would rise. If non-failed, relief valve should open to lower pressure.	10	
2B	Gland Steam Control Valve, D512, same type as above	Stays closed.	Lose steam flow to gland steam header to main turbine and turbo-generator.	Would result in loss of vacuum; main engine would trip if trip circuitry non-failed.	10	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 4.0 EXHAUST AND BLEED STEAM CONTROL

REP. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	9th Stage H.P. Control Valve ES17, pneumatically operated	Stays open.	9th stage H.P. bleed steam would always be available to exhaust steam system.	No effect during steaming (normal operation); during maneuvering could cause different pressures in bleed steam and turbine steam and thus cause backflow of steam into turbine; possible turbine damage.	8	
1B	9th Stage H.P. Control Valve ES17, pneumatically operated	Stays closed.	9th stage H.P. bleed steam would never be available to exhaust steam system.	No effect during maneuvering (normal operation); during steaming could cause different pressures in bleed steam and turbine steam and thus cause backflow of steam into turbine; possible turbine damage.	12	
2A	9th Stage H.P. Bleed Make-Up Control Valve ES16, pneumatically operated	Stays open.	Lose control of amount of 9th stage H.P. bleed steam released to exhaust system; release would always be max.	Would cause rise in condenser level; would result in loss of vacuum if level rise not corrected, also possibly rupture condenser due to overpressure.	8	
2B	9th Stage H.P. Bleed Make-Up Control Valve ES16, pneumatically operated	Stays closed.	Same as #1B.	Same as #1B.	12	
3A	ES16 Make-Up Valve Controller, pneumatic (PRA-1)	Lose output signal.	ES16 would stay closed--same as #1B.	Same as #1B.	14	
3B	ES16 Make-Up Valve Controller, pneumatic (PRA-1)	Output signal max or too high.	Same as #2A.	Same as #2A.	6	
4A	Desuperheated Steam Make-Up Control Valve DS8, pneumatically	Stays open.	Lose control of amount of desuperheated steam release to exhaust system; release would be max, continuously.	Same as #2A.	8	
4B	Desuperheated Steam Make-Up Control Valve DS8, pneumatically	Stays closed.	Desuperheated steam would never be available to exhaust steam system.	Overpressure of desuperheated steam system; could cause damage and subsequent loss of atomizing steam and gland steam.	12	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A — SUBSYSTEM: 4.0 EXHAUST AND BLEED STEAM CONTROL — PAGE: 2

REP. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
5A	DS8 Control Valve Volume Boost Relay, pneumatic	Stays open.	DS8 would always receive max. signal--same as #4A.	Same as #4A/2A.	16	
5B	DS8 Control Valve Volume Boost Relay, pneumatic	Stays closed.	DS8 would stay closed--same as #4B.	Same as #4B.	4	
6A	High Select Unit, pneumatic (output to volume boost relay)	Lose output.	Lose input to volume boost relay, and therefore output; same as #5B.	Same as #4B.	6	
6B	High Select Unit, pneumatic (output to volume boost relay)	Lose input from controller off exhaust header.	HSS output would always be from superheated steam pressure measured valve; i.e., lose exhaust header measured valve.	Lose ability to automatically correct for high exhaust header pressure.	4.5	
6C	High Select Unit, pneumatic (output to volume boost relay)	Lose input from controller off HSS100.	HSS output would always be from exhaust header measured value; i.e., lose superheated steam pressure measured value.	Lose ability to correct for high superheater header pressure.	4.5	
7A	DS8 Pressure Controller Off Exhaust Header (PRAP-1)	Lose output signal.	Same as #6B.	Same as #6B.	14	
7B	DS8 Pressure Controller Off Exhaust Header (PRAP-1)	Output signal max or too high.	Same as #5A.	Same as #4A/2A.	6	
8A	DS8 Pressure Controler Off HSS100	Lose output signal.	Same as #6C.	Same as #6C.	14	
8B	DS8 Pressure Controller Off HSS100	Output signal max or too high.	Same as #5A.	Same as #4A/2A.	6	
9A	High Select Unit HSS100	Lose output.	Lose superheated steam pressure measured valve signal to #8 above pressure controller from both P and S.H. steam headers.	Same as #6C.	6	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 4.0 EXHAUST AND BLEED STEAM CONTROL

PAGE: [illegible]

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURE RATE/10^6 HRS.	COMMENTS (IN [illegible])
9B	High Select Unit HH5103	Lose either input	Lose superheated steam pressure measured value signal to EE above pressure controller from either P or S.H. steam header.	Same as 9C but for affected boiler.	9	
10A	Exhaust Header Dump Control Valve EH21, pneumatically operated	Stays open.	Lose control of amount of steam dumped to main and atmosphere condensers; amount would always be max	Same as 9A.	8	
10B	Exhaust Header Dump Control Valve EH21, pneumatically operated	Stays closed.	Exhaust steam would never be dumped to main or atmosphere condensers.	Exhaust steam lines would overpressurize and probably rupture. Feedwater would become depleted and eventually cause drum level low-low in both boilers	12	
11A	EH21 Pressure Controller, pneumatic (PDAP-1)	Lose output signal.	EH21 would never open--same as 10B.	Same as 10B	14	
11B	EH21 Pressure Controller, pneumatic (PDAP-1)	Output signal max or too high.	Same as 10A.	Same as 10A/9A.	6	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 5.6 L.P. STEAM GENERATOR CONTROL

PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS	COMMENTS INDEX
1A	Desuperheated Steam Control Valve DS17	Stays open.	Max. flow of desuperheated steam would always enter L.P. steam generator. Lose pressure control.	If relief valve fails to activate, L.P. steam generator would become overpressured and rupture-safety hazard.	6	
1B	Desuperheated Steam Control Valve DS17	Stays closed.	Lose desuperheated steam supply to L.P. steam generator; lose heating steam to F.O. Heaters.	Same as F.O. Temperature and Pressure Control Item #1A.	12	
2A	L.P. Steam Generator Heating Steam Pressure Controller and Shell Pressure Controller (2 pneumatic pressure controllers)	Lose output	DS 17 would close--same as #1B.	Same as F.O. Temperature and Pressure Control Item #1A.	28	
2B	L.P. Steam Generator Heating Steam Pressure Controller and Shell Pressure Controller (2 pneumatic pressure controllers)	Output signal max or too high.	Same as #1A.	Same as #1A.	12	
3A	L.P. Steam Generator F.W. Control Valve FD70, pneumatically operated	Stays open.	Lose L.P. steam generator F.W. control--F.W. would flow at max rate; F.W. level would get too	Possible water carryover into contaminated steam supply--some loss of F.O. heating efficiency	8	
3B	L.P. Steam Generator F.W. Control Valve FD70, pneumatically operated	Stays closed	Lose F.W. supply to L.P. steam generator causing loss of contaminated steam.	Same as F.O. Temperature and Pressure Control Item #1A.	12	
4A	L.P. Steam Generator F.W. Level Controller, pneumatic	Lose output signal.	Same as #1B.	Same as F.O. Temperature and Pressure Control Item #1A.	14	
4B	L.P. Steam Generator F.W. Level Controller, pneumatic	Output signal max or too high	Same as #1A.	Same as #1A.	6	

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP A

SUBSYSTEM: 5.0 L.P. STEAM GENERATOR CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS	COMMENTS INDEX
5A	Drain Cooler Condensate Level Control Valve PD73, pneumatically operated	Stays open.	Max condensate drainage to deaerator.	Probably not noticeable during normal operation.	8	
5B	Drain Cooler Condensate Level Control Valve PD73, pneumatically operated	Stays closed.	Loss condensate drainage to deaerator; drain cooler and and L.P. steam generator could become overpressured.	If controls in items #1 and #2 fail, and if relief valve fails, drain cooler or LP steam generator would rupture--safety hazard.	12	
6A	Drain Cooler Condensate Level Controller, pneumatic	Loss output signal.	PD73 would stay closed--same as #5B.	Same as #5B.	14	
6B	Drain Cooler Condensate Level Controller, pneumatic	Output signal max or too high.	PD73 would stay open--same as #5A.	Same as #5A.	6	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 6.0 3RD AND 4TH STAGE FEED HEATER CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 1000 HRS.	COMMENTS (NOTE)
1A	3rd Stage H.P. Bleed Control Valve MS19, pneumatically operated	Stays open.	3rd stage H.P. bleed steam always available to 4th stage feed heater.	No effect during steaming (normal operations); during maneuvering could cause different pressures in bleed steam and turbine steam and thus cause back-flow of steam into turbine; possible turbine damage.	8	
1B	3rd Stage H.P. Bleed Control Valve MS19, pneumatically operated	Stays closed.	3rd stage H.P. bleed steam never available to 4th stage	No effect during maneuvering (normal operation) during steaming could cause different pressures in bleed steam and turbine steam and thus cause back-flow of steam into turbine; possible turbine damage.	13	
2A	4th Stage Feed Heater Level Control Valve FD115, pneumatically operated	Stays open.	Heating steam in 4th stage feed heater would always be dumped to deaerator.	Decrease in feed heating; loss in efficiency.	8	
2B	4th Stage Feed Heater Level Control Valve FD115, pneumatically operated	Stays closed.	3rd stage H.P. Bleed line would be "blocked"; 4th stage feed heater level would rise.	4th stage feed heater could be damaged if its relief valve did not function.	12	
3A	4th Stage Feed Heater Level Controller, pneumatic	Loss output signal.	FD115 would close--same as #2B.	Same as #2B.	14	
3B	4th Stage Feed Heater Level Controller, pneumatic	Output signal max or too high.	FD115 would open--same as #2A.	Same as #2A.	4	
4A	4th Stage H.P. Bleed Control Valve MS18, pneumatically operated	Stays open.	4th stage H.P. bleed steam always available to 3rd stage feed heater.	No effect during steaming (normal operation); during maneuvering, could cause different pressures in bleed steam and turbine steam and thus cause back-flow of steam into turbine; possible turbine damage.	8	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A   SUBSYSTEM: 6.0 3RD AND 4TH STAGE FEED HEATER CONTROL   PAGE: 3

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	COMMENTS INDEX
4B	6th Stage H.P. Bleed Control Valve BB10, pneumatically operated	Stays closed.	6th stage H.P. bleed steam never available to 3rd stage feed heater.	No effect during maneuvering (normal operation); during steaming, could cause different pressures in bleed steam and turbine steam and thus cause back-flow of steam into turbine; possible turbine damage.	12	
5A	3rd Stage Feed Heater Level Control Valve PD142, pneumatically operated	Stays open.	Heating steam in 3rd stage feed heater would always be dumped to deaerator.	Same as #7A.	8	
5B	3rd Stage Feed Heater Level Control Valve PD142, pneumatically operated	Stays closed.	6th stage H.P. bleed steam line would be "blocked"; 3rd stage feed heater level would rise.	3rd stage feed heaters could be damaged if its relief valve did not function.	13	
6A	3rd Stage Feed Heater Level Controller, pneumatic	Lose output signal.	PD1422 would close--same as #5B.	Same as #5B.	14	
6B	3rd Stage Feed Heater Level Controller, pneumatic	Output signal was too high.	PD142 would open--same as #5A.	Same as #5A/7A.	6	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 7.0 LUBE OIL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	COMMENTS INDEX
1A	L.O. Temperature Control Valve, LO60, 3-way, pneumatically controlled	Bypass stays open	L.O. cooler always bypassed; lose L.O. cooling.	L.O. temperature would get too high. Main engine could overheat and be damaged.	8	
1B	L.O. Temperature Control Valve, LO60, 3-way, pneumatically controlled	Bypass stays closed	L.O. cooler never bypassed--has cooling continuously.	No effect unless L.O. becomes too viscous to flow (remote possibility) in which case main engine would be damaged.	8	
1C	L.O. Temperature Control Valve, LO60, 3-way, pneumatically controlled	Output blocked.	Lose L.O. supply to main engine.	Main engine would trip on L.O. pressure low-low.	4	
2A	L.O. Temperature Control Volume Boost Relay, pneumatic	Stays open.	Temperature Control Valve LO60 would always receive max signal--L.O. cooler would stay bypassed.	Same as #1A.	18.4	
2B	L.O. Temperature Control Volume Boost Relay, pneumatic	Stays closed	Lose control signal to LO60; #1B would occur.	Same as #1B.	2.6	
3A	L.O. Temperature Controller, SP-1; pneumatic	Complete loss of instrument.	Same as #2B.	Same as #1B.	12	
3B	L.O. Temperature Controller, SP-1; pneumatic	Output too high.	Same as #2A.	Same as #1A.	4	
3C	L.O. Temperature Controller, SP-1; pneumatic	Output too low.	LO60 would allow too much L.O. to flow through cooler.	Same as #1B.	4	
4	P/S Main Engine L.O. Service Pump Switch, SPST (206)	Fails open.	Lose ability to start pump associated with failure from MBC.	No effect if affected pump can be selected as standby unit or other pump is non-failed. Loss of both pumps causes L.O. pressure to drop and main engine trip.	0.1604	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 7.6 LUBE OIL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODE: SUBSYSTEM	FAILURE MODE: SYSTEM	FAILURES/ 10E6 HRS	COMMENTS INDEX
5	P/S Main Engine L.O. Service Pump Standby Switching	Fails open.	Lose ability to switch pump associated with failure to standby status from EOC.	No effect if affected pump can be selected as running unit or other pump is non-failed. Loss of both pumps causes L.O. pressure to drop and main engine trip.	0.1406	
6	P/S Main Engine L.O. Service Pump Stop Switch, SPST (2S6)	Fails open.	Lose ability to stop pump associated with failure from EOC - inconvenience.	Same as subsystem effect.	0.1406	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 3.0 CONDENSATE SYSTEM CONTROLS | PAGE: 1

REF NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODE &	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS	COMMENTS INDEX
1A	Hotwell Level Controller, pneumatic, differential pressure (LAPB)	Complete loss of instrument.	Loss signal to recirculation valve PD35- valve would close; loss recirculation to hotwell.	Hotwell level would fall; condensate pumps could be damaged due to cavitation. (No indications provided for this condition.)	12	
1B	Hotwell Level Controller, pneumatic, differential pressure (LAPB)	Output too high.	Signal to PD35 too high--recirculation valve would open wider than desired; excessive recirculation.	Hotwell level would rise. Level High alarm would occur and standby condensate pump would start. If the standby pump has failed, level would rise and backup into LP turbine. Safety hazard	4	
1C	Hotwell Level Controller, pneumatic, differential pressure (LAPB)	Output too low.	Signal to PD35 too low--recirculation valve would close more than desired--insufficient recirculation.	Same as 01A.	4	
2	P/S Hotwell Level Limit Switches, LS207, SPST	Stays open.	Loss start signal to standby condensate pump.	Loss standby condensate pump. If both pumps lost, hotwell level could get too high and backup into LP turbine--safety hazard.	26	
3A	Hotwell Level High Alarm	Stays true	Condenser Hotwell Level High alarm would occur continuously.	False alarm.	11.0027	
3B	Hotwell Level High Alarm	Stays false.	Loss Condenser Hotwell Level High alarm.	Same as subsystem effect	11.0027	
4A	Condenser Hotwell Recirculation Valve PD35, pneumatically operated (DDL-3E)	Stays closed.	PD35 would stay closed--loss recirculation to Hotwell.	Same as 01A.	12	
4B	Condenser Hotwell Recirculation Valve PD35, pneumatically operated (DDL-3E)	Stays open.	PD35 would continuously recirculate.	Same as 01B.	8	
5	Pressure Sensor, Condensate Pump Discharge (PI204)	Loss output.	Loss condensate pump(s) discharge pressure gauge reading (local gauge).	Same as subsystem effect		

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 8.0 CONDENSATE SYSTEM CONTROLS

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	COMMENTS (NOTE)
6	P/S Condensate Pump Run Switch (SPST)	Fails open.	Condensate pump associated with failed switch could not be selected as the "running" pump.	Same as #10; also if both pumps lost, lose F.W. supply to to both boilers. Boilers would trip on drum level low-low	0.1606	
7	P/S Condensate Pump Standby Switching	Fails open.	Condensate pump associated with failed switch could not be selected as the "standby" pump.	Lose standby pump, same as #6.	20.1406	
8A	P/S Condensate Pump Fail Alarm	Stays false.	Lose P or S Condensate Pump Fail alarm.	Same as subsystem effect.	17.6054	
8B	P/S Condensate Pump Fail Alarm	Stays true	P or S Condensate Pump Fail alarm occurs continuously.	False alarm.	17.6054	
9	Condenser Recirculation Valve Open Switch, SPST	Fails open.	Condenser recirculation valve could not be opened manually from EOC.	Lose manual backup.	0.1701	
10	Condenser Recirculation Valve Closed Switch, SPST	Fails open	Condenser recirculation valve could not be closed manually from EOC.	Lose manual backup.	0.1701	
11A	LP Bleed Control Valve, EB15, solenoid operated	Stays open.	LP bleed steam never shutoff from condensate cooled distiller and first stage feed heater.	Normal operation during steaming; during manuevering, could cause different pressures in bleed steam and turbine steam and thus cause backflow of steam into turbine, possible turbine damage	14	
11B	LP Bleed Control Valve, EB15, solenoid operated	Stays closed.	LP bleed steam stays shutoff to condensate cooled distiller and first stage feed heater.	Loss in steam plant efficiency	16	
12A	F.W. Drain Collecting Tank Make Up Valve, FD7	Stays open.	F.W. from reserve feed tanks would continuously flow into F.W. drain collecting tank.	Control loop would attempt to recirculate excess F.W. but drain collecting tank could overflow	8	
12B	F.W. Drain Collecting Tank Make Up Valve, FD7	Stays closed.	F.W. from reserve feed tanks could never flow into F.W. drain collecting tank.	Depletion of F.W. supply both boilers would eventually trip on drum level low-low.	12	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A | SUBSYSTEM: 8.0 CONDENSATE SYSTEM CONTROLS | PAGE: 1

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS	COMMENTS (NOTE)
13A	F.W. Drain Collecting Tank Level Controller, pneumatic, differential pressure (LAFB)	Complete loss of instrument.	Lose F.W. drain tank level control.	Same as #12B.	12	
13B	F.W. Drain Collecting Tank Level Controller, pneumatic, differential pressure (LAFB)	Output too high.	Control loop would "think" the tank level was too high and cycle the drain pumps excessively.	Same as #12B.	4	
13C	F.W. Drain Collecting Tank Level Controller, pneumatic, differential pressure (LAFB)	Output too low.	Control loop would "think" the tank level was too low and cycle down (or shutdown) the drain pumps.	Same as #12A.	4	
14	Drain Pump On/Off Pressure Switches PS715, PS716, PS717 (1 per drain pump)	Lose output	Drain pump associated with failures would not be stopped or started.	Effect not noticeable unless more than 1 pressure switch fails; then, could cause either high drain tank level or low level which could cause #12A	11	
15A	F.W. Drain Collecting Tank Level High Alarm	Stays true	Drain Collecting Tank Level High alarm occurs continuously.	False alarm.	0.0070	
15B	F.W. Drain Collecting Tank Level High Alarm	Stays false.	Lose Drain Collecting Tank Level High alarm.	Same as subsystem effect	0.3070	
16A	F.W. Drain Collecting Tank Level Control Valve, pneumatically operated (DL II, PD60	Stays open.	All drain pump(s) discharge would flow to deaerator or dump valve.	No effect if drain pumps operating and cycling correctly.	12	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 8.0 CONDENSATE SYSTEM CONTROLS

PAGE 4

REF #	ITEM NOMENCLATURE FUNCTION	FAILURE MODE(S)	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/10E6 HRS	COMMENTS (NONE)
16C	F.W. Drain Collecting Tank Level Control Valve, pneumatically operated (DL-1) TDAD	Stays closed	Discharge from all drain pumps shutdown	Drain collecting tank would overflow	8	
17A	Deaerator Level Controller, 2 Stage (High Low), pneumatic, differential pressure	Complete loss of instrument	Lose deaerator level control - both high and low	Same as 811A (worst case)	4	
17B	Deaerator Level Controller, 2 Stage (High Low), pneumatic, differential pressure	Loss of high level control	Deaerator level could rise above high limit.	Deaerator could rupture if its relief valve failed to function, thus causing shutdown of steam plant.	8	
17C	Deaerator Level Controller, 2 Stage (High Low), pneumatic, differential pressure	Loss of low level control	Deaerator level could fall below low limit.	Same as 811A.	8	
18A	Deaerator Level Alarm, Indicator Sensor	Lose sensor.	Lose high/low level alarms and gauge reading for deaerator level ("DC Heater" level)	Same as subsystem effect	11.8148	
18B	Deaerator Level Alarm/Indicator Sensor	Lose high level signal.	Lose High Level alarm.	Same as subsystem effect.	27.6297	
18C	Deaerator Level Alarm/Indicator Sensor	Lose Low Level signal.	Lose Low Level alarm.	Same as subsystem effect.	27.6297	
19	DC Heater Level Gauge (1 meter)	Any	Lose gauge reading or reading incorrect	Same as subsystem effect.	10	
20A	Condensate Dump Control Valve, pneumatically operated (DDL-1) FDID	Stays open.	Condensate dump line always open - deaerator level would drop and could not be corrected.	Same as 811A.	8	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A — SUBSYSTEM: 8.0 CONDENSATE SYSTEM CONTROLS — PAGE: 5

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE'S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES 1000 HRS	COMMENTS INDEX
208	Condensate Dump Control Valve, pneumatically operated (DDL 1) F010	Stays closed	Condensate dump line always closed; deaerator high level would not be corrected	No effect normally. If "dump" required, same as 21IB	12	
21A	Condenser Vacuum Low Alarm	Stays true	Condenser Vacuum Low alarm occurs continuously.	False alarm		
21B	Condenser Vacuum Low Alarm	Stays false	Lose Condenser Vacuum Low alarm.	Same as subsystem effect		
22	Condenser Vacuum Gauge	Any	Lose condenser vacuum meter reading or reading incorrect	Same as subsystem effect	10	
23	P S Vacuum Pump Standby Switch, 1 pressure switch PS-48 '69	Stays open	Standby pump would not start	Lose standby vacuum pump; if both pumps lost, lose vacuum, main engine would trip	26	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A — SUBSYSTEM: 1.1 CONTROL POWER SUPPLY — PAGE: 1

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE'S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 1000 HRS	COMMENTS INDEX
1	Console Power Supply #1 (redundant to unit #2 below)	Any	Loss of or incorrect power output from unit	No effect unless redundant unit failed. If both failed, control system would shut down and vessel would come to a stop.	9.2600	
2	Console Power Supply #2 (redundant to unit #1 above)	Any	Same as #1	Same as #1.	9.2600	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

UNIT: Turbine Control

SUBSYSTEM: POSITION CONTROL BOARD 1A
One Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS.	CRITICAL INDEX NO.
20.2 1A	R...t Power	(a) Output shorted	(a) See position control board 1B, ref. 02A.	(a) See same.	0.1374	
20.2 2A	Valve Position Command	(a) Output approx +15V.	(a) See position control board 1B, ref. 03A.	(a) See same.	0.14475	402(.50) 403(.25) 401(.25)
2B		(b) Output approx -15V.	(b) See position control board 1B, ref. 03B.	(b) See same.	0.14475	401(.25) 402(.50) 401(.25)
20.1 3A	Rate Logic	(a) K1 permanently energized.	(a) Ahd valve closure rate permanently increased.		0.202108	405
3B		(b) K1 permanently de-energized.	(b) No MPC and closure rate, no full crash back.		0.202108	406(.5) 407(.5)
3C		(c) K2 permanently energized.	(c) Ast valve closure rate permanently increased.		0.202108	408
3D		(d) K2 permanently de-energized.	(d) No MPC ast closure rate, no full crash back.		0.202108	406(.5) 407(.5)
3E		(e) S1 permanently energized.	(e) Both valve travel rates locked in maneuver mode response.		0.606324	405(.5) 408(.5)
3F		(f) K1 permanently de-energized.	(f) Both valve travel rates locked in normal mode response.		0.606324	405(.5) 408(.5)
20.2 4A	Rate Limiter	(a) Defective Relay Contacts	(a) See position control board 1a, ref. 03A-F.		0.93918	401(.25) 402(.50) 401(.25)
4B		(b) Output approx +15V.	(b) Ast valve position unlimited increase.	(b) Ast vol condition and turbine trip.	0.31306	401
4C		(c) Output approx. -15V.	(c) Ahd valve position unlimited increase.	(c) Ahd vol condition and turbine trip.	0.31306	401
20.3 5A	AH Feedback Sys Dmod	(a) Output high	(a) K1 de-energized	(a) Both valve travel rates in normal mode response.	0.9611	405(.25) 408(.25)
			Ast valve position unlimited increase. Ast and ahd valve position meter increase.	Ast vol condition and turbine trip.		401(.50)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control   SUBSYSTEM: POSITION CONTROL BOARD 1A   PAGE: 2
One Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10⁶ HRS.	CRITICAL INDEX (C)
5B		(b) Output low	(b) K1 energized. Ahd valve position unlimited increase. Ahd valve position meter increase.	(b) Both valve travel rates in maneuver mode response. Ahd vot condition and turbine trip.	0.9611	4(1)
20.2 6A	All Feedback Syn Demod	(a) Output high	(a) Same as position control board 1B, ref. 01A. Aat and ahd valve position meter increase.	(a) See same.	0.9611	4(1)(.25) 4(2)(.50) 4(3)(.25)
6B		(b) Output low	(b) Aat valve position unlimited increase. Aat valve position meter increase.	(b) Aat vot condition and turbine trip	0.9611	4(1)
20.2 7A	LVDT Demod	(a) Output high.	(a) Same as position control board 1B ref., 01A.	(a) See same.	0.9611	4(1)(.25) 4(2)(.50) 4(1)(.25)
7B		(b) Output low	(b) Same as position control board 1B, ref. 01B.	(b) See same.	0.9611	4(1)(.25) 4(2)(.50) 4(1)(.25)
20.2 8A	Automatic Rollover				0.0456	
20.2 9A	Servo Output	(a) Output high	(a) Aat valve position unlimited increase.	(a) Aat vot condition and turbine trip.	0.942	4(1)
9B		(b) Output low.	(b) Ahd valve position unlimited increase.	(b) Ahd vot condition and turbine trip.	0.942	4(1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control

SUBSYSTEM: POSITION CONTROL BOARD IB
One Per Vessel

PAGE: 1

REF. #	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL (MOD) NO.
20.1 1A	AC Ref Control	(a) Output low.	(a) Increase in supply voltage to synchro and lvdt, rotors and demodulators causing possible damage to any or all synchros and lvdt.	(a) Either both ahd and ast valve closure or initial ahd or ast unlimited valve opening leading to valve over travel condition and turbine trip	0.2902	97 401
1B		(b) Output high.	(b) Decrease in supply voltage to synchro and lvdt, rotors and demodulators.	(b) Throttle valve closure proportional to voltage decrease.	0.2902	402
1C		(c) Output open.	(c) Loss of supply voltage to synchro and lvdt, rotors and demodulators.	(c) Throttle valve closure	0.2902	401
1D		(d) Output oscillation	(d) Variable voltage supplied to synchro and lvdt, rotors and demodulators.	(d) Throttle valve oscillations or hunting.	0.2902	402
20.1 2A	Board Power	(a) Output shorted.	(a) None, due to power supply redundancy.	(a) None.	0.0916	
20.1 3A	Demodulator	(a) Output more positive than called for.	(a) Incorrect valve position command signal level.	(a) RPM's will be either: 1) Faster ahd than called for. 2) Ahd rather than ast. 3) Slower ast the called for. 4) Valve over travel condition (vot) and turbine trip.	2.27765	402(.25) 401(.25) 402(.25) 401(.25)
3B		(b) Output more negative than called for.	(b) Incorrect valve position command signal level.	(b) RPM's will be either: 1) Slower than called for. 2) Ast rather than ahd. 3) Faster ast than called for 4) Vot and turbine trip.	2.27765	402(.25) 401(.25) 402(.25) 401(.25)
20.1 4A	Function Generator	(a) Same as ref. 3).	(a) Same as ref. 3).	(a) Same as ref 3).	1.50	402(.25) 401(.25) 402(.25) 401(.25)
20.1 5A	Valve Position Command	(a) Output approx. +15V	(a) Desired valve position command will be at maximum ahead.	(a) Ahead vot condition and turbine trip.	0.35815	401
5B		(b) Output approx. -15V	(b) Desired valve position command will be at maximum astern.	(b) Astern vot condition and turbine trip.	0.35815	404

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control   SUBSYSTEM: POSITION CONTROL BOARD 1B
One Per Vessel   PAGE: 3

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
20 1 6A	Limit Function	(a) Output approx. +15V	(a) Incorrect valve position command signal level.	(a) Same as ref. 03B.	0.41215	4(2)(.50) 4(3)(.25) 4(1)(.25)
6B		(b) Output approx. -15V.	(b) Limit function effectively out of circuit.	(b) No effect.	0.41215	

UNIT: Turbine Control | **SUBSYSTEM:** SPEED FEEDBACK BOARD | PAGE 1

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
20.1 1A	Board Power	(a) Output shorted.	(a) Same as position control board 1B, ref. 02A.	(a) See same.	0.1812	
20.1 2A	RP 01 One-Shot	(a) Output high.	(a) When throttle is set to 60% or below max. and speed, incorrect valve position signal, otherwise no effect.	(a) Same as position control board 1B, ref. 03A/3B depending on desired speed signal direction.	0.4622	401(.25) 402(.50) 403(.25)
2B		(b) Output low.	(b) When throttle is set to 60% or below max. and speed, incorrect valve position signal, otherwise no effect.	(b) Same as position control board 1B, ref. 03A/3B depending on desired speed signal	0.4622	401(.25) 402(.50) 403(.25)
20.1 3A	RP 02 One-Shot	(a) Output high.	(a) No effect unless RP 01 RPM pick-up is malfunctioning.	(a) If RP 01 RPM pick-up is malfunctioning, same as above ref., 02A.	0.2402	
3B		(b) Output low.	(b) Same as above, ref. 02B.	(b) Same as above, ref. 02B.	0.2402	401(.25) 402(.50) 403(.25)
20.1 4A	Direction Control Ampl.	(a) Output high.	(a) R1 permanently de-energized.	(a) No effect when desired speed is ahd. When ast, same as position control board 1B, ref. 03B.	0.62716	411(.25) 409(.50) 410(.25)
4B		(b) Output low.	(b) R1 permanently energized.	(b) No effect when desired speed is ast. When ahd, same as position control board 1B, ref. 03A.	0.62716	413(.25) 403(.25) 413(.25) 401(.25)
20.1 5A	Smoothing Amplifier	(a) Output high.	(a) Same as above, ref. 02A.	(a) See same.	1.268165	401(.25) 402(.50) 403(.25)
5B		(b) Output low.	(b) Same as above, ref. 02B.	(b) See same.	1.268165	401(.25) 402(.50) 403(.25)
22.1 6A	Limiters	(a) Output high.	(a) Same as above, ref. 02A.	(a) See same.	1.0235	401(.25) 402(.50) 403(.25)
6B		(b) Output low.	(b) Same as above, ref. 02B.	(b) See same.	1.0235	401(.25) 402(.50) 403(.25)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: SPEED FEEDBACK BOARD

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
20.1 7A	Output	(a) Output high.	(a) Same as above, ref. 02A.	(a) See same.	0.30095	401(.25) 402(.50) 401(.25)
7B		(b) Output low.	(b) Same as above, ref. 02B.	(b) See same.	0.30095	401(.25) 402(.50) 401(.25)
20.1 8A	Disable Logic	(a) Output high	(a) R2 permanently de-energised.	(a) No speed feedback to trim actual RPM within 2% of desired RPM.	0.690149	415
8B		(b) Output low.	(b) R2 permanently energised.	(b) Speed feedback operative in normal mode, continual valve hunting normal mode.	0.690149	402(.5)
20.3	Speed Command	Not used.				

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control

SUBSYSTEM: 20.4 AUTOMATIC ROLLOVER BOARD

REF NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS	CRITICAL INDEX NO.
20.4 1	Board Power	(a) Output shorted.	(a) Same as position control board 1B, ref. #2A.	(a) See same.	0.1032	
20.4 2	MP #1 One Shot	(a) Output high.	(a) RPM input is permanently zero.	(a) Turbine trip and shaft stopped alarm when in aro mode.	0.4736	
		(b) Output low.	(b) See above, ref. #2A.	(b) See same.	0.4736	
20.4 4	Gate	(a) Output high.	(a) See above, ref. #2A.	(a) See same.	0.159415	
		(b) Output low.	(b) See above, ref. #2A.	(b) See same.	0.159415	
20.4 5	Zero Speed One Shot	(a) Output high.	(a) Aro circuit defeated.	(a) Shaft stop with no shaft stop alarm.	0.2168	417
		(b) Output low.	(b) See above, ref #2A.	(b) See same.	0.2168	
20.4 6	Rollover RPM	(a) Output high.	(a) Reset of valve set flipflop only by back-up timing.	(a) Shaft stop alarm.	0.891461	417
		(b) Output low.	(b) Valve set flipflop in indeterminate state.	(b) Erratic turbine operation in aro mode. Possible trip.	0.891461	
20.4 7	Valve Set Flipflop	(a) Output high.	(a) No reset of valve set flipflop	(a) Turbine trip.	0.998645	416
		(b) Output low.	(b) Aro circuit defeated.	(b) Shaft stop with no shaft stop alarm.	0.998645	
20.4 8	Zero Speed Flipflop	(a) Output high.	(a) R2 permanently de-energized.	(a) Erratic turbine operation in aro mode. Possible trip.	0.58657	416
		(b) Output low	(b) R2 permanently energized.	(b) Same as Ref. #5A.	0.58657	
20.4 9	Back Up Timing	(a) Output high.	(a) Undeterminate valve set flipflop condition.	(a) Shaft stop alarm and possible turbine trip shaft stop alarm.	0.917825	416
		(b) Output low.	(b) Shaft stop flipflop defeated.	(b) Shaft stop alarm defeated.	0.917825	413
20.4 10	Zero Speed Timing	(a) Output high.	(a) Same as above Ref. #9.	(a) See same.	0.949225	
		(b) Output low.	(b) Same as above Ref. #8A.	(b) See same.	0.949225	416

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: 20.4 AUTOMATIC ROLLOVER BOARD

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
20.4 11	Direction Control	(a) Output high.	(a) Permanent ast. direction signal.	(a) Shaft turns only in ast. direction in aro mode	1.75093	010
		(b) Output low.	(b) Permanent ahd. direction signal.	(b) Shaft turns only in ahd. Direction in aro mode.	1.75091	010
20.4 12	Disable Logic	(a) K1 permanently energized.	(a) Aro disable disabled.	(a) Turbine trip when RPM's greater than plus or minus 5.	0.142929	001
		(b) K1 permanently de-energized.	(b) Aro disable permanently enabled.	(b) Shaft stop alarm.	0.142929	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control

SUBSYSTEM: 20.5 OVERSPEED BOARD

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO.
20.5 1	Power Board	(a) Output shorted.	(a) Same as Position Control Board in Ref. 02A.	(a) See same.	0.3290	
20.5 2	HP #1 One Shot	(a) Output high	(a) HP turbine overspeed circuitry defeated.	(a) When overspeed condition occurs, there will be no overspeed proportional and increased rate closure of ahd. valve.	0.4621	419
		(b) Output low	(b) HP turbine overspeed circuitry permanently actuated.	(b) Ahd. valve closure overspeed alarm.	0.4621	412
20.5 3	HP #2 One Shot	(a) Output high	(a) No effect unless HP #1 RPM pick-up is malfunctioned.	(a) If HP #1 RPM pick up is malfunctioning, same as above Ref. 02A.	0.1402	
		(b) Output low.	(b) Same as above Ref 02B.	(b) See same.	0.2402	419
20.5 4	LP One Shot	(a) Output high.	(a) LP turbine overspeed circuitry permanently actuated.	(a) Ast valve closure and overspeed alarm or ahd. valve closure and overspeed alarm.	0.2402	411
		(b) Output low	(b) LP turbine overspeed circuitry defeated.	(b) When overspeed condition occurs, there will be no overspeed proportional and increased rate closure of ahd or ast. valve.	0.2402	419
20.5 5	Direction Logic	(a) Output high	(a) (HP/LP) Ahd. overspeed control permanently defeated.	(a) See above Ref. 02A.	1.202175	419
		(b) Output low.	(b) (LP) Ast overspeed control permanently defeated.	(b) When overspeed condition occurs, there will be no overspeed proportional control and increased rate closure of ast valve.	1.202175	420
20.5 6	HP Amps	(a) Output high	(a) HP turbine overspeed control permanently defeated.	(a) See above Ref. 02A.	1.611275	419
		(b) Output low	(b) HP turbine overspeed control permanently actuated.	(b) Ahd. valve closure and overspeed alarm.	1.611275	412

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

UNIT: Turbine Control SUBSYSTEM: 20.5 OVERSPEED BOARD

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 1000 HRS.	CRITICAL (MODE NO).
20.5.7	LP Amps	(a) Output high.	(a) LP turbine overspeed control permanently actuated.	(a) Ast valve closure and overspeed alarm or ahd. valve closure and overspeed alarm.	1.29655	401
		(b) Output low.	(b) LP turbine overspeed control permanently defeated.	(b) See above Ref. 04B.	1.29655	411
20.5.8	Enabling Logic	(a) All output high.	(a) See above Ref. 04B.	(a) See same.	1.0252975	411
		(b) All--output low.	(b) See above Ref. 06A.	(b) See same.	1.0252975	411
		(c) Al4--output high.	(c) See above Ref. 07A.	(c) See same.	1.0252975	411
		(d) Al4--output low.	(d) See above Ref. 07B.	(d) See same.	1.0252975	411

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP Turbine Control SUBSYSTEM: 20.6 BOILER CONTROL BOARD PAGE: 1

REF NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS	CRITICAL INDEX NO
20.6 1	Board Power	(a) Output shorted	(a) Same as Positional Control Board in Ref. 02A.	(a) See same	0.1174	
20.6 2	Drum Level #1	(a) A1 Output high	(a) Permanent hi #1 drum level condition.	(a) Throttle valve closure and drum level alarm.	0.73435	401
		(b) A1 Output low	(b) Permanent hi #1 drum level control disable	(b) Throttle not responsive to hi #1 drum level and no alarm	0.73435	421
		(c) A2 Output high	(c) Permanent lo #1 drum level control disable	(c) Throttle not responsive to lo #1 drum level.	0.73435	422
		(d) A2 Output low	(d) Permanent lo #1 drum level condition.	(d) Throttle valve closure and drum level alarm.	0.73435	401
20.6 3	Drum Level #2	Same as above Ref. 02A, B, C, D, MUTATIS MUTANDIS A1 for A1 and A4 for A2	See same	See same	0.73435	401 421 422 401
20.6 4	Boiler Pressure Level	(a) A15 Output high	(a) Permanent lo boiler pressure condition.	(a) Throttle valve closure and low boiler pressure alarm	0.4618	401
		(b) A15 Output low	(b) Permanent lo boiler pressure control disable	(b) Throttle not responsive to low boiler pressure condition and no alarm.	0.4618	421
20.6 5	MPC Amps	(a) Output high	(a) Both boiler hi/lo drum level and pressure level control disable.	(a) No throttle response to abnormal boiler conditions.	1.2466	421, 422 423 (1505 for 411)
		(b) Output low.	(b) Permanent MPC and boiler malfunction valve rate enable condition.	(b) Throttle valve closure	1.2466	401
20.6 6	Direction Control	(a) Output high	(a) Permanent MPC and boiler malfunction valve rate enable condition.	(a) Throttle response at MPC rates, less rpm's than desired if not total valve closure	0.96201	402(.5) 401(.5)
		(b) Output low	(b) Same as above Ref. 02A.	(b) See same	0.96201	411
20.6 7	Drum Level Alarm	(a) Output high	(a) Permanent drum level alarm disable.	(a) Abnormal drum level condition produces no alarm	0.47895	414
		(b) Output low.	(b) Permanent drum level alarm.	(b) Permanent drum level alarm.	0.47895	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: 20.6 BOILER CONTROL BOARD PAGE: 2

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE'S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL ISSUE NO.
20.6.8	Drum Level Disable	(a) Output high.	(a) Permanent drum level disable disable.	(a) No capability to override boiler control circuit.	0.9121	
		(b) Output low.	(b) Permanent drum level disable activation.	(b) No throttle response to abnormal drum level condition.	0.9121	475
20.6.9	Boiler Pressure Disable	(a) Output high	(a) Permanent boiler pressure disable disable.	(a) No capability to override boiler pressure control circuit.	0.41219	
		(b) Output low.	(b) Permanent boiler pressure disable activation.	(b) No throttle response to abnormal boiler pressure condition.	0.41219	476

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

MODEL: Turbine Control | SUBSYSTEM: 20.7 VIBRATION BOARD

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES 10E6 HRS	INITIAL [illegible] NO.
20.7.1	Board Power	(a) Output shorted	(a) Same as Position Control Board in Ref. 02A	(a) See same	0.1032	
20.7.2	NI Vibration Amp.	(a) Output high	(a) NP vibration control disabled	(a) No throttle response to excessive NP turbine vibration	2.2941	42
		(b) Output low	(b) Permanent excessive NP vibration condition	(b) Throttle valve closure and alarm	2.2941	40
20.7.3	LP Vibration Amp.	Same as above Ref 2A, MUTATIS MUTANDIS, LP for NP	See same	See same	2.1480	42? 40?
20.7.4	NP 1 One Shot	(a) Output high	(a) No effect unless NP P1 pick up is defective and excessive vibration condition exists	(a) No effect	0.2596	
		(b) Output low	(b) No effect, due to NP pick-up redundancy.	(b) No effect	0.2596	
20.7.5	NP 02 One Shot	(a) Output high	(a) Same as above Ref. 04B	(a) See same	0.2482	
		(b) Output low	(b) Same as above Ref. 04A.	(b) See same	0.2482	
20.7.6	[illegible]	(a) A1A B[illegible] Output high	(a) K1 permanently de-energized	(a) No ahd throttle response to excessive turbine vibration	0.8645175	414
		(b) A1A [illegible] Output low	(b) K2 permanently de-energized.	(b) No aat. throttle response to excessive turbine vibration	0.8645175	414
		(c) A1 Output high	(c) Either K1 or K2 permanently energized	(c) Throttle closure at actual rpm offset from desired rpm and throttle response at NP rate.	0.8645175	411 [illegible] 411 [illegible]
		(d) A1 Output low	(d) K1 and K2 permanently de-energized	(d) Throttles not responsive to excessive turbine vibration condition.	0.8645175	410
20.7.7	Vib Disable	(a) Output high	(a) Vib disable disable	(a) No excessive vibration over (time capability) vibration alarm	0.110225	
		(b) Output low	(b) Vib disable permanently actualized	(b) Throttles not responsive to excessive vibration	0.110225	443

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: 20.0 TEST BOARD PAGE: 1

REF NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS	CRITICAL ITEM NO.
20.0 1	Board Power	(a) Output shorted	(a) Same as Positional Control Board 18 Ref. 02A.	(a) See same	0.1174	
20.0 2	Speed Feedback Limit	(a) Output high	(a) Same as Speed Feedback Board Ref. 02A.	(a) See same	1.04475	003
		(b) Output low	(b) No subsystem effect.	(b) No system effect.	1.04475	
20.0 3	Thumbwheel Volts	(a) Output high.	(a) Volts thumbwheel not operative	(a) Testing of MPC circuits not possible.	0.7049	
		(b) Output low	(b) Same as above Ref. 03A.	(b) See same.	0.7049	
20.0 4	Oscillator	(a) Output high.	(a) RPM thumbwheel not operative.	(a) Testing control utilizing speed pick up signals not possible.	0.1739	
		(b) Output low	(b) Same as above Ref. 04A.	(b) See same.	0.1739	
		(c) Output off frequency	(c) Same as above Ref. 04A.	(c) See same.	0.1739	
20.0 5	Test Switch Logic	(a) MS1 output high.	(a) No subsystem effect due to pick up redundancy.	(a) No effect.	0.505620	
		(b) MS1 output low.	(b) Same as above Ref. 05A.	(b) See same	0.505620	
		(c) AH1 output high.	(c) No system ahd. valve direction signals.	(c) Erratic response of ahd. valve in the following ahd. modes: (1) maneuver; (2) ove.speed; (3) excessive turbine vibration.	0.505620	414
		(d) AH1 output low	(d) Permanent system ahd. valve direction signals.	(d) Erratic response of both valves when ast. rpm desired.	0.505620	009
		(e) AH2 output high	(e) No system ast. valve signals.	(e) See above Ref. 05C MUTATIS MUTANDIS, ast. for ahd.	0.505620	009
		(f) AH2 output low.	(f) Permanent system ast. valve direction signals.	(f) See above Ref. 05E.	0.505620	009
		(g) MS1 output high	(g) No subsystem effect unless MP #1 pick up is malfunctioning.	(g) No effect.	0.505620	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control

SUBSYSTEM: 20.0 TEST BOARD

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
		(h) NS 2 output low.	(h) Same as Ref. 65g.	(h) See same.	0.505620	
		(i) LPS output high.	(i) No system LP turbine rpm signal.	(i) No response of throttle in the following modes: (1) LP overspeed; (2) NPO overspeed.	0.505620	
		(j) LPS output low.	(j) Same as above Ref. 85I.	(j) See same.	0.505620	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: 20.9 INTERFACE BOARD

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE'S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS.	CRITICAL INDEX NO.
20.9 1	Power Board	(a) Output shorted.	(a) Same as Positional Control Board in Ref. 02A.	(a) See same.	0.1032	
20.9 2	Rate Select	(a) A5 output high.	(a) Throttle valves will not respond at following rates: (1) Ahd--Normal rate; (2) Ast--MPC rate.	(a) Throttle valves will instead respond at following rates: (1) Ahd--maneuver rate; (2) Crash back rate.	0.05757	406(.5) 408(.5)
		(b) A5 output low	(b) Throttle valves will not respond at following rates: (1) Crash back rate; (2) Ahd--MPC rate.	(b) Throttle valves will instead respond at following rates: (1) Ast--MPC rate; (2) Normal rate.	0.05757	407(.5) 405(.5)
		(c) A4 output high.	(c) Throttle valves will not respond at following rates: (1) Ahd--Normal rate (2) Ahd--MPC rate	(c) Throttle valves will instead respond at following rates: (1) Ast--MPC rate (2) Crash back rate	0.05757	402(.5) 405(.5)
		(d) A4 output low.	(d) Throttle valves will not respond at following rates: (1) Crash back rate (2) Ast--MPC rate	(d) Throttle valves will instead respond at following rates: (1) Ahd--MPC rate (2) Ahd--Normal rate	0.05757	407(.5) 408(.5)
20.9 3	Speed Feedback Disable	(a) Output high.	(a) Speed feedback permanently disabled.	(a) Actual rpm will not be held within 2% of desired rpm in maneuver or ast. mode.	0.175925	415
		(b) Output low.	(b) Speed feedback permanently actuated.	(b) Continual valve hunting in in normal mode.	0.175925	402
20.9 4	Hi/Lo Drum Level Disable	(a) Output high.	(a) Both boiler hi/lo drum level control circuits permanently disabled.	(a) Throttle valve position not responsive to hi/lo boiler level condition.	0.175925	425
		(b) Output low.	(b) Both boiler hi/lo drum level control circuits permanently activated.	(b) No hi/lo boiler drum level override.	0.175925	421, 422 (100% both)
20.9 5	Vibration Disable	(a) Output high.	(a) Vibration control permanently disabled.	(a) Throttle valve position not responsive to excessive turbine vibration level.	0.175925	410
		(b) Output low.	(b) Vibration control permanently activated.	(b) No vibration control override.	0.175925	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: . Turbine Control | SUBSYSTEM: 28.9 INTERFACE BOARD | PAGE: 3

REF. №	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX №.
20.9 6	Boiler Pressure Disable	(a) Output high.	(a) Boiler pressure control permanently disabled.	(a) Throttle valve position not responsive to low boiler pressure.	0.175925	426
		(b) Output low	(b) Boiler pressure control permanently activated.	(b) No boiler pressure control override.	0.175925	
20.9 7	Boiler #1 Out (Port)	Same as above Ref. #6A, 6B except for Boiler #1 only	See same.	See same.	0.175925	A- 425 B- 421, 422 (100% both)
20.9 8	Boiler #2 Out (Stbd)	Same as above Ref. #6A, 6B except for Boiler #2 only.	See same.	See same.	0.175925	A- 425 B- 421, 422 (100% both)
20.9 9	Ahd. Valve Open	(a) Output high.	(a) Under abnormal boiler conditions, R1 permanently energized in boiler control circuit.	(a) When ahd. valve is open under abnormal boiler conditions, there will be no MPC rate of ahd. valve closure.	0.175925	405
		(b) Output low.	(b) Under abnormal boiler conditions, R1 permanently de-energized in boiler control circuit.	(b) When ast. valve is open under abnormal boiler conditons, there will be no MPC rate of ast. valve closure.	0.175925	408
20.9 10	Ast valve open.	(a) Output high.	(a) Same as above Ref. #9a, now regarding R2.	(a) See same. MUTATIS MUTANDIS regarding ahd. and ast.	0.175925	408
		(b) Output low.	(b) Same as above Ref. #9b, now regarding R2.	(b) See same. MUTATIS MUTANDIS regarding ahd. and ast.	0.175925	405
20.9 11	Aro Disable	(a) Output high.	(a) R3 of aro circuit permanently energized.	(a) No aro circuit override when throttle at stop and turning gear disengaged.	0.10615	
		(b) Output low.	(b) R3 of aro circuit permanently de-energized.	(b) Aro circuit disabled. Aro malfunction trip disabled.	0.10615	417
20.9 12	Aro Trip	(a) Output open.	(a) Aro malfunction relay permanently disengaged.	(a) Turbine trip when throttle at stop.	1.221805	416
		(b) Output low.	(b) Aro malfunction relay permanently engaged.	(b) Aro malfunction permanently disabled.	1.221805	417

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: 20.10 AXIAL POSITION BOARD

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO.
20.10 1	Board Power	(a) Output shorted.	(a) Same as Position Control Board in Ref. 02A.	(a) See same.	0.0916	
20.10 2	Axial Power	(a) Output high.	(a) Turbine tirp and alarm relays permanently de-energised.	(a) Turbine trip and axial position alarm actuated.	0.042	401
		(b) Output low.	(b) Same as above Ref. 02A.	(b) See same.	0.042	401
20.10 3	Alarm Circuit	(a) Output high.	(a) Alarm relay permanently de-energised.	(a) Axial position alarm actuated.	0.9144	
		(b) Output low.	(b) Alarm relay permanently energised.	(b) Axial position alarm defeated.	0.9144	411
20.10 4	Trip Circuit	(a) Output high	(a) Turbine trip relay permanently de-energised.	(a) Turbine trip actuated.	0.0088	401
		(b) Output low.	(b) Turbine trip relay permanently energised.	(b) Turbine trip defeated.	0.0088	412
20.10 5	Failure Comparators	(a) Output high.	(a) Probe-failure lamp permanently defeated.	(a) If probe fails (opens or shorts to ground), no probe failure indication and turbine trip possible.	0.9150	401
		(b) Output low.	(b) Probe fialure lamp permanently activated.	(b) Probe failure lamp on and abnormal axial position turbine trip not possible.	0.9150	417
20.10 6	Probe Voltage	(a) Output--AC riding on DC.	(a) Same as above Ref. 05B.	(a) See same.	0.0511	417
		(b) Output--AC	(b) Same as above Ref. 05B.	(b) See same.	0.0511	417
		(c) Output shorted to ground.	(c) Possibly no probe failure lamp indication.	(c) Turbine monitor 20vac power supply fuse blown lamp on.	0.0511	
20.10 7	Test Circuit	No electronics involved. Failure modes dealt within electromechanical study of system.			0.0492	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control   SUBSYSTEM: 20.11 VIBRATION MONITOR BOARD   PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
20.11 1	Board Power	(a) Output shorted.	(a) Same as Position Control Board 1B Ref. 03A.	(a) See same.	0.1031	
20.11 2	Accelerometer	(a) Output high.	(a) Excessive vib. turbine trip and alarm relays actuated.	(a) Turbine trip and vibration alarm actuated.	1.3641	401
		(b) Output low.	(b) Excessive vib. turbine trip and alarm relays permanently defeated. Vibration MPC signal to vibration board is negative.	(b) No turbine trip, vibration alarm or MPC throttle response to excessive turbine vibration.	1.3641	411,406 (100% both)
		(c) Output zero.	(c) Same as above Ref. 02B.	(c) See same.	1.3641	411,406 (100% both)
20.11 3	Speed Signal	(a) Output high.	(a) Forces accelerometer circuit output to zero.	(a) See above Ref. 02C.	2.5	411,406 (100% both)
		(b) Output low.	(b) See above Ref. 03A.	(b) See same.	2.5	411,406 (100% both)
		(c) Output zero.	(c) No subsystem effect.	(c) No system effect.	2.5	
		(d) HP/LP speed pick-up malfunction.	(d) No subsystem effect due to protection circuitry activating K4.	(d) No system effect.	2.5	
20.11 4	Failure Comparators	(a) Output high.	(a) Permanent accelerometer failure mode.	(a) High accelerometer meter reading, accelerometer alarm and failure lamp activated, permanent disable of excessive vib. turbine trip and MPC response.	0.0774	406,411 (100% both)
		(b) Output low.	(b) Permanent disable of either accelerometer open or shorted failure detection capability.	(b) No system response to possible accelerometer failure.	0.0774	406,411 (100% both)
20.11 5	Vibration MPC Signal	(a) K1 permanently energized	(a) Vibration MPC signal permanently transmitted to vibration board.	(a) Possible spurious signals from malfunctioning accelerometer causing throttle closure and MPC rate response.	0.0728	401
		(b) K4 permanently de-energized.	(b) No vibration MPC signal transmitted to vibration board.	(b) No MPC throttle response under excessive turbine vibration condition.	0.0728	406,411 (100% both)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control SUBSYSTEM: 20.11 VIBRATION MONITOR BOARD PAGE: 2

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL THORE NO.
20.11 6	Trip Relay	(a) Output high.	(a) Turbine trip relay permanently de-energized.	(a) Turbine trip.	0.51925	001
		(b) Output low.	(b) Turbine trip relay permanently energized.	(b) Turbine trip not responsive to excessive turbine vibration.	0.51925	011
20.11 7	Alarm Relay	(a) Output high.	(a) Alarm relay permanently de-energized.	(a) Continuous excessive vibration alarm.	0.09225	
		(b) Output low.	(b) Alarm relay permanently energized.	(b) No alarm when excessive turbine vibration occurs.	0.09225	014
20.11 8	Test Circuit	(a) K1 permanently energized.	(a) Accelerometer input disconnected from vibration monitor board.	(a) No system response to excessive turbine vibration.	0.1755	006,013 (1506 both)
		(b) K1 permanently de-energized.	(b) Accelerometer input permanently connected to vibration monitor board.	(b) No vibration circuitry test capability.	0.1755	
		(c) K2 permanently de-energized.	(c) Speed pick up signal.		0.1755	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

UNIT: Turbine Control SUBSYSTEM: 20.12 HYDRAULICS PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
20.12 1A	Radial Piston Variable Displacement Hydraulic Pump	(a) Internal failure.	(a) Loss of hydraulic pressure.	(a) Stop interlocks stop pumps, primary isolating valves close, steam valve activates locks in existing position--loss of control.	14.014	415
		(b) Internal leakage or blockage.	(b) Low hydraulic pressure.	(b) Same as above.	46.066	415
20.12 2A	Gear Pump	(a) Internal failure.	(a) Loss of hydraulic pressure.	(a) Primary isolating valves close, steam valve activates locks in existing position--loss of control.	19.62	415
		(b) Internal leakage or blockage.	(b) Low hydraulic pressure.	(b) Pump interlocks stop pump, same as above.	10.0006	415
20.12 3A	Slide Block Control LVDT	(a) Internal open.	(a) Loss of output.	(a) No slide position feedback--loss of control.	10.15	415
		(b) Internal short.	(b) Incorrect output.	(b) Incorrect feedback, loss of control.	10.15	415
20.12 4A	Hydraulic Actuators (2)	(a) Leak.	(a) Loss of response.	(a) Loss of control.	2.14	415
20.12 5A	Slide Block Control Torque Motor	(a) Internal open.	(a) Loss of control of servo valve.	(a) Steam valves remain at existing position, loss of control.	2.20	415
		(b) Internal binding.	(b) Incorrect control of servo valve.	(b) Incorrect steam valve position, loss of control.	1.19	415
20.12 6A	Slide Block Control Servo Motor	(a) Binds.	(a) Incorrect slide block control.	(a) Same as above.	5.15	415
		(b) Stuck.	(b) Incorrect slide block control.	(b) Same as above.	5.15	415
20.12 7A	Pressure Switch	(a) Fail closed.	(a) False low hydraulic pressure signal.	(a) Sotp interlock stops pumps--loss of control.	9.0	415
		(b) Fail open	(b) Loss of low hydraulic signal.	(b) Low hydraulic pressure could result in loss of control.	11.5	415
20.1 8A	Trip Valves T1 or T2	(a) Binds.	(a) Fails to open.	(a) Turbine fails to trip, possible turbine damage.	5.04	415

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control | SUBSYSTEM: 20.12 HYDRAULICS | PAGE: 2

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
		(b) Contaminated.	(b) Remain open.	(b) Loss of control, both must fail open.	7.56	415
20.12 9A	Control Mode Selector	(a) Binds.	(a) Fails to switch mode.	(a) Loss of handpump back-up.	10.01	417
20.12 10A	Control Mode Selector Valve	(a) Binds.	(a) Fails to change positions.	(a) Loss of handpump back-up.	7.96	417
20.12 11A	Primary Isolating Valves P1 or P2	(a) Contaminated.	(a) Fail to close when pilot oil pressure drop.	(a) Steam valves close, turbine stops.	15.92	418
20.12 12A	Secondary Isolating Valves H1 or H2	(a) Bind.	(a) Fail to close when handpump pressure drops.	(a) Steam valve close, turbine trips when using handpump.	15.92	419

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Turbine Control

SUBSYSTEM: 20.11 TURBINE TRIP CIRCUIT

PAGE: 1

REF NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO
20.11 1A	Primary Trip Solenoid	(a) Internal open	(a) De-energizes, pilot oil to valves T1 and T2.	(a) Turbine trip.	14.05	418
		(b) Stuck in energized state.	(b) Loss of oil to T1 and T2 when trip occurs.	(b) Loss of turbine trip, possible turbine damage.	14.05	416
20.11 2A	PTS Relay, Coil	(a) Fails to energize.	(a) PTS 1 fails to open.	(a) Same as above.	0.11	416
20.11 3A	PTS, Relay, Contact 1	(a) Fails to open.	(a) Same as above.	(a) Same as above.	0.16	416
		(b) Fails to close.	(b) Primary trip solenoid de-energized.	(b) Turbine trip.	0.16	418
20.11 4A	PTS, Relay Contact 2	(a) Fails to open.	(a) X relay energized.	(a) Loss of turbine trip, when throttle in astern mode.	0.16	440
		(b) Fails to close.	(b) Fails to energize X relay.	(b) Turbine tripped in astern mode.	0.16	418
20.11 5A	ARM Relay Coil	(a) Fail open	(a) Contact closes.	(a) Trips turbine of throttle on stop.	0.31	441
20.11 6A	ARM Relay, Contact	(a) Fail to close.	(a) PTS relay not energized.	(a) Fails to trip turb as when propeller speed exceeds 5 rpm.	0.62	442
20.11 7A	CB Relay Coil	(a) Internal open.	(a) CB contact open.	(a) Loss of trip--possible turbine damage.	0.11	443
20.11 8A	CB Relay Contact	(a) Fails to open.	(a) Trip signal could energize PTS relay.	(a) Could trip turbine during crash back maneuver.	0.62	444
20.11 9A	TG Switch	(a) Fails open.	(a) PTS not energize when turning gear used.	(a) Loss of turning gear back up	1.41	445
		(b) Fails closed	(b) PTS energized.	(b) Turbine trip.	1.41	446
20.11 10A	TG Relay Coil	(a) Fails to energize	(a) PTS not energized when turning gear used.	(a) Loss of turning gear back up	0.11	445

SHIP: Turbine Control SUBSYSTEM: 20.11 TURBINE TRIP CIRCUIT

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
20.11 11A	TG Relay Contact	(a) Fails to open.	(a) PTS relay energized.	(a) Turbine trip.	0.62	446
20.11 12A	Trip Switches (8)	(a) Fail to close.	(a) Loss of trip.	(a) Possible turbine damage.	1.41	443
		(b) Fail closed.	(b) Energize PTS relay.	(b) False turbine trip.	1.41	446
20.11 13A	Trip Relays Coil (4)	(a) Fail to energize.	(a) Loss of trip.	(a) Possible turbine damage.	1.24	443
20.11 14A	Trip Relays Contacts (4)	(a) Fail to close.	(a) Loss of trip.	(a) Same.	1.24	443
		(b) Fail to open.	(b) Energize PTS relay.	(b) False turbine trip.	1.24	446

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

UNIT: Turbine Control SUBSYSTEM: MISCELLANEOUS PAGE: 3

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO.
20 14 1A	Astern Guard Valve Solenoid (Fails open on loss of air)	(a) Internal open.	(a) Fails to open.	(a) Loss of astern mode.	19.21	447
		(b) Internal binding.	(b) Partial open in all modes.	(b) Loss of control.	19.21	
20 15	Drain Valve	(a) Fail closed	(a) Fails to open when steam inlet valve is closed.	(a) Possible turbine damage.	12.75	448
20 16	HP and LP Speed Sensors (2)HP, (1)LP	(a) No output.	(a) Loss of rpm to logic input.	(a) No effect input redundancy	28.7 *(Note 1)	449
		(b) No output.	(b) Loss of direction to logic input.	(b) Same.	28.7 *(Note 2)	450
20 17	Vibration Accelerometers (2)	(a) No output	(a) Loss of turbine vibration sensing.	(a) Possible turbine damage	76.2	451
20 18	Boiler System Input to ITC 1. Steam Pressure Transmitter (2) 2. Drum Level In Indicator 3. Lube Oil Pressure Sensor					
		(a) Fails high.	(a) Sends false high signal to ITC MPC and trip logic.	(a) Possible false turbine trip	11.6	452
		(b) Fails low	(b) Sends false low signal to ITC MPC and trip logic.	(b) Loss of turbine trip	11.6	

The probability for the fault trees due to redundant sensor is 3.01.

APPENDIX C

SHIP B FAILURE MODE SUMMARIES AND DETAILED FMEA

INDEX-C

SUMMARY OF SHIP B SYSTEM EFFECTS
1.0 Burner Management, Master

I.#	SYSTEM FAILURE EFFECT	FMEA ITEM NO
1.24	Boiler tripped	1.12(b), 1.13(a), 1.14(a), 1.15(b), 1.16(a), 1.17(b), 1.18(a), 1.19(b), 1.20(a), 1.22(a), 1.23(a), 1.29(a), 1.29(b), 1.33(b), 1.38(a), 1.39(a), 1.40(a), 1.41(b), 1.42(a), 1.43(a), 1.44(b), 1.45(b), 1.47(a), 1.48(b), 1.49(b), 1.51(a), 1.52(a), 1.53(b), 1.56(a), 1.57(a), 1.58(b), 1.59(b), 1.60(b), 1.61(a), 1.63(b), 1.64(a), 1.65(b), 1.66(b), 1.68(b)
1.43	Recirculation and FOT valve	1.91(b), 1.94(a)
1.47	F.O. valve opens without purge	1.4(a), 1.15(a), 1.20(b), 1.33(a), 1.42(b), 1.43(b), 1.44(a), 1.64(b), 1.65(a), 1.66(a)
1.55	Loss of F.O. to trip	1.14(b), 1.15(a), 1.20(b), 1.61(b), 1.63(a)
1.56	Loss of purge trip. Boiler trip when no flame	1.59(a), 1.60(a), 1.64(b), 1.65(a)
1.63	Loss of purge	1.3A, 1.4(a), 1.5(b), 1.6(a), 1.7(b), 1.8(a), 1.9(b), 1.10(a), 1.11(a), 1.21(a), 1.23(a), 1.24(b), 1.27(a), 1.28(b), 1.30(b), 1.85(a), 1.86(a), 1.87(b)
1.64	Purge started, air flow low	1.8(b), 1.9(a)
1.65	Could purge with air register closed, possible explosion.	1.27(b), 1.28(a)
1.66	Loss of increased air flow for purge, loss of purge	1.67(a), 1.68(b), 1.76(a), 1.77(b)
1.67	F.O. trip valves open loss of F.O. trip.	1.18(b), 1.19(a), 1.20(b), 1.23(b), 1.24(a), 1.50(b)

I

SUMMARY OF SHIP B SYSTEM EFFECTS
1.0 Burner Management, Master

F.A	SYSTEM FAILURE EFFECT	FMEA ITEM NO
F 44	Initiates purge if other conditions are high.	1.6(b), 1.7(a), 1.11(b), 1.29(b), 1.30(a)
F 201	Loss of fuel recirculation.	1.4(b), 1.22(a), 1.25(a)
F 202	Initiates purge if other conditions are also high.	1.4(b), 1.5(a)
F 203	Could result in incomplete purge. Possible explosion.	1.10(b), 1.12(a)
F 204	F.O. trip valve could open.	1.16(b), 1.17(a)
F 205	Could initiate recirculation.	1.25(b), 1.26(a), 1.80(b), 1.81(a), 1.82(b), 1.81(a),
F 206	Loss of F.O. recirculation	1.26(b), 1.79(a), 1,80(a), 1.10(b), 1.82(a), 1.81(b), 1.91(a), 1.93(b), 1.94(b), 1.95(a)
F 207	Indicates burner valves closed when open. Could purge or recirculate with burner valve open	1.10(a), 1.06(b) 1.07(a)
F 208	Air flow to light off not decreased. Loss of second burner	1.11(a)
F 209	Would trip boiler before light off possible	1.11(b), 1.12(b)
F 210	Decreased air flow, poor combustion	1.12(a)

SUMMARY OF SHIP B SYSTEM EFFECTS
1.0 Burner Management, Master

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.211	Second burner light signal.	1.33(a)
P.212	Loss of trip due to air flow low	1.45(a), 1.47(b), 1.48(a), 1.49(a)
P.213	Loss of purge trip, boiler trip when burner valves close.	1.50(a)
P.214	Loss of purge trip. Boiler trip when F.O. pressure low	1.52(b), 1.53(a), 1.54(b), 1.55(a)
P.216	Air flow increases.	1.67(b), 1.68(a)
P.217	Decrease oil flow	1.69(a)
P.218	Loss of decrease oil flow for	1.69(b)
P.219	Open air register.	1.70(a)
P.220	Close air register.	1.70(b)
P.221	Decrease air flow due to false drum pressure low signal.	1.75(a)
P.222	Loss of decreased air flow when drum pressure low.	1.76(b), 1.77(a)
P.223	Initiates F.O. recirculation.	1.90(b)

SUMMARY OF SHIP B SYSTEM EFFECTS
2.0 Burner Module

F #	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
F 24	Boiler trips	2.10(b)
F 28	Burner trips	2.17(b), 2.18(b), 2.19(a), 2.20(a), 2.22(b), 2.24(a), 2.32(b), 2.31(a), 2.33(b), 2.34(a), 2.40(b), 2.49(a), 2.43(b), 2.44(a), 2.45(b), 2.46(a), 2.47(a), 2.50(a), 2.60(b), 2.61(a), 2.62(b)
F 57	Burner valve open	2.47(b), 2.48(a)
F 58	Cannot trip burner	2.5(b), 2.12(b), 2.18(a), 2.20(b), 2.22(a)
F 224	Initiates burner firing; could be with burner valve open.	2.5(b)
F 225	Cannot retract ignitor	2.8(b), 2.9(a), 2.10(a)
F 226	False burner trip signal.	2.13(a), 2.14(a)
F 227	Cannot generate burner trip signal	2.13(b), 2.14(b)
F 228	False burner trip signal	2.12(a), 2.25(a)
F 229	False burner open signal	2.27(a), 2.28(a), 2.29(b)
F 230	Could initiate burner light off with burner open.	2.28(b), 2.29(a), 2.31(a), 2.32(a)
F 232	Ignitor retracted early	2.34(b)
F 233	Ignitor not retracted.	2.35(a), 2.36(b), 2.37(a)
F 234	Ignitor not extended.	2.35(b), 2.36(a), 2.37(b)

SUMMARY OF SHIP B SYSTEM EFFECTS
2.0 Burner Module

P.N	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.235	Indicates air register open;	2.38(a), 2.39(a), 2.40(b), 2.42(b)
P.236	Could light with air register	2.39(b), 2.40(a)
P.237	Indicates air register closed, burner trip.	2.41(a), 2.42(a)
P.238	Fails to trip when atomizing	2.49(b)
P.239	Loss of ignition extended	2.51(a)
P.240	False ignitor on signal.	2.51(b)
P.241	Burner valve could open when ignitor not extended.	2.53(b)
P.242	Burner valve open immediately when oil switch activated.	2.46(b)
P.243	False permission to fire.	2.54(a)
2.44	Air register close during purge.	2.55(a)
2.45	Air register closes.	2.56(b), 2.57(a)

SUMMARY OF SHIP B SYSTEM EFFECTS
3.0 Combustion Control, Boiler Demand Logic

P.N	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.4	Will always select other boiler signal.	3.1A(a), 3.2A, 3.2C, 3.2D, 3.2E, 3.2F, 3.2B
P.5	Could result in high steam pressure and loss of accurate signal to ITC.	3.1A(a), 3.2A, 3.2C, 3.2D, 3.2E, 3.2F, 3.5E, 3.5F, 3.7E, 3.7D, 3.8B, 3.9B, 3.10B, 3.12B, 3.13B, 3.14B, 3.15C, 3.16C, 3.17C
P.44C	Reduced steam pressure.	3.1B(b), 3.2B, 3.3G, 3.4B, 3.5A, 3.5D, 3.7A, 3.7C, 3.7E, 3.8A, 3.8C, 3.9A, 3.9C, 3.10C, 3.11C, 3.12D, 3.12F, 3.13A, 3.15A, 3.15B, 3.16A, 3.16B, 3.17A, 3.17B

SUMMARY OF SHIP & SYSTEM EFFECTS
4.0 Combustion Control, Airflow

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	High air flow.	4.2A, 4.4A, 4.5A(b), 4.5A(d), 4.8C, 4.9A, 4.10A, 4.11B, 4.12B, 4.13A, 4.14C, 4.15B, 4.16C, 4.18B, 4.23D, 4.27C, 4.28B, 4.29B, 4.30(a)
P.44B	Low air flow.	4.1A, 4.5A(a), 4.5A(c), 4.5A(e), 4.6A, 4.8B, 4.10B, 4.10C, 4.11C, 4.12A, 4.12C, 4.13C, 4.14B, 4.16A, 4.16B, 4.22D 4.22B, 4.23B, 4.27A, 4.28A, 4.28C, 4.29C, 4.30(b)
P.46A	Increase fuel and decrease air flow.	4.7A
P.46B	Increase air flow and decrease fuel.	4.7B

SUMMARY OF SHIP & SYSTEM EFFECTS
5.0 Combustion Control, Fuel Oil Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	High fuel oil flow.	5.1A, 5.2A, 5.2D, 5.1B, 5.2F, 5.3B, 5.3D, 5.3F, 5.4B, 5.5B, 5.6B, 5.7C, 5.8E, 5.9B, 5.10C, 5.14A, 5.19A, 5.19B, 5.19C, 5.20C, 5.21C, 5.23B, 5.27C, 5.27D, 5.28C, 5.28D, 5.29B, 5.30B, 5.31A(a), 5.32A(a)
P.12	Low fuel oil flow.	5.1B, 5.2B, 5.2C, 5.2E, 5.3C, 5.3E, 5.3G, 5.4A, 5.4C, 5.5A, 5.5C, 5.6C, 5.7B, 5.8D, 5.8F, 5.10A, 5.10B, 5.16B, 5.16E, 5.17B, 5.17E, 5.20B, 5.21A, 5.21B, 5.17A, 5.27B, 5.28B., 5.28E, 5.29C, 5.30C, 5.31A(b), 5.32(b)
P.200	Fuel oil variation, slight loss on control	5.6A, 5.7A, 5.8A, 5.8B, 5.8C, 5.9A, 5.11A, 5.14A, 5.19B, 5.18C, 5.30A
P.201	Loss of control in auto.	5.12A, 5.13A, 5.17A, 5.20A, 5.20B, 5.20D, 5.23A, 5.24A, 5.25A, 5.28A, 5.29A
P.202	Loss of control in manual.	5.15A, 5.16A, 5.26A, 5.27A
P.203	Poor air fuel ratio.	5.16C, 5.16D, 5.17C, 5.17D

SUMMARY OF SHIP B SYSTEM EFFECTS
6.0 Drum Level Control, Starboard

P.E	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.44	High tank level.	6.1A, 6.1D, 6.5A, 6.6B, 6.7A, 6.7B, 6.12B, 6.13D, 6.14B, 6.15C, 6.17B, 6.18B, 6.19B, 6.20B, 6.20D, 6.30C, 6.32C, 6.34B, 6.38C, 6.38D, 6.39C, 6.39D, 6.41B, 6.42B, 6.43(a), 6.45(a), 6.46(b), 6.47(b), 6.49(a), 6.50(b), 6.50(c), 6.51(a), 6.53(a), 6.54(b), 6.55(a), 6.57(a), 6.58(b), 6.59(a), 6.61(a), 6.62(b), 6.63(a), 6.65(a), 6.66(b), 6.67(a)
P.45	No alarm output.	6.9B
P.50	Low tank level.	6.1C, 6.5B, 6.6A, 6.8A, 6.12A, 6.12C, 6.13A, 6.13C, 6.14C, 6.15B, 6.17D, 6.17F, 6.18A, 6.18C, 6.20A, 6.20C, 6.20E, 6.38B, 6.38E, 6.39B, 6.39E, 6.41A, 6.41C, 6.42A, 6.42C, 6.43(b), 6.46(a), 6.46(c), 6.47(b), 6.50(a), 6.50(c), 6.52(b), 6.54(a), 6.56(c), 6.55(b), 6.58(a), 6.58(c), 6.59(b), 6.62(a), 6.62(c), 6.63(b), 6.66(a), 6.66(c), 6.67(b)

SUMMARY OF SHIP B SYSTEM EFFECTS
7.0 Feedpump Control

P.E	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.19	Low pressure.	7.1C, 7.2B, 7.3A, 7.5A, 7.6B, 7.6D, 7.6F, 7.8C, 7.9B, 7.10A, 7.11C, 7.14A, 7.14C, 7.15B, 7.17B, 7.17C, 7.18A, 7.18B, 7.20A, 7.20C, 7.21A, 7.21C, 7.22C, 7.23B, 7.24D, 7.24F, 7.26A, 7.26B, 7.30A, 7.31B, 7.31E, 7.32B, 7.32E, 7.33A, 7.33C, 7.34C, 7.35(b)

SUMMARY OF SHIP B SYSTEM EFFECTS
8.0 Feedwater Recirculation Valve Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.32	Valve opens.	8.1A, 8.1B, 8.2A(b), 8.3A(a), 8.5A(a)

SUMMARY OF SHIP B SYSTEM EFFECTS
9.0 Superheater Steam Temperature Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.88	Low temperature.	9.1A, 9.1B, 9.2A, 9.6A, 9.4B, 9.7B, 9.8A, 9.11A, 9.13A, 9.13B, 9.15A, 9.15B, 9.17B, 9.17C, 9.18A, 9.18C, 9.19A, 9.20C, 9.21B, 9.22A, 9.22B, 9.22C, 9.23A, 9.23B, 9.24B, 9.25C, 9.26B, 9.27B, 9.27B, 9.[illegible], 9.[illegible], 9.34C, 9.34D, 9.35C, 9.33D, 9.40B, 9.41B, 9.42(a)

SUMMARY OF SHIP B SYSTEM EFFECTS
10.0 Steam Dump Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.1	High steam pressure, fails to dump.	10.1B, 10.2B, 10.3B, 10.4C, 10.5C, 10.6C, 10.7B, 10.9D, 10.9F, 10.11A, 10.11C, 10.12C, 10.13(b)
P.44	Low steam pressure.	10.1A, 10.2A, 10.2C, 10.3A, 10.4B, 10.5B, 10.6B, 10.7C, 10.9E, 10.10B, 10.11B, 10.12B, 10.13(a),

SUMMARY OF SHIP & SYSTEM EFFECTS
11.0 FWD Feedpump Start/Stop Control Module

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.20	Stops FWD pump.	11.44(b), 11.45(a), 11.46(b), 11.49(b), 11.50(b), 11.51(a), 11.52(b), 11.53(a)
P.21	Loss of standby pump capability.	11.33(a), 11.34(a), 11.35(a), 11.35(b), 11.37(b), 11.42(b), 11.54(b), 11.55(b), 11.56(a), 11.57(a), 11.62(b), 11.64(b), 11.65(a), 11.68(a), 11.69(a), 11.70(b), 11.71(a)

SUMMARY OF SHIP & SYSTEM EFFECTS
12.0 Deaerator Level Control

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.15	Low deaerator level.	12.2A(c), 12.6A, 12.6C, 12.7B, 12.8A, 12.8C, 12.9A, 12.9C, 12.10C, 12.11B, 12.12D, 12.12F, 12.13C, 12.15B, 12.18C, 12.18D, 12.19C, 12.19D, 12.21A, 12.21C, 12.22A, 12.23A(b), 24A(a), 12.26A(a), 12.27(a), 12.28(a)
P.4	High deaerator level.	12.1A, 12.2A(b), 12.5B, 12.6B, 12.7A, 12.8B, 12.9B, 12.10B, 12.12B, 12.13B, 12.13A, 12.13B, 12.18B, 12.18E, 12.19C, 12.19B, 12.21B, 12.22B, 12.23A(a), 12.24A(a), 12.25A(a), 12.25A(b), 12.27(b), 12.28(b)

SUMMARY OF SHIP & SYSTEM EFFECTS
13.0 Oil Header Temperature

P.X	SYSTEM FAILURE EFFECT	FMEA ITEM NO.
P.11	Low temperature.	13.1A, 13.2A, 13.3A, 13.3C, 13.4A, 13.4C, 13.5C, 16.6B, 13.7D, 13.7F, 13.8A, 13.8C, 13.10A, 13.10C, 13.11A, 13.11B, 13.15B, 13.15E, 13.16B, 13.16E, 13.17A, 13.17C, 13.18C, 13.19(b)
P.48	High temperature.	13.2B(a), 13.2B(b), 13.3B, 13.4B, 13.5B, 13.6C, 13.7B, 13.8B, 13.9B, 13.10B, 13.10D, 13.11C, 13.13B, 13.15C, 13.15D, 13.16C, 13.16D, 13.17B, 13.18B, 13.19(a)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
1. 1	Boiler Front Sw S4-1	(a) Fails open.	(a) Loss of power.	(a) Loss of power and F.O. recirculation from boiler ft.	0.23	
		(b) Fails short.	(b) Power to recirculation sw and st. boiler sw.	(b) No effect; start boiler sw prevents purge.	0.23	
1. 2	Console Sw S4-4	(a) Fails open.	(a) Loss of power.	(a) Loss of purge and F.O. recirculation from console	0.23	
		(b) Fails short	(b) Power to recirculation sw and at boiler sw.	(b) No effect; start boiler sw prevents purge.	0.23	
1. 3	Start Boiler Firing Switches,	(a) Fails open.	(a) Loss of power to Input Circuit 3P-4.	(a) Inability to purge.	0.23	1
		(b) Fails short.	(b) Signal to Input Circuit 3P-4.	(b) Boiler purges if other permissives OK.	0.23	1
1. 4	Input circuit 3P-4	(a) Fails high.	(a) High signal to NAND gate 1N-6 and diode 3P4.	(a) Inability to purge.	0.01064	1
		(b) Fails low.	(b) Low signal to NAND gate 1N-6 and diode 3P4.	(b) Loss of fuel recirculation or initiates purge if other conditions are also high.	0.01064	2
1. 5	NAND Gate 1N-8	(a) Fails high.	(a) High signal to NAND gate 1N-8.	(a) Initiate purge if other conditions are also high.	0.148015	2
		(b) Fails low.	(b) Low signal to NAND gate 1N-8.	(b) Loss of purge.	0.148015	1
1. 6	NAND Gate 1N-8	(a) Fails high.	(a) High signal to NAND gate 1N-6.	(a) Loss of purge.	0.11395	115
		(b) Fails low.	(b) Low signal to NAND gate 1N-6.	(b) Initiates purge if purge air flow is satisfactory.	0.11395	114, 116
1. 7	NAND Gate 1N-6	(a) Fails high.	(a) High signal to NAND gate 11-5 and output circuit 1D-5.	(a) Initiates purge if purge air flow is satisfactory.	0.11023	114, 116
		(b) Fails low.	(b) Low signal to NAND gate 11-5 and output circuit 1D-5.	(b) Loss of purge.	0.11023	115

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP 5

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
1.8	NAND Gate 1I-5	(a) Fails high	(a) High signal to inverter 1R-6.	(a) Loss of purge.	0.140015	1
		(b) Fails low.	(b) Low signal to inverter 1R-6.	(b) Initiates purge.	0.140015	2
1.9	Inverter 1R 6	(a) Fails high.	(a) High signal to time delay 1J-11.	(a) Same as above.	0.110231	2
		(b) Fails low.	(b) Low signal to time delay 1J-11.	(b) Loss of purge.	0.110231	1
1.10	Time Delay 1J-11	(a) Fails short.	(a) No signal to inverter 1R-8.	(a) Loss of purge.	2.5100	132
		(b) Fails to time.	(b) Short time cycle.	(b) Could result incomplete purge--possible explosion	2.5100	1
1.11	Inverter 1R 8	(a) Fails high.	(a) High signal to NAND gate 1I-8.	(a) Loss of purge.	0.110231	1
		(b) Fails low.	(b) Low signal to NAND gate 1I-8.	(b) Completes purge if other conditions are high.	0.110231	132
1.12	NAND Gate 1I-8	(a) Fails high.	(a) High signal to time delay 1J-8 and NAND gate 1I-11.	(a) False purge complete signal, could result in explosion.	0.140015	128, 132
		(b) Fails low	(b) Low signal to time delay 1J-8 and NAND gate 1I-11.	(b) Boiler tripped.	0.140015	127
1.13	Time Delay 1J-8	(a) Fails short	(a) No signal to NAND gate 2N-8, to NAND gate 1N-10 and to buffer 1L-16.	(a) Boiler tripped.	2.5100	127
		(b) Fails to time.	(b) Short time cycle.	(b) Light cycle starts too soon, flame blown out.	2.5100	1
1.14	NAND Gate 2N 8	(a) Fails high	(a) High signal to inverter 1R-10.	(a) Boiler trips.	0.140015	127
		(b) Fails low	(b) Low signal to inverter 1R-10.	(b) F.O. trip valve opens without purge or not lo/lo signal. Loss of trip when in operation.	0.140015	128
1.15	Inverter 1R 10	(a) Fails high.	(a) High signal to time delay 1J-5 and to NAND gate 2I-11.	(a) Same as above.	0.110231	128
		(b) Fails low.	(b) Low signal to time delay 1J-5 and to NAND gate 2I-11.	(b) Boiler trip.	0.110231	127

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS	CRITICAL (MORE NO).
1.16	Time Delay 1J-5	(a) Fails high.	(a) No signal to NAND gate 1N-11.	(a) Boiler trip.	2.5100	127
		(b) Fails to time	(b) Short time cycle to NAND 1N-11.	(b) F.O. trip valve may not open entirely.	2.5100	4
1.17	NAND Gate 1N-11	(a) Fails high.	(a) High signal to NAND gate 2I-11.	(a) Boiler trip False permissive to open FOTV.	0.100015	4
		(b) Fails low.	(b) Low signal to NAND gate 2I-11.	(b) Boiler trip.	0.100015	127
1.18	NAND Gate 2I-11	(a) Fails high	(a) High signal to output circuit 1D-4.	(a) Boiler trip.	0.100015	127
		(b) Fails low.	(b) Low signal to output circuit 1D-4.	(b) F.O. trip valve opens, could result in explosion. Loss of trip when in operation.	0.100015	120
1.19	Output Circuit 1D-4	(a) Fails high.	(a) High signal to relay coil FO TV.	(a) Same as above.	0.56458	120
		(b) Fails low.	(b) Low signal to relay coil FO TV.	(b) Boiler trip.	0.56458	127, 140
1.20	Solenoid coil FO TV	(a) Fails to energize.	(a) Valve remains closed.	(a) FOT valve fails to open Boiler tripped.	0.91	140
		(b) Stuck open	(b) Valve remains open.	(b) FOT valve opens, could result in explosion, loss of trip when in operation.	0.91	4
1.21	Limit Switch FOTVCL, wiring and connections	(a) Fails open	(a) No power to field interface circuit 2P-6.	(a) Indicate FOT valve open, loss of purge.	1.20	1
1.22	Limit Switch FOTVOP, wiring	(a) Fails open	(a) No power to field interface circuit 2P-8.	(a) Indicate FOT valve closed when open. Loss of FO recirculation and boiler trip.	1.20	4
1.23	Field Interface Circuit 2P-6	(a) Fails high.	(a) High signal to inverter 1N-4.	(a) Loss of purge.	0.01064	1
		(b) Fails low.	(b) Low signal to inverter 1N-4.	(b) Could purge with FOT valve open. Possible explosion.	0.01064	5

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

REF NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO
1.24	Inverter 1N-8	(a) Fails high.	(a) High signal to NAND gate 1M-8.	(a) Same as above.	0.11021	5
		(b) Fails low.	(b) Low signal to NAND gate 1M-8.	(b) Loss of purge	0.11021	1
1.25	Field interface circuit 2P-8	(a) Fails high.	(a) High signal to inverter 1R-13 and NAND gate 1M-11	(a) Loss of FO recirculation boiler trip	0.01064	4
		(b) Fails low	(b) Low signal to inverter 1R-13 and NAND gate 1M-11.	(b) Could initiate recirculation with FOT valve closed	0.01064	4
1.26	Inverter 1R-13	(a) Fails high	(a) High signal to NAND gate 2M-14	(a) Same as above.	0.11021	6
		(b) Fails low	(b) Low signal to NAND gate 2M-14.	(b) Loss of FO recirculation	0.11021	6
1.27	NAND Gate 2J-14	(a) Fails high	(a) High signal to inverter 2L-12.	(a) Loss of purge.	0.140015	1
		(b) Fails low	(b) Low signal to inverter 2L-12.	(b) Could purge with air register closed- possible explosion	0.140015	5
1.28	Inverter 2L-12	(a) Fails high.	(a) High signal to NAND gate 1M-8.	(a) Same as above.	0.11021	5
		(b) Fails low.	(b) Low signal to NAND gate 1M-8.	(b) Loss of purge	0.11021	1
1.29	NAND Gate 2J-1C	(a) Fails high	(a) High signal to inverter 1R-4, time delay 1J-12, differentiator 2H-2 and NAND gate 20-8.	(a) Indicates burner valves open when closed, loss of recirculation, purge, decrease air flow and boiler trip.	0.140015	4
		(b) Fails low	(b) Low signal to inverter 1R-4, time delay 1J-12, differentiator 2H-2 and NAND gate 20-8.	(b) Indicates both burner valves closed when one or two are open air flow will not decrease oil flow, air register close boiler trip.	0.140015	111

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP II

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE'S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX WT.
1.10	Inverter 1H-4	(a) Fails high	(a) High signal to NAND gate 1H-8 and NAND gate 1H-14.	(a) Indicates burner valves closed when open. Could purge or recirculate with burner valve open.	0.13021	5
		(b) Fails low.	(b) Low signal to NAND gate 1H-4B and NAND gate 1H-14.	(b) Indicates burner valve open when closed. Loss of purge or recirculation.	0.13021	1
1.11	Time Delay 1J-12	(a) Fails open.	(a) No output to NAND gate 2I-14 to output circuit 1G-6 to output circuit 1D-6.	(a) Air flow to light off not decreased, loss of second burner.	2.5100	3
		(b) Fails to time	(b) Short time cycle to NAND gate 2I-14 to output circuit 1G-6 to output circuit 1D-6.	(b) Would trip boiler before light off possible.	2.5100	3
1.12	Output circuit 1D-6	(a) Fails high	(a) High signal to AFC-L/O Solenoid.	(a) Decreased air flow, poor combustion.	0.56454	117
		(b) Fails low	(b) Low signal to AFC-L/O Solenoid.	(b) Would not get decreased air flow for light off.	0.56454	116
1.13	NAND Gate 2I-14	(a) Fails high	(a) High signal to differentiator 2H-4.	(a) Loss of second burner light signal.	0.140015	3
		(b) Fails low	(b) Low signal to differentiator 2H-4.	(b) Loss of second burner light.	0.140015	3
1.13A	Inverter 2D-8	(a) Fails high.	(a) High signal to NAND gate 2H-8.	(a) Boiler will not trip when drum water lo/lo.	0.13021	4
		(b) Fails low.	(b) Low signal to NAND gate 2H-8.	(b) Boiler trip	0.13021	1
1.14	Differentiator 2H-4	(a) Fails high	(a) Fails high to time delay 2B-12.	(a) Loss of second burner light capability.	0.01455	1
		(b) Fail low.	(b) Fail low to time delay 2B-12.	(b) Initiates second burner light.	0.01455	131
1.15	Time Delay 2B-12	(a) Fails open.	(a) Fails open to buffer 2A-7.	(a) Loss of second burner light capability	2.5100	131
		(b) Fail to time.	(b) Fails to time to buffer 2A-7	(b) Premature light of second burner.	2.5100	131

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

PAGE: [illegible]

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO.
1.[illegible]	Buffer 2A 7	(a) Fails high	(a) High signal to light second burner	(a) Initiate second burner light.	0.10675	[illegible]
		(b) Fails low.	(b) Low signal to light second burner.	(b) Loss of second burner light capability.	0.10675	[illegible]
1.[illegible]	NAND gate 2[illegible] 6	(a) Fails high	(a) High signal to NAND gate 21-14.	(a) Initiates light of second burner.	0.140015	[illegible]
		(b) Fails low.	(b) Low signal to NAND gate 21-14.	(b) Light of second burner inhibited	0.140015	[illegible]
1.[illegible]	BM Trip Selector Switch [illegible] wiring and connectors	(a) Fails open	(a) No power to S2/R BM trip remote selector switch	(a) Loss of purge, boiler trip	0.44	[illegible]
1.[illegible]	BM Trip Remote Selector Switch S2 R 1 wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 2P-10.	(a) Loss of purge, boiler trip	0.44	[illegible]
1.[illegible]	Field Interface Circuit 2P 10	(a) Fails high	(a) High signal to inverter 1N-8.	(a) Same as above.	0.01064	[illegible]
		(b) Fails low	(b) Low signal to inverter 1N-8.	(b) Loss of BM trip.	0.01064	[illegible]
1.[illegible]	Inverter 1N 8	(a) Fails high.	(a) High signal to NAND gate 2Q 8 and to NAND gate 1N-8	(a) Same as above.	0.11021	[illegible]
		(b) Fails low.	(b) Low signal to NAND gate 2Q-8 and to NAND gate 1N-8.	(b) Loss of purge, boiler trip.	0.11021	[illegible]
1.[illegible]	Relay contact [illegible]	(a) Fails open.	(a) No power to field interface circuit 2P-12	(a) Boiler trip due to false lo lo.	0.0121	[illegible]
		(b) Fails closed	(b) Continuous power to field interface circuit 2P-12.	(b) Loss of lo/lo boiler trip.	0.0121	[illegible]
1.[illegible]	Field Interface Circuit 2P 12	(a) Fails high	(a) High signal to NAND gate 20-11 and to inverter 2D-11.	(a) Boiler trip due to false lo/lo.	0.01064	[illegible]
		(b) Fails low.	(b) Low signal to NAND gate 20-11 and to inverter 2D-8.	(b) Loss of lo/lo boiler trip	0.01064	[illegible]

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

EFF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
1.44	NAND Gate 2D 11	(a) Fails high.	(a) High signal to NAND gate 2G-8.	(a) Loss of lo/lo trip.	0.148015	4
		(b) Fails low.	(b) Low signal to NAND gate 2G-8.	(b) Loss of purge and boiler trip due to false lo/lo.	0.148015	111
1.45	Relay Contact 51 and F.I. Fan Fail	(a) Both relays fail close.	(a) No power to field interface circuit 2P-14.	(a) Loss of trip due to air flow low.	0.381	111
		(b) Both relays fail open.	(b) Continuous power to field interface circuit 2P-14.	(b) Loss of purge and boiler trip due to false air flow low.	0.001	1
1.47	Field Interface Circuit 2P 14	(a) Fails high.	(a) High signal to time delay 2R-8.	(a) Same as above.	0.01064	111
		(b) Fails low.	(b) Low signal to time delay 2R-8.	(b) Loss of trip due to air flow low.	0.01064	1
1.48	Time Delay 2R 8	(a) Fail open.	(a) No signal to inverter 2L-8. 2L-8.	(a) Same as above.	2.5100	1
		(b) Fails to time.	(b) Short time cycle to inverter 2L-8.	(b) Boiler trip due to false air flow low.	2.5100	7
1.49	Inverter 2L 8	(a) Fails high	(a) High signal to NAND gate 2C 8.	(a) Loss of trip due to air flow low.	0.11021	4
		(b) Fails low.	(b) Low signal to NAND gate 2C-8.	(b) Loss of purge or boiler trip due to false air flow low.	0.11021	111
1.50	Differentiator 2R 2	(a) Fails high	(a) Fails high to NAND gate 2G 8.	(a) Loss of boiler trip when burner valves close.	0.01655	4
		(b) Fa[illegible]	(b) Fails low to NAND gate 2G-8.	(b) Loss of purge, boiler trip.	0.01655	1
1.51	Pressure Switch PS715 Fuel Oil Pressure Low	(a) [illegible]	(a) No power to field interface circuit 1P-4.	(a) Boiler trip. Inability to light off.	22.86	111
1.52	Field Interface Circuit 1P 4	(a) Fails high.	(a) High signal to NAND gate 2D-8.	(a) Boiler trip due to false oil pressure lo	0.01064	111 signal
		(b) Fails low.	(b) Low signal to NAND gate 2D-8.	(b) Loss of boiler trip when oil pressure lo.	0.01064	4

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
1.53	NAND Gate 2G-8	(a) Fails high	(a) High signal to inverter 2L-4.	(a) Same as above.	0.168015	6
		(b) Fails low.	(b) Low signal to inverter 2L-4.	(b) Purge trip, boiler trip due to false oil pressure lo signal.	0.168015	111
1.54	Inverter 2L-4	(a) Fails high.	(a) High signal to time delay 2R-11.	(a) Same as above.	0.11023	111
		(b) Fails low.	(b) Low signal to time delay 2R-11.	(b) Loss of purge trip, boiler trip when oil pressure lo.	0.11023	4
1.55	Time delay 2R-11	(a) Fails open.	(a) Fails open to inverter 2L-6.	(a) False boiler trip.	2.5108	7
		(b) Fails to time.	(b) Fail to time to inverter 2L-6.	(b) False boiler trip.	2.5108	7
1.56	Inverter 2L-6	(a) Fails high.	(a) High signal to NAND gate 2G-8.	(a) Loss of purge trip, boiler trip when FO pressure low.	0.11023	4
		(b) Fails low.	(b) Low signal to NAND gate 2G-8.	(b) Loss of purge, boiler trip due to false FO low signal.	0.11023	111
1.57	Field Interface Circuit 1F-8	(a) Fails high	(a) High signal to inverter 2F-10.	(a) Purge trip, boiler trip due to false manual trip signal.	0.03064	111
		(b) Fails low.	(b) Low signal to inverter 2F-10.	(b) Loss of manual trip capability.	0.03064	4
1.58	Inverter 2F-10	(a) Fails high	(a) High signal to NAND gate 2G-8.	(a) Same as above.	0.11023	4
		(b) Fails low	(b) Low signal to NAND gate 2G-8.	(b) Purge trip, boiler trip due to false manual trip signal.	0.11023	111
1.59	NAND Gate 2G-10	(a) Fails high.	(a) High signal to differentiator 2H-10.	(a) Loss of boiler trip when no flame.	0.11395	114
		(b) Fails low.	(b) Low signal differentiator 2H-10.	(b) Boiler trip due to false no flame signal.	0.11395	1

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

PAGE: 9

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HOR.	CRITICAL INDEX NO.
1.60	Differentiator 2H-10	(a) Fails high	(a) High signal to NAND gate 2G-8.	(a) Loss of purge trip, boiler trip when no flame.	0.03655	129
		(b) Fails low.	(b) Low signal to NAND gate 2G-8.	(b) Purge trip and boiler trip due to false no flame.	0.03655	7
1.61	NAND Gate 3H-6	(a) Fails high.	(a) High signal to time delay 1H-5.	(a) Purge trip, boiler trip due to false unsuccessful shutdown signal.	0.148015	111
		(b) Fails low.	(b) Low signal to time delay 1H-5.	(b) Loss of purge trip, boiler trip due to unsuccessful shutdown.	0.148015	4
1.62	Time Delay 1H-5	(a) Fails open.	(a) Fails open to inverter 2F-6.	(a) Boiler trip.	2.5100	7
		(b) Fails to time.	(b) Fails to time to inverter 2F-6.	(b) May get boiler trip when burner shutdown.	2.5100	7
1.63	Inverter 2F-6	(a) Fails high.	(a) High signal to NAND gate 2G-8.	(a) Loss of purge trip, boiler trip due to unsuccessful shutdown.	0.13023	4
		(b) Fails low.	(b) Low signal NAND gate 2G-8.	(b) Purge trip, boiler trip due to false unsuccessful shutdown signal.	0.13023	111
1.64	NAND Gate 2G-8	(a) Fails high.	(a) High signal to inverter 1H-14	(a) False purge trip, boiler trip.	0.11105	111
		(b) Fails low.	(b) Low signal to inverter 1H-14.	(b) Loss of purge trip, boiler	0.11105	4, 128a
1.65	Inverter 1H-14	(a) Fails high	(a) High signal to NAND gate 11-11.	(a) Same as above.	0.13023	4, 128a
		(b) Fails low.	(b) Low signal to NAND gate 11-11.	(b) False purge trip, boiler trip.	0.13023	111
1.66	NAND Gate 11-11	(a) Fails high.	(a) High signal to NAND gate 11-14 and NAND gate 11-8.	(a) False boiler trip.	0.148015	4, 128a
		(b) Fails low.	(b) Low signal to NAND gate 11-14 and to NAND gate 11-8.	(b) Loss of boiler trip.	0.148015	111

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP A

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
1.67	NAND Gate 1I-14	(a) Fails high.	(a) High signal to output circuit 1D-5.	(a) Loss of increased air flow for purge, loss of purge.	0.140015	135
		(b) Fails low.	(b) Low signal to output circuit 1D-5.	(b) Air flow increases to purge.	0.140015	136
1.68	Output Circuit 1D-5	(a) Fails high.	(a) High signal to increase air flow.	(a) Same as above.	0.56454	136
		(b) Fails low.	(b) Low signal to increase air flow.	(b) Loss of increased air flow, loss of purge.	0.56454	135
1.69	Output Circuit 1G-6	(a) Fails high.	(a) High signal to decrease oil flow.	(a) Decrease oil flow.	0.56454	139a(.5) 139b(.5)
		(b) Fails low.	(b) Low signal to decrease oil flow.	(b) Loss of decrease oil flow for light off.	0.56454	[illegible]
1.70	Buffer 1L-14	(a) Fails high.	(a) High signal to air register close.	(a) Open air register.	0.30675	
		(b) Fails low.	(b) Low signal to air register close.	(b) Close air register.	0.30675	[illegible]
1.71	NAND Gate 1M-10	(a) Fails high.	(a) High signal to inverter 1O-8.	(a) Loss of permission to fire and auto light #1.	0.140015	[illegible]
		(b) Fails low.	(b) Low signal to inverter 1O-8.	(b) False permission to fire and auto light #1.	0.140015	[illegible]
1.72	Inverter 1O-8	(a) Fails high.	(a) High signal to buffer 1L-8 and time delay 3R-8.	(b) Same as above.	0.13021	[illegible]
		(b) Fails low	(b) Low signal to buffer 1L-9 and time delay 3R-8.	(b) Loss of permission to fire and auto light #1.	0.13021	[illegible]
1.73	Buffer 1L-8	(a) Fails high.	(a) High signal to burner subsystem	(a) Loss of permission to fire.	0.30675	[illegible]
		(b) Fails low	(b) Low signal to burner subsystem	(b) False permission to fire.	0.30675	[illegible]
1.74	Time Delay 3R-8	(a) Fails open.	(a) Fails open to burner subsystem	(a) Loss of auto light command	2.9100	[illegible]
		(b) Fails low.	(b) Fails to time to burner subsystem	(b) Loss of auto light command	2.9100	[illegible]

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
1.75	Pressure Switch	(a) Fails open.	(a) No power to field interface circuit 1P-4.	(a) Decrease air flow due to false drum pressure low signal.	11.47	117
		(b) Fails closed.	(b) Continuous power to field interface circuit 1P-4.	(b) Increase air flow due to false drum pressure low signal.	11.47	118
1.76	Field Interface Circuit 1P-4	(a) Fails high.	(a) High signal to inverter 1N-10.	(a) Air flow decreased due to false drum pressure low signal.	0.03064	117
		(b) Fails low.	(b) Low signal to inverter 1N-10.	(b) Loss of decreased air flow when drum pressure low.	0.03064	118
1.77	Inverter 1N 10	(a) Fails high.	(a) High signal to output circuit 1D-6.	(a) Same as above.	0.11021	118
		(b) Fails low.	(b) Low signal to output circuit 1D-6.	(b) Air flow decreased due to false drum pressure signal.	0.11021	117
1.79	Limit Switch B Recirculation Valve Open wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 1P-6.	(a) Loss of recirculation due to false recirculation valve closed signal.	3.20	6
1.80	Field Interface Circuit 1P 6	(a) Fails high.	(a) High signal to inverter 1N-14	(a) Same as above.	0.03064	6
		(b) Fails low.	(b) Low signal to inverter 1N-14.	(b) Could initiate recirculation valve closed.	0.03064	6
1.81	Inverter 1N 14	(a) Fails high.	(a) High signal to NAND gate 2N-14.	(a) Could initiate recirculation with valve closed.	0.11021	4
		(b) Fails low.	(b) Low signal to NAND gate 2N-14.	(b) Loss of recirculation due to false valve closed signal.	0.11021	6
1.82	NAND Gate 2N 14	(a) Fails high.	(a) High signal to NAND gate 2N-11 and inverter 2L-14.	(a) Loss of recirculation when POT and recirculation valve open.	0.11021	6
		(b) Fails low.	(b) Low signal to NAND gate 2N-11 and inverter 2L-14.	(b) Could recirculate with POT or recirculation valve closed.	0.11021	6
1.83	NAND Gate 2N 11	(a) Fails high	(a) High signal to NAND gate 1N-14.	(a) Same as above	0.148815	6
		(b) Fails low.	(b) Low signal to NAND gate 1N-14	(b) Loss of recirculation capability	0.148815	4

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 BURNER MANAGEMENT, MASTER
One Per Boiler, Two Per Vessel

NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
1.85	Limit Switch 1 Recirculation Valve Closed wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 1P-12.	(a) Loss of purge due to false recirculation valve open signal.	1.20	1
1.86	Field Interface Circuit 1P 12	(a) Fails high.	(a) High signal to inverter 2D-12.	(a) Loss of purge due to false recirculation valve open signal.	0.01064	1
		(b) Fails low.	(b) Low signal to inverter 2D-12.	(b) Could initiate purge with valve open.	0.01064	6
87	Inverter 2D-12	(a) Fails high	(a) High signal to purge gate 2N-1	(a) Same as above.	0.11023	6
		(b) Fails low.	(b) Low signal to purge gate 2N-1	(b) Loss of purge due to false recirculation valve open signal.	0.11023	1
1.88	Selector Switch DW4/L-2 Recirculation Start wiring and connectors.	(a) Fails open.	(a) No power to field interface circuit 1P-10.	(a) Loss of recirculation capability from boiler.	0.66	6
1.89	Selector Switch S4/R-2 Recirculation Start wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 1P-10.	(a) Loss of recirculation capability from console.	0.66	6
1.90	Field Interface Circuit 1P 10	(a) Fails high.	(a) High signal to NAND gate 2N-14.	(a) Loss of recirculation capability from console or boiler	0.01064	6
		(b) Fails low.	(b) Low signal to NAND gate 2N-14.	(b) Initiate FO recirculation.	0.01064	6
1.91	NAND Gate 1N-14	(a) Fails high	(a) High signal to output circuit 1D-3 and to output circuit 1D-4.	(a) Loss of recirculation.	0.11105	6
		(b) Fails low.	(b) Low signal output circuit 1D-3 and to output circuit 1D-4.	(b) Recirculation and FOT valve open.	0.11105	120, 161

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 1.6 BURNER MANAGEMENT, MASTER One Per Boiler, Two Per Vessel |

NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
1.92	Selector Switch S4/R-1 Recirculation Start wiring and connectors	(a) Fails open.	(a) No power to field interface circuit IF-14.	(a) Loss of recirculation stop.	0.66	6
1.93	Field Interface Circuit IF 14	(a) Fails high.	(a) High signal to NAND gate 1N-14.	(a) Same as above.	0.01064	6
		(b) Fails low.	(b) Low signal to NAND gate 1N-14.	(b) Loss of recirculation capability.	0.01064	6
1.94	Output Circuit 10-1	(a) Fails high.	(a) High signal to solenoid coil FO RV.	(a) Open recirculation valve.	0.56454	6
		(b) Fails low.	(b) Low signal to relay coil FO RV.	(b) Loss of recirculation--recirculation valve remains closed.	0.56454	6
1.95	Solenoid Coil FO RV	(a) Contacts fail energise.	(a) Fails to energise.	(a) Same as above.	1.44	6
1.96	Fuel Oil Trip Valve, pneumatic operated	(a) Contamination, damaged seat or worn seat.	(a) Internal leaking or fails to seat.	(a) Cannot completely close FOTV.	16.38	278a
		(b) Pneumatic operator fails.	(b) Fails to open.	(b) Cannot open FOTV.	16.38	327a
1.97	Fuel Oil Recirculation Valve, pneumatic operated	(a) Contamination, damaged seat or worn seat	(a) Internal leaking or fails to seat.	(a) Cannot completely close FOTV	16.38	6
		(b) Pneumatic operator fails.	(b) Closes or fails to open.	(b) Cannot open recirculation valve.	16.38	6

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

PAGE: 1

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
2.1	Selector Switch S1/L-2 wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 1G-4.	(a) Loss of burner firing from boiler front.	0.46	
2.2	Selector Switch S1/R-2	(a) Fails open.	(a) No power to field interface circuit 1G-4.	(a) Loss of burner firing from console.	0.46	
2.3	Field Interface Circuit 1G-4	(a) Fails high.	(a) High signal to NAND gate 1C-14.	(a) Loss of manual burner firing.	0.03064	
2.4	NAND Gate 1C-14	(a) Fails high.	(a) High signal to NAND gate 1E-8.	(a) Same as above.	0.148015	
		(b) Fails low.	(b) Low signal to NAND gate 1E-8.	(b) Loss of burner firing function.	0.148015	
2.5	NAND Gate 1E-8	(a) Fails high.	(a) High signal to flip flop 1D-11 and to flip flop 1D-9.	(a) Same as above.	0.148015	
		(b) Fails low	(b) Low signal to flip flop 1D-11 and to flip flop 1D-9.	(b) Initiates burner firing--could be with burner value open. Possible explosion.	0.148015	1
2.6	Flip Flop 1D-11	(a) Fails to set.	(a) Low signal to NAND gate 2D-10.	(a) Loss of burner firing function.	0.29601	1
		(b) Fails to reset.	(b) High signal continues to NAND gate 2D-10.	(b) Cannot trip burner.	0.29601	111,124 125,126
2.7	NAND Gate 2D-10	(a) Fails high.	(a) High signal to flip flop 1D-5.	(a) Cannot extend ignitor.	0.148015	2
		(b) Fails low	(b) Low signal to flip flop 1D-5.	(b) Ignitor extended	0.148015	2
2.8	Flip Flop 1D-5	(a) Fails to set	(a) Low signal to Inverter 2E-10.	(a) Cannot extend ignitor.	0.29601	2
		(b) Fails to reset.	(b) High signal continues to Inverter 2E-10.	(b) Cannot retract ignitor.	0.29601	3
2.9	Inverter 2E-8	(a) Fails high.	(a) High signal to output circuit 2B-1.	(a) Same as above.	0.13023	121
		(b) Fails low.	(b) Low signal to output circuit 2B-1.	(b) Cannot extend ignitor.	0.13023	120

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

PAGE: 7

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS.	CRITICAL INDEX NO.
2.10	Output Circuit 2B-1	(a) Fails high.	(a) High signal to relay coil--extend ignitor	(a) Cannot retract ignitor.	0.56454	130
		(b) Fails low.	(b) Low signal to relay coil--extend ignitor	(b) Cannot extend ignitor.	0.56454	141
2.11	Relay - Extend Ignitor	(a) Coil open or contacts fail to close	(a) Fails to energize.	(a) Cannot extend ignitor.	1.44	141
2.12	Flip Flop 1D-9	(a) Fails to set.	(a) Low signal to NAND gates 1C-11 and 1B-14.	(a) False burner tripped.	0.29603	3
		(b) Fails to reset.	(b) High signal to NAND gates 1D-11 and 1B-14.	(b) Cannot trip burner.	0.29603	4
2.13	NAND Gate 1C-11	(a) Fails high.	(a) High signal to flip flop 1D-6.	(a) False burner trip signal.	0.148015	3
		(b) Fails low.	(b) Low signal to flip flop 1D-6.	(b) Cannot generate burner trip signal.	0.148015	4
2.14	Flip flop 1D-6	(a) Fails to set.	(a) Low signal to burner trip indicator.	(a) False burner trip signal.	0.29603	3
		(b) Fails to reset.	(b) High signal continues to burner trip indicator.	(b) Cannot generate burner trip signal.	0.29603	4
2.15	Selector Switch S1/L-1.	(a) Fail open.	(a) No power to field interface circuit 1G-6.	(a) Loss of boiler front manual burner trip.	0.46	4
2.16	Selector Switch S1/R-1	(a) Fails open.	(a) No power to field interface circuit 1G-6.	(a) Loss of console manual burner trip.	0.46	4
2.17	Field Interface Circuit 1G-6	(a) Fails high.	(a) High signal to diode 19, diode 25 and flip flop 1D-9.	(a) Loss of manual burner trip.	0.03066	4
		(b) Fails low.	(b) Low signal to diode 19, diode 25, and flip flop 1D-9.	(b) Burner trips.	0.03066	3
2.18	Differentiator Circuit 1B	(a) Fails high.	(a) High signal to NAND gate 1B-14.	(a) Loss of burner trip.	0.03655	4
		(b) Fails low.	(b) Low signal to NAND gate 1B-14.	(b) Burner trips.	0.03655	3

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
2.19	Diode 19	(a) Fails open.	(a) No signal to NAND gate 1B-14.	(a) None.	0.0053	1
2.20	NAND Gate 1B 14	(a) Fails high.	(a) High signal to NAND gate 1C-11 to capacitor 21 and to inverter 2B-14.	(a) Burner trips.	0.11395	122
		(b) Fails low.	(b) Low signal to NAND gate 1C-11, to capacitor 21 and inverter 2B-14.	(b) Loss of burner trip.	0.11395	113,124 125,126
2.21	Capacitor 21	(a) Fails short	(a) Shorts to ground.	(a) Loss of burner trip	0.0096	4
2.22	Inverter 2B 14	(a) Fails high	(a) High signal to flip flop 1D-11.	(a) Loss of burner trip.	0.11023	113,124 125,126
		(b) Fails low	(b) Low signal to flip flop 1D-11.	(b) Burner trips.	0.11023	122
2.23	Capacitor 21	(a) Fails shorts.	(a) Shorts to ground.	(a) Burner trips	0.0096	1
2.24	Resistor 24	(a) Fails open.	(a) No signal to NAND gate 1B-16.	(a) Loss of delay in light-off trip of burner	0.0102	1
2.25	Diode 25/26	(a) Fails open.	(a) No signal to flip flop 1D-4.	(a) False burner trip signal	0.0053	
2.27	Limit Switch 27	(a) Fails open	(a) No power to field interface circuit 1G-8.	(a) False burner valve opens signal, cannot fire burner. Could generate false unsuccessful shutdown signal.	1.20	115
2.28	Field Interface Circuit 1G 8	(a) Fails high	(a) High signal to inverter 1F-8 and buffer 1G-7.	(a) False burner valve open signal - cannot fire burner	0.01064	1
		(b) Fails low.	(b) Low signal to inverter 1F-8 and buffer 1G-7.	(b) Could initiate burner light off with burner valve open - possible explosion.	0.01064	115
2.29	Inverter 1F 8	(a) Fails high.	(a) High signal to NAND gate 1E-8 and to module NPC (2P).	(a) Same as above.	0.11021	115
		(b) Fails low.	(b) Low signal to NAND gate 1E-8 and to module NPC (2P).	(b) False burner valve open - cannot fire burner.	0.11021	1

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

[illegible] SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
2.10	Buffer 3G 7	(a) Fails high.	(a) High signal to unsuccessful shutdown.	(a) Loss of unsuccessful shutdown signal.	0.38675	6
		(b) Fails low.	(b) Low signal to unsuccessful shutdown.	(b) False unsuccessful shutdown signal--boiler trip.	0.38675	3
2.11	Limit Switch 11, wiring and connectors	(a) Fails open. (short)	(a) No power to field interface circuit 1G-10.	(a) Loss of burner valve open signal	7.30	122,126
2.12	Field Interface Circuit 1G 10	(a) Fails high.	(a) High signal to inverter 1F-10 and NAND gate 2C-8.	(a) Same as above.	0.03064	122
		(b) Fails low.	(b) Low signal to inverter 1F-10 and NAND gate 2C-8.	(b) False indicate burner valve open	0.03064	126
2.13	Inverter 1F 10	(a) Fails high.	(a) High signal to time delay 1F-8.	(a) Indicates burner open.	0.13023	126
		(b) Fails low.	(b) Low signal to time delay 1F-8.	(b) Indicates burner closed, burner trip after 30 seconds.	0.13023	117,122
2.14	Time Delay 1F 8	(a) Fails open.	(a) No signal to inverter 2E-4 2E-4 and to NAND gate 2D-6.	(a) Same as above.	2.5108	117
		(b) Fails to time.	(b) Short time cycle to inverter 2E-4 and to NAND gate 2D-6.	(b) Ignitor retracted early.	2.5108	2
2.15	Inverter 2E 4	(a) Fails high	(a) High signal to NAND gate 1C-5.	(a) Indicates burner closed Ignitor not retracted.	0.13023	117
		(b) Fails low.	(b) Low signal to NAND gate 1C-5	(b) Ignitor not extended.	0.13023	2
2.15	NAND Gate 1C-5	(a) Fails high.	(a) High signal to NAND gate 2C-5 and inverter 2E-10.	(a) Same as above.	0.148815	3
		(b) Fails low.	(b) Low signal to NAND gate 2C-5 and inverter 2E-10.	(b) Ignitor not retracted	0.148815	117
2.17	Inverter 2E 10	(a) Fails high	(a) High signal to flip flop 1D-5.	(a) Same as above.	0.13023	117
		(b) Fails low.	(b) Low signal to flip flop 1D-5.	(b) Ignitor not extended.	0.13023	2

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

PAGE: 5

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 1000 HRS.	CRITICAL ITEMS NO
2.38	Limit Switch 38 wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 1G-12	(a) Indicates air register open--cannot extend ignitor.	1.20	2
2.39	Field Interface circuit 1G 12	(a) Fails high	(a) High signal to inverter 1F-12.	(a) Indicate air register open-- cannot extend ignitor.	0.01044	2
		(b) Fails low	(b) Low signal to inverter 1F-12.	(b) Indicate air register closed-- could light off with air register open.	0.01044	[illegible]
2.40	Inverter 1F 12	(a) Fails high.	(a) High signal to NAND gate 2D-10.	(a) Same as above.	0.11013	1
		(b) Fails low.	(b) Low signal to NAND gate 2D-10.	(b) Indicates air register open-- cannot extend ignitor	0.11013	1
2.41	Limit Switch 43 wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 1G-14.	(a) Indicates air register closed Burner trip.	1.20	126,127
2.42	Field Interface circuit 1G-14	(a) Fails high	(a) High signal to inverter 1E-4.	(a) Same as above.	0.01044	122
		(b) Fails low.	(b) Low signal to inverter 1E-4.	(b) Indicates air register open. Burner could be in service with air register closed.	0.01044	124
2.43	Inverter 1E 4	(a) Fails high.	(a) High signal to NAND gate 2D-6.	(a) Indicate air register open Burner could be in service with register closed.	0.11013	124
		(b) Fails low.	(b) Low signal to NAND gate 2D-6.	(b) Indicate air close, burner trip.	0.11013	127
2.44A	Time Delay 1F 5	(a) Fails open	(a) No signal to NAND gate 1C-8	(a) Burner does not trip after 5 sec and no flame.	5.02160	6,111
2.44B	NAND Gate 2D 6	(a) Fails high	(a) High signal to NAND gate 2C-14 and NAND gate 2D-10.	(a) Indicates burner not in service, burner trip	0.140015	112,111
		(b) Fails low.	(b) Low signal to NAND gate 2C-14 and NAND gate 2D-10.	(b) Indicates burner in service, cannot extend ignitor.	0.140015	114,120 124,125
2.44C	NAND Gate 1C-8	(c) Fails high	(c) High signal to NAND gate 1E-16.	(c) Loss of burner trip.	0.29601	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

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REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
2.45	NAND Gate 2C-10	(a) Fails high.	(a) High signal to time delay 1F-11.	(a) Burner valve open after an on switch actuated.	0.148015	128,124
		(b) Fails low.	(b) Low signal to time delay 1F-11.	(b) Cannot open burner valve.	0.148015	122
2.46	Time Delay 1F 11	(a) Fails open.	(a) No signal to NAND gate 2C-11.	(a) Same as above.	2.5100	1
		(b) Fails to time.	(b) Short time cycle to NAND gate 2C-11.	(b) Burner valve opens immediate when oil switch activated.	2.5100	1
2.47	NAND Gate 2C 11	(a) Fails high	(a) High signal to output circuit 2B-5, buffer 3G-7 and inverter 2E-12.	(a) Burner trip.	0.148015	119
		(b) Fails low.	(b) Low signal to output circuit 2B-5, buffer 3G-7, and inverter 2E-12.	(b) Burner valve open. Possible explosion.	0.148015	128,124 125,121
2.48	Output Circuit 2B 5	(a) Fails high	(a) High signal to pressure switch 49 atom. steam.	(a) Burner valve open.	0.56456	121
		(b) Fails low.	(b) Low signal to pressure switch 49 atom. steam.	(b) Burner trip.	0.56456	119
2.49	Pressure Switch 49 Atom Steam.	(a) Fails open.	(a) No power to relay coil 50 OPEN MOV.	(a) Burner trip.	11.47	119
		(b) Fails closed	(b) Continuous power to relay coil 50 OPEN MOV.	(b) Fails to trip when atom. steam. lost.	11.28	6
2.50	Relay 50 OPEN MOV	(a) Coil open or contact fails to close.	(a) Fails to energize.	(a) Burner trip.	0.91	3
2.51	Relay Contact 51 1 ON (ON (FFF)	(a) Fails to close	(a) No power to limit switch 52.	(a) Loss of ignitor extended signal, burner valve not open.	0.26	3
		(b) Fails to open.	(b) Continuous power to limit switch 52.	(b) False ignitor on signal.	0.26	3
2.52	Limit Switch 52 wiring and connectors	(a) Fails open.	(a) No power to field interface circuit 2D-6.	(a) Loss of ignitor extended signal, burner valve not open.	1.28	3

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
2.53	Field Interface Circuit 2G-6	(a) Fails high.	(a) High signal to NAND gate 2C-14.	(a) Ignitor not extended signal, burner valve not open.	0.03064	3
		(b) Fails low.	(b) Low signal to NAND gate 2C-14.	(b) Burner valve could open when ignitor not extended.	0.03064	3
2.54	Inverter 1F-4	(a) Fails high.	(a) High signal to NAND gate 1B-14, NAND gate 1B-8 and diode 19.	(a) Could get false permission to fire--possible explosion.	0.13023	1
		(b) Fails low.	(b) Low signal to NAND gate 1B-14, NAND gate 1B-8 and diode 19.	(b) Loss of permission to fire signal cannot fire burner.	0.13023	1
2.55	NAND Gate 2C-5	(a) Fails high.	(a) High signal to NAND gate 2C-8.	(a) Air register could close without purge complete.	0.148015	1
		(b) Fails low.	(b) Low signal to NAND gate 2C-8.	(b) Air register will not close.	0.148015	1
2.56	NAND Gate 2C-8	(a) Fails high.	(a) High signal to output circuit 2B-4.	(a) Same as above.	0.148015	116
		(b) Fails low.	(b) Low signal to output circuit 2B-4.	(b) Air register close.	0.148015	118
2.57	Output Circuit 2B-4	(a) Fails high.	(a) High signal to relay coil 58--CLOSE AR.	(a) Same as above.	0.56454	118
		(b) Fails low.	(b) Low signal to relay coil 58--CLOSE AR.	(b) Air register will not close.	0.56454	116
2.58	Relay Coil 58 CLOSE AR	(a) Coil fails open or contact does not cease.	(a) Fails to energize.	(a) Air register will not close	1.44	1
2.60	NAND Gate 3D-5	(a) Fails high.	(a) High signal to inverter 1B-6, diode 66, and module MFC (2F).	(a) Indicates flame could prevent light-off or burner shutdown.	0.148015	1
		(b) Fails low.	(b) Low signal to inverter 1B-6, diode 66 and module MFC (2F).	(b) Loss of flame indication. Burner trip.	0.148015	3

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

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REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
2.61	Inverter 2E-6	(a) Fails high.	(a) High signal to NAND gate 1E-8.	(a) Indicates no flame.	0.13023	3
		(b) Fails low.	(b) Low signal to NAND gate 1E-8.	(b) Indicates flame. Prevent light off.	0.13023	1
2.62	NAND Gate 2D-14	(a) Fails high.	(a) High signal to NAND gate 1E-16.	(a) Indicates flame could prevent burner trip.	0.168015	4
		(b) Fails low.	(b) Low signal to NAND gate 1E-16.	(b) Indicates no flame, burner trip.	0.168015	3
2.63	Inverter 3E-6	(a) Fails high.	(a) High signal to NAND gate 3D-11 and to module NPC (2F).	(a) False loss of flame indication.	0.13023	1
		(b) Fails low.	(b) Low signal to NAND gate 3D-11 and to module NPC (2F).	(b) False flame present indication.	0.13023	1
2.64	NAND Gate 3D-11	(a) Fails high.	(a) High signal to module NPC (2F).	(a) Same as above.	0.168015	3
		(b) Fails low.	(b) Low signal to module NPC (2F).	(b) False flame present indication.	0.168015	4
2.65	Time Delay 1F-14	(a) Fails open.	(a) Fails open NAND gate 2D14.		2.5108	3
		(b) Fails to time.	(b) Fails to time to NAND gate 2D14.		2.5108	3
2.68	Inverter 3E-12	(a) Fails high.	(a) High signal to NAND gate 3D-14.	(a) Loss of unsuccessful flame test light.	0.13023	5
		(b) Fails low.	(b) Low signal to NAND gate 3D-14.	(b) False unsuccessful flame test light.	0.13023	5
2.69	NAND Gate 3D-14	(a) Fails high.	(a) High signal to no flame to boiler trip logic.	(a) Indicates no flame could trip boiler.	0.168015	5
		(b) Fails low.	(b) Low signal to no flame to boiler trip logic.	(b) Indicates flame could inhibit boiler trip.	0.168015	5

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 2.0 BURNER MODULE
Two Per Boiler, Four Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
2.72	Igniter actuator	(a) Stuck or bound closed.	(a) Cannot extend igniter.	(a) Light-off fails and burner shuts down.	0.62	121a
		(b) Stuck or bound open.	(b) Cannot retract igniter.	(b) Loss of burner trip.	0.62	120a
2.73	Igniter	(a) Igniter	(a) Insufficient fuel for light-off.	(a) Light-off fails and burner shuts down.	0.04	3
2.74	Air Register Actuator	(a) Stuck or bound closed.	(a) Cannot open air register.	(a) Light-off fails.	0.62	116a
		(b) Stuck or bound open.	(b) Cannot close air register.	(b) Light-off fails.	0.62	118a
2.75	Burner Valve Pneumatic Operator	(a) Contamination, damaged seat or worn seat.	(a) Internal leaking.	(a) Cannot complete close burner valve.	16.38	121a
		(b) Pneumatic operator fails.	(b) Fails to open.	(b) Cannot open burner valve.	16.38	119a

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One for Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
	Steam Pressure Transmitter Rosemount PN 11 44-C-1280-A-12 - Starboard -					
1. 1A	Starboard	(a) Fails open.	(a) Loss of signal to hi/lo select.	(a) Will always select other boiler signal. Could result in high steam pressure and loss of accurate signal to ITC.	10.38	59
1. 1B		(b) Short to positive.	(b) High signal to hi/lo select.	(b) Reduces steam pressure.	10.38	58
	Current to Voltage Converter Module I/E MD-A101GP PN C-22930 01-C Starboard -					
1. 2A	Input	(a) Open circuit.	(a) Low output.	(a) High steam pressure.	0.9436	59
1. 2B	Input	(b) Short circuit.	(b) High output.	(b) Low steam pressure.	0.9436	58
1. 2C	Reference Amplifier	(c) Short to negative or open.	(c) High output signal.	(c) Low steam pressure.	0.9436	58
1. 2D	Reference Amplifier	(d) Short to positive.	(d) Decreased output signal.	(d) High steam pressure.	0.9436	59
1. 2E	First Stage	(e) Internal open.	(e) Decreased output.	(e) High steam pressure.	0.9436	59
1. 2F	First Stage	(f) Internal short to negative.	(f) Decreased output.	(f) High steam pressure.	0.9436	59
1. 2G	Driver	(g) Short to positive.	(g) Increased output.	(g) Low steam pressure.	0.9436	58
	Pressure Indicators, PI 107 and 108 Starboard -					
1. 3A		(a) Fails to indicate.	(a) Cannot verify steam pressure.	(a) No effect, lo alarm if lo, steam dumps if high.		

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One Per Vessel

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REF. NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO
	Alarm Module BALM-C2010R PN C-310455-01 Steam Pressure Starboard					
1.4A		(a) Internal short.	(a) False out of range signal.	(a) False alarm.	5.085	81
1.4B		(b) Internal open.	(b) No signal when out of range.	(b) No alarm output.	5.085	84
	Steam Pressure Transmitter Rosemount PN 11 44-C-1200-A 12 Port					
1.1A		(a) Fails open.	(a) Loss of signal to hi/lo select.	(a) Will always select other boiler signal. Could result in high steam pressure and loss of accurate signal to ITC.	10.30	59
1.1B		(b) Short to positive.	(b) High signal to hi/lo select.	(b) Reduces steam pressure.	10.30	58
	Current to Voltage Converter Module I/E MD-A1010R PN C-22930-01-C Port					
1.2A	Input	(a) Open circuit.	(a) Low output.	(a) High steam pressure.	0.9436	59
1.2B	Input	(b) Short circuit.	(b) High output.	(b) Low steam pressure.	0.9436	58
1.2C	Reference Amplifier	(c) Short to negative or open.	(c) High output signal.	(c) Low steam pressure.	0.9436	58
1.2D	Reference Amplifier	(d) Short to negative or open.	(d) Decreased output signal.	(d) High steam pressure.	0.9436	59
1.2E	First Stage	(e) Internal open.	(e) Decreased output.	(e) High steam pressure.	0.9436	59

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 3.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1086 HRS.	CRITICAL INDEX NO.
3.2F	First Stage	(f) Internal short to negative.	(f) Decreased output.	(f) High steam pressure.	0.9436	59
3.2G	Driver	(g) Short to positive.	(g) Increased output.	(g) Low steam pressure.	0.9436	58
	Pressure Indicators, PI 107 and 108 - Port -					
3.3A		(a) Fails to indicate.	(a) Cannot verify steam pressure.	(a) No effect, in alarm if lo, steam dumps if high.		
	Alarm Module BALM-C201GR PN C-310455-01 Steam Pressure - Port -					
3.4A		(a) Internal short.	(a) False out of range signal.	(a) False alarm.	5.085	63
3.4B		(b) Internal open.	(b) No signal when out of range.	(b) No alarm output.	5.085	64
	High Signal, Steam Pressure Selector HI/LO-AIO1GR PN C-22316-01-B					
3.5A	Input Buffer	(a) Short to positive.	(a) High output.	(a) Low steam pressure.	1.3131	58
3.5B	Input Buffer	(b) Short to negative.	(b) Slight output variation.	(b) Slight pressure variation.	1.3131	
3.5C	Input Buffer	(c) Fails open.	(c) Slight output variation.	(c) Slight pressure variation.	1.3131	
3.5D	Output Buffer	(d) Short to positive.	(d) High output.	(d) Low steam pressure.	1.3131	58
3.5E	Output Buffer	(e) Short to negative.	(e) Zero output.	(e) High steam pressure.	1.3131	59
3.5F	Output Buffer	(f) Open.	(f) Zero output.	(f) High steam pressure.	1.3131	59

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Filter Steam Pressure Signal to ITC FIL/INP A1G1GA						
1. 6A	Resistance ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
1. 6B	Input Buffer	(b) Open/or short to negative.	(b) Minimum output signal.	(b) ITC reduces RPM or trips turbine.	0.5761	452
1. 6C	Input Buffer	(c) Short to positive.	(c) High output.	(c) No effect.	0.2470	
1. 6D	Inverter 1	(d) Open/or short to positive.	(d) Loss of output signal.	(d) ITC reduces RPM or trips turbine.	0.4807	452
1. 6E	Inverter 1	(e) Short to negative.	(e) High output.	(e) No effect.	0.2580	
1. 6F	Inverter 2	(f) Open short to negative.	(f) Loss of output signal.	(f) ITC reduces RPM or trips turbine.	0.5840	452
1. 6G	Inverter 2	(g) Short to positive.	(g) High output.	(g) No effect.	0.3144	
Setpoint Module SRPT-A1G1GB PN C-11910-01						
1. 7A		(a) Open--wiper on pos. lead/pot	(a) Decrease output.	(a) Decreased steam pressure.	0.6064	58
1. 7B		(b) Open--negative lead/pot	(b) Increase output.	(b) Increased steam pressure.	0.2021	58
1. 7C		(c) Internal open.	(c) Decreased output.	(c) Decreased steam pressure.	0.0086	58
1. 7D		(d) Short to positive.	(d) Increased output.	(d) Increased steam pressure.	1.213	58
1. 7E		(e) Short to negative.	(d) Decreased output.	(e) Decreased steam pressure.	1.213	58

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 3.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
	Control Module CNTL-C101GR PN C-39283-006					
3. 8A	Differential	(a) Internal open.	(a) No control.	(a) Low steam pressure.	0.3920	58
3. 8B	Differential	(b) Short to positive.	(b) Increased output.	(b) High steam pressure.	0.2940	59
3. 8C	Differential	(c) Short to negative.	(c) Decreased output.	(c) Low steam pressure.	0.2940	58
3. 9A	Proportional Section	(a) Internal open.	(a) No control.	(a) Low steam pressure.	0.9165	58
3. 9B	Proportional Section	(b) Short to positive.	(b) Increased output.	(b) High steam pressure.	0.6074	59
3. 9C	Proportional Section	(c) Short to negative.	(c) Decreased output.	(c) Low steam pressure.	0.6074	58
3.10A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Steam pressure variation, slight loss of control.	0.2966	
3.10B	Signal Inversion Section	(b) Short to negative.	(b) Increased output.	(b) Steam pressure high.	0.2225	59
3.10C	Signal Inversion Section	(c) Short to positive.	(c) Decreased output.	(c) Low steam pressure.	0.2225	58
3.11A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Low steam pressure variation, slight loss of control.	0.4170	
3.11B	Integral Gain Section	(b) Short to negative.	(b) Decreased output.	(b) Low steam pressure.	0.3127	58
3.11C	Integral Gain Section	(c) Short to positive.	(c) Increased output.	(c) Increased steam pressure.	0.3127	59
3.12A	Integrator	(a) Relay fails to open.	(a) Transfer from manual to auto causes system upset.	(a) Temporary steam pressure variations.	0.4730	
3.12B	Integrator	(b) Relay fails to close.	(b) Loss of accurate control.	(b) Steam pressure variation, slight loss of control.	0.2030	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 1.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
1.12C	Integrator	(c) Internal open or C1 short.	(c) Loss of accurate control.	(c) Temporary steam pressure variations.	0.2707	
1.12D	Integrator	(d) Open C1.	(d) Output decreased.	(d) Low steam pressure.	0.1354	58
1.12E	Integrator	(e) Short to positive.	(e) Increased output.	(e) High steam pressure.	0.1354	59
1.12F	Integrator	(f) Short to negative.	(f) Decreased output.	(f) Low steam pressure.	0.1354	58
1.13A	Summing Section	(a) Internal open.	(a) Decreased output.	(a) Low steam pressure.	3.3	58
1.13B	Summing Section	(b) Short positive.	(b) Increased output.	(b) High steam pressure	3.3	59
1.13C	Summing Section	(c) Short negative.	(c) Decreased output.	(c) Low steam pressure.	3.3	58
1.14A	Output Limiting	(a) Internal open.	(a) No effect during normal operation.	(a) No effect--could possibly give a wide steam pressure variation in abnormal condition--less 0.5% of time.	1.3392	
1.14B	Output Limiting	(b) Internal short.	(b) High output.	(b) High steam pressure.	1.3392	59
	Balance Module BAL A1D1GR PN22985-01-D Op Amps (4)					
1.15A		(a) Fails open.	(a) Loss of signal to one boiler.	(a) Possible insufficient steam.	3.6192	
1.15B		(b) Short to negative.	(b) Loss of signal to one boiler.	(b) Possible insufficient steam.	2.7144	
1.15C		(c) Fails positive.	(c) One boiler signal to the high side.	(c) Temporary high steam pressure.	2.7144	
	Add/Subtract Module, ADD/SUB B1D1GR L-30115-01-B All					
1.16A		(a) Fail to open.	(a) Zero output.	(a) Temporary low steam pressure.	1.6825	
1.16B		(b) Short to negative.	(b) Zero output.	(b) Temporary loss steam pressure.	1.2619	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 3.0 COMBUSTION CONTROL, MASTER DEMAND LOGIC
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
3.16C		(c) Short to positive.	(c) High output.	(c) Temporary high steam pressure.	1.3619	
	Adjustable Reference Module ADJ REF-A101GR C-22991-01-B					
3.17A		(a) Fails open.	(a) Zero output.	(a) Temporary low steam pressure.	0.3291	
3.17B		(b) Short to negative.	(b) Zero output.	(b) Temporary low steam pressure.	0.2470	
3.17C		(c) Short to positive.	(c) High output.	(c) Temporary high steam pressure.	0.2470	

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10^6 HRS.	CRITICAL INDEX NO.
Windbox/Furnace Transmitter						
4.1A		(a) Internal failure.	(a) High output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	17.40	143a(.8), 143b(.2)
4.1B		(b) Internal failure or open from field.	(b) Low output.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	17.100	142a(.6), 142b(.3), 142c(.1)
Current to Voltage Converter, 1E						
4.2A	Input	(a) Open circuit.	(a) Low output.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke	0.9436	142a(.6), 142b(.3), 142c(.1)
4.2B	Input	(b) Short circuit.	(b) High output.	(b) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.9436	143a(.8), 143b(.2)
4.3A	Reference Amplifier	(a) Short to negative or open.	(a) High output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.9436	143a(.8), 143b(.2)
4.3B	Reference Amplifier	(b) Short to positive.	(b) Decreased output signal.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	142a(.6), 142b(.3), 142c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

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REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
4.4A	First Stage	(a) Internal open.	(a) Decreased output.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	142a(.4), 142b(.3), 142c(.3)
4.4B	First Stage	(b) Internal short to negative.	(b) Decreased output.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	142a(.4), 142b(.3), 142c(.3)
4.5A	Driver	(a) Short to positive.	(a) Increased output.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	142a(.4), 142b(.3), 142c(.3)
Filter/Impulse, 2B FIL/IMP A101GR						
4.6A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
4.7A	Input Buffer	(a) Open or short to negative.	(a) Minimum output signal.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9763	142a(.4), 142b(.3), 142c(.3)
4.8A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Actual air flow is decreased. F.O. flow remains at desired rate. Excess F.O. and black smoke. No alarm for low air Possible explosion.	0.2470	143a(.8), 143b(.2)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.8B	Inverter 1	(b) Open/short to positive.	(b) Loss of output signal.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.4809	142a(.6), 142b(.3), 142c(.3)
4.8C	Inverter 1	(c) Short to negative.	(c) High output.	(c) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.2500	143a(.8), 143b(.2)
4.9A	Inverter 2	(a) Open/short to negative.	(a) Loss of output signal.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.5840	142a(.6), 142b(.1), 142c(.3)
4.9B	Inverter 2	(b) Short to positive.	(b) High output.	(b) Actual air flow is decreased. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.3160	14[illegible](.8), 143b(.2)
	Square Root, 3C NURT 81D10R					
4.10A	Clock	(a) Internal circuit failure.	(a) Locked output.	(a) Either one of the following occurs: (1) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion. (2) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.0807	103a(.8), 103b(.2)

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FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.11A	Reference Amplifier	(a) Internal circuit failure	(a) High or low output.	(a) Either one of the following occurs: (1) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	1.8183	143a(.8), 143b(.2)
4.12A	D to A Converter	(a) Internal short	(a) Max. output signal zero.	(a) Temporary high or low steam	7.1794	
4.13A	Counter	(a) Internal failure.	(a) Minor error in output signal.	(a) Minor variation in steam.	3.0773	
Filter/Impulse 2B FIL/IMP A1G1GR						
4.14A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
4.15A	Input Buffer	(a) Open or short to negative.	(a) Minimum output signal.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.5763	142a(.4), 142b(.3), 142c(.3)
4.16A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.2070	143a(.8), 143b(.2)
4.16B	Inverter 1	(b) Open/short to positive.	(b) Loss of output signal.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.4009	142a(.4), 142b(.3), 142c(.3)
4.16C	Inverter 1	(c) Short to negative.	(c) High output.	(c) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.2508	143a(.8), 143b(.2)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 6.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.17A	Inverter 2	(a) Open/short to negative.	(a) Loss of output signal.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.5040	147a(.6), 147b(.3), 147c(.3)
4.17B	Inverter 2	(b) Short to positive.	(b) High output.	(b) Actual air flow is decreased. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.1144	163a(.8), 163b(.2)
Relay REL A1D1GH						
4.18A		(a) Fails to switch.	(a) High output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	5.0	163a(.8), 163b(.2)
4.18B		(b) Fails open.	(b) No output.	(b) Actual air flow increases Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	5.0	143a(.6), 143b(.3) 143c(.3)
Air Fuel Ratio, 2D RATIO PM B1D1G						
4.19A	Input Stage	(a) Short to positive.	(a) Output to zero.	(a) Decrease fuel flow. Poor air/fuel ratio. White smoke. Possible flameout.	1.3081	81a(.5), 81b(.5)
4.19B	Input Stage	(b) Short to negative.	(b) Increase output.	(b) Increase in fuel flow and decrease in air flow. Poor air/fuel ratio. Black smoke. Possible flameout.	1.3081	81a(.5), 81b(.5)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

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REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODES	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.20A	Output Amplifier	(a) Short to positive.	(a) Increase output.	(a) Increase fuel and decrease air flow. Poor air/fuel ratio. Black smoke, possible flameout.	1.3083	81a(.5) 81c(.5)
4.20B	Output Amplifier	(b) Open	(b) Decrease output.	(b) Increase air flow and decrease fuel. Poor air/fuel ratio. White smoke, possible flameout.	1.3083	81a(.5) 81b(.5)
4.20C	Output Amplifier	(c) Short to negative.	(c) Decrease output.	(c) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	1.3083	14(a)(.6), 14(b)(.3), 14(c)(.1)
	Manual/Auto, 3B M/A AI2ICN					
4.21A	Output Buffer (Auto or Manual)	(a) Open	(a) Decreased output.	(a) Low steam pressure.	0.10914	58
4.21B	Output Buffer (Auto or Manual)	(b) Short to negative.	(b) Decreased output.	(b) Low steam pressure.	0.2120	58
4.21C	Output Buffer (Auto or Manual)	(c) Short to positive.	(c) Increased output.	(c) High steam pressure.	0.2120	59a(.9), 59b(.1)
4.22A	I to A Converter (Auto Mode)	(a) Internal failure.	(a) Minor output fluctuation.	(a) Minor steam pressure variation.	4.8565	
4.23A	Comparators (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Loss of control.	0.4362	80
4.23B	Comparators (Auto Mode)	(b) Short to positive.	(b) Output increased.	(b) High steam pressure.	0.4362	59a(.9) 59b(.1)
4.24A	Auto Clock (Auto Mode)	(a) Internal failure.	(a) In auto mode locks in present point.	(a) Loss of control.	0.2806	80
4.25A	Output Inverter (Manual)	(a) Internal failure.	(a) Temporary process upset.	(a) Loss of control.	0.7162	80

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.26A	Manual Clock Circuit	(a) Internal failure.	(a) No change in output sets at current point.	(a) Loss of control	0.2806	80
4.27A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Loss of manual.	0.0657	83
4.27B	Control Logic (Manual)	(b) Internal failure.	(b) No increase of output signal.	(b) Loss of control.	0.0657	80
4.27C	Control Logic (Manual)	(c) Internal failure.	(c) No decrease of output signal.	(c) Loss of control.	0.0657	80
4.27D	Control Logic (Manual)	(d) Internal failure.	(d) Increased output to maximum.	(d) High steam pressure.	0.0657	59a(9) 59b(1)
4.27E	Control Logic (Manual)	(e) Internal failure.	(e) Decrease output to minimum.	(e) Low steam pressure.	0.0657	58
4.28A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Loss of auto.	0.1771	80
4.28B	Control Logic (Auto)	(b) Internal failure.	(b) No increase of output signal.	(b) Loss of control.	0.1771	80
4.28C	Control Logic (Auto)	(c) Internal failure.	(c) No decrease of output signal.	(c) Loss of control.	0.1771	80
4.28D	Control Logic (Auto)	(d) Internal failure.	(d) Increases to maximum.	(d) High steam pressure.	0.1771	59a(9) 59b(1)
4.28E	Control Logic (Auto)	(e) Internal failure.	(e) Decreases to minimum.	(e) Low steam pressure.	0.1771	58
	Low/High Select, IC (4-MI-A1010B					
4.29A	Input Buffer	(a) Short to positive.	(a) High output.	(a) High F.O. flow. Hi steam pressure. F.O. increase lead air. Could explode.	1.3131	41a(5) 41b(3) 41c(2)
4.29B	Input Buffer	(b) Short to negative.	(b) Slight output variation.	(b) Slight F.O. flow variation.	1.3131	
4.29C	Input Buffer	(c) Fails open.	(c) Slight output variation.	(c) Slight F.O. flow variation.	1.3131	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per vessel

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REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
4.10A	Output Buffer	(a) Short to positive	(a) High output.	(a) High F.O. flow. Hi steam pressure. F.O. increase lead air. Could explode.	1.3131	43a(.5) 43b(.3) 43c(.2)
4.10B	Output Buffer	(b) Short to negative	(b) Zero output.	(b) Low F.O. flow, low steam pressure. Excess air. Could lose flame.	1.3131	42a(.6) 42b(.4)
4.10C	Output Buffer	(c) Open.	(c) Zero output.	(c) Low F.O. flow, low steam pressure. Excess air. Could lose flame.	1.3131	42a(.6) 42b(.4)
	Adjustable Signal Relay, 1B AKRL-B101A FOX 1/O					
4.11A		(a) Fails open	(a) Loss of output.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.0445	(42a(.4), (42b(.3), (42c(.3)
4.11B		(b) Short to negative.	(b) Loss of output.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint. and reduces F.O. flow. Excess air alarm for low air or smoke.	0.0445	42a(.6) 42b(.4)
4.11C		(c) Short to positive.	(c) High output.	(c) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	0.0445	43a(.6) 43b(.3) 43c(.1)
4.11D		(d) Fails to switch.	(d) Low F.O. flow signal inhibited.	(d) F.O. flow does not decrease for light off. Possible explosion.	0.0445	43a(.6) 43b(.3) 43c(.1)
4.11E		(e) Fails to reset.	(e) Low air flow signal remain.	(e) F.O. flow remains low.	0.0445	42a(.6) 42b(.4)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.9 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

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REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.12A	Input Buffer	(a) Short to positive	(a) High output.	(a) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	1.1111	41a(.6), 41b(.3), 41c(.1)
4.12B	Input Buffer	(b) Short to negative.	(b) Slight output variation.	(b) F.O. flow varies.	1.1111	NO
4.12C	Input Buffer	(c) Fails open.	(c) Slight output variation.	(d) F.O. flow varies.	1.1111	NO
4.13A	Output Buffer	(a) Short to positive.	(a) High output.	(a) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	1.1111	41a(.6), 41b(.3), 41c(.1)
4.13B	Output Buffer	(b) Short to negative.	(b) Zero output.	(b) Low F.O. flow, excess air.	1.1111	142a(.4), 142b(.3), 142c(.3)
4.13C	Output Buffer	(c) Open.	(c) Zero output.	(c) Low F.O. flow, excess air.	1.1111	142a(.4), 142b(.3), 142c(.3)
Control Module, 1A CNTRL C1010R						
4.14A	Differential	(a) Internal open.	(a) No control.	(a) Loss of control.	0.1970	NO
4.14B	Differential	(b) Short to positive.	(b) Increased output.	(b) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	0.2940	41a(.6), 41b(.3), 41c(.1)
4.14C	Differential	(c) Short to negative.	(c) Decreased output.	(c) Low F.O. flow, excess air.	0.2940	42a(.6), 42b(.4)
4.15A	Proportional Section	(a) Internal open.	(a) No control.	(a) Loss of control.	0.9165	NO
4.15B	Proportional Section	(b) Short to negative.	(b) Increased output.	(b) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	0.6074	41a(.6), 41b(.3), 41c(.1)
4.15C	Proportional Section	(c) Short to positive.	(c) Decreased output.	(c) Low F.O. flow, excess air.	0.6074	42a(.6), 42b(.4)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
4.16A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Loss of control.	0.2966	8B
4.16B	Signal Inversion Section	(b) Short to negative.	(b) Increased output.	(b) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	0.2225	4(a(.6), 4(b(.3)), 4(c(.1))
4.16C	Signal Inversion Section	(c) Short to positive.	(c) Decreased output.	(c) Low F.O. flow, excess air.	0.2225	4(a(.6), 4(b(.4))
4.17A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Loss of control.	0.4170	8B
4.17B	Integral Gain Section	(b) Short to negative.	(b) Decreased output.	(b) Low F.O. flow.	0.3127	8B
4.17C	Integral Gain Section	(c) Short to positive.	(c) Increased output.	(c) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	0.3127	4(a(.6), 4(b(.3)), 4(c(.1))
4.18A	Output	(a) Internal open.	(a) No effect during normal operation.	(a) No effect.	1.3392	
4.18B	Output	(b) Internal short.	(b) High output.	(b) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	1.3392	4(a(.6), 4(b(.3)), 4(c(.1))
	Manual/Auto, ID M-A-A101GH PN11918 01 M					
4.19A	Output Buffer (Auto or Manual)	(a) Open	(a) Decreased output.	(a) Decreased fuel flow, excess air. Possible flame out.	0.3094	4(a(.6), 4(b(.4))
4.19B	Output Buffer (Auto or Manual)	(b) Short to negative.	(b) Decreased output.	(b) Decreased fuel flow, excess air. Possible flame out.	0.2320	4(a(.6) 4(b(.4))
4.19C	Output Buffer (Auto or Manual)	(c) Short to positive	(c) Increased output.	(c) Increase fuel flow. High steam pressure. Level air, possible explosion.	0.2320	4(a(.6), 4(b(.3)), 4(c(.1))
4.40A	D to A Converter (Auto Mode)	(a) Internal failure.	(a) Minor output fluctuation.	(a) Small output offset.	4.8525	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B   SUBSYSTEM: 4.0 COMBUSTION CONTROL   PAGE: 11

One Per Boiler, Two Per Vessel

KEY NO	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
4.41A	Comparators (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Loss of control in auto.	0.43615	60
4.41B	Comparators (Auto Mode)	(b) Short to positive.	(b) Output increased.	(b) Increase fuel flow. High steam pressure leads air. Possible explosion.	0.43615	43a(.6), 43b(.3), 43c(.1)
4.42A	Auto Clock Circuit (Auto Mode)	(a) Internal failure.	(a) In auto mode locks in present point.	(a) Loss of control in auto.	0.2804	NO
4.43A	Output Inverter (Manual)	(a) Internal failure.	(a) Temporary process upset.	(a) Temporary instability of fuel flow.		
4.44A	Manual Clock Circuit	(a) Internal failure.	(a) No change in output sets at current point.	(a) Loss of control in manual.	0.2804	02
4.45A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Maintains auto control	0.0657	02
4.45B	Control Logic (Manual)	(b) Internal failure.	(b) No increase of output signal.	(b) Low fuel flow. Poor air/fuel ratio.	0.0657	42a(.6), 42b(.4)
4.45C	Control Logic (Manual)	(c) Internal failure.	(c) No decrease of output signal.	(c) F.O. flow remains high when demand decreases.	0.0657	43a(.6), 43b(.3), 43c(.1)
4.45D	Control Logic (Manual)	(d) Internal failure.	(d) Increased output to maximum.	(d) Increase fuel flow. High steam pressure leads air. Possible explosion.	0.0657	43a(.6), 43b(.3), 43c(.1)
4.45E	Control Logic (Manual)	(e) Internal failure.	(e) Decrease output to minimum.	(e) Decreased fuel flow, excess air. Possible flame out.	0.0657	42a(.6), 42b(.4)
4.46A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Able to use manual but not auto.	0.1771	NO
4.46B	Control Logic (Auto)	(b) Internal failure.	(b) No increase of output signal.	(b) Decreased fuel flow, excess air. Possible flame out.	0.1771	42a(.6), 42b(.4)
4.46C	Control Logic (Auto)	(c) Internal failure.	(c) No decrease of output signal.	(c) F.O. flow remains high when demand decreases.	0.1771	43a(.6), 43b(.3), 43c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.46D	Control Logic (Auto)	(d) Internal failure.	(d) Increases to maximum.	(d) Increase fuel flow. High steam pressure leads air. Possible explosion.	0.1771	43a(.6), 43b(.3), 43c(.1)
4.46E	Control Logic (Auto)	(e) Internal failure.	(e) Decreases to minimum.	(e) Decreased fuel flow, excess air. Possible flame out.	0.1771	42a(.6), 42b(.4)
Voltage to Current, IC E/I D10:GN						
4.47	All, except Reference Amp	(a) Internal open.	(a) No output signal.	(a) Low F.O. flow, excess air. Possible flame out.	1.7008	42a(.6), 42b(.4)
4.47B	All, except Reference Amp	(b) Short transistor or IC to positive.	(b) Maximum output signal.	(b) High F.O. flow. High steam pressure. F.O. increase leads air and possible explosion.	1.7008	43a(.6), 43b(.3), 43c(.1)
4.47C	All, except Reference Amp	(c) IC short to negative.	(c) Minimum output signal.	(c) Low F.O. flow, excess air. Possible flame out.	1.7008	42a(.6), 42b(.4)
4.48A	Reference Amplifier	(a) Internal failure open	(a) Loss of precision of control.	(a) Loss of control.	0.2781	80
4.48B	Reference Amplifier	(b) Internal short to positive	(b) Output high.	(b) High F.O. flow. High steam pressure. F.O. increase leads air. Possible explosion.	0.2781	43a(.6), 43b(.3), 43c(.1)
4.48C	Reference Amplifier	(c) Internal short to negative	(c) Low output.	(c) Low F.O. flow. Excess air. Possible flame out.	0.2781	42a(.6), 42b(.4)
Fuel Oil Contol C/r						
4.49A		(a) Internal failure.	(a) Fails open.	(a) Low F.O. flow. Excess air. Possible flame out.	1.84	42a(.6), 42b(.4)
4.49B		(b) Internal failure.	(b) Fails closed.	(b) High F.O. flow. High steam pressure. F.O. increase leads air, possible explosion.	1.44	43a(.6), 43b(.3), 43c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Fuel Oil Flow Transmitter						
4.50A		(a) Fails open.	(a) Loss of signal.	(a) F.O. increases, air remains at demand signal level. Excess F.O. and possible explosion.	14.84	43a(.6), 43b(.1), 43c(.1)
4.50B		(b) Short to positive.	(b) Increased output.	(b) Decrease F.O. flow, decrease steam pressure. High air. Possible loss of flame.	14.46	42a(.6), 42b(.4)
Current to Voltage Converters (END-AIDICK, 2 Modules, Port and Starboard						
4.51A	Input	(a) Open circuit.	(a) Low output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion	0.9436	141a(.8), 141b(.2)
4.51B	Input	(b) Short circuit.	(b) High output.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	142a(.4), 142b(.3), 142c(.3)
4.52A	Reference Amplifier	(a) Short to negative or open.	(a) High output.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	142a(.4), 142b(.3), 142c(.3)
4.52B	Reference Amplifier	(b) Short to positive.	(b) Decreased output.	(b) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.9436	141a(.8), 141b(.2)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B   SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.51A	First Stage	(a) Internal open.	(a) Decreased output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.9436	(43a(.8), (43b(.2)
4.51B	First Stage	(b) Internal short to negative.	(b) Decreased output.	(b) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.9436	(43a(.8), (43b(.2)
4.54A	Driver	(a) Short to positive.	(a) Increased output.	(a) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.9436	(42a(.4), (42b(.3), (42c(.3)
Filter/Impulse FIL/IMP A101GP						
4.55A	Resistance Ladder	(a) Internal failure	(a) Minimum effect.	(a) No effect.	1.1795	
4.56A	Input Buffer	(a) Open/or short to negative.	(a) Minimum output signal.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.5761	(43a(.8), (43b(.2)
4.56B	Input Buffer	(b) Short to positive	(b) High output.	(b) Actual air flow increases. Minimum select logic sens false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.2670	(42a(.4), (42b(.3), (42c(.3)
4.57A	Inverter 1	(a) Open/or short to positive	(a) Loss of output signal.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm forn low air. Possible explosion.	0.4887	(43a(.8), (43b(.2)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS	CRITICAL INDEX NO.
4.57B	Inverter 1	(b) Short to negative	(b) High output.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.2588	162a(.6), 162b(.3), 162c(.1)
4.58A	Inverter 2	(a) Open/short to negative.	(a) Loss of output.	(a) Actual air flow is decreased. F.O. flow remains at demand rate. Excess F.O. and black smoke. No alarm for low air. Possible explosion.	0.5840	161a(.8), 161b(.2)
4.58B	Inverter 2	(b) Short to positive.	(b) High output.	(b) Actual air flow increases. Minimum select logic sends false low air flow signal to fuel oil control setpoint and reduces F.O. flow. Alarm for low air or excess smoke.	0.1144	162a(.6), 162b(.3), 162c(.1)
	Adjustable Signal Relay, 1R APC 1/0					
4.59A		(a) Fails open	(a) Loss of output.	(a) No effect. High select logic uses F.O. flow signal decrease.	0.0445	
4.59B		(b) Short to negative.	(b) Loss of output.	(b) No effect. High select logic uses F.O. flow signal decrease.	0.0445	
4.59C		(c) Short to positive.	(c) High output.	(c) High air flow, excess air. Possible flame out.	0.0445	162a(.6), 162b(.3), 162c(.1)
4.59D		(d) Fails to switch.	(d) High air flow--signal inhibited.	(d) High air flow low during light-off.	0.0445	115
4.59E		(e) Fails to reset.	(e) High air flow signal remains.	(e) No effect.	0.0445	

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10^6 HRS.	CRITICAL INDEX NO.
High Signal Selector Module HI/LO-A1010A PN 22916-01-B						
4.60A	Input Buffer	(a) Short to positive.	(a) High output.	(a) High air, excess air. Could lose flame.	1.3131	k42a(.6), k42b(.3), k42c(.1)
4.60B	Input Buffer	(b) Short to negative.	(b) Slight output variation.	(b) Slight air flow variation.	1.3131	
4.60C	Input Buffer	(c) Fails open	(c) Slight output variation	(c) Slight air flow variation.	1.3131	
4.61A	Output Buffer	(a) Short to positive.	(a) High output.	(a) High air flow, excess air. Could lose flame.	1.3131	k42a(.6), k42b(.3), k42c(.1)
4.61B	Output Buffer	(b) Short to negative.	(b) Zero output.	(b) Minimum air flow. Low pressure. Decreased air lead F.O. Possible explosion.	1.3131	k43a(.4), k43b(.1), k43c(.2), k43d(.3)
4.61C	Output Buffer	(c) Open.	(c) Zero output.	(c) High air flow, excess air. Could lose flame.	1.3131	k42a(.6), k42b(.3), k42c(.1)
Control Module, 2A CNTRL-C1010A PN 19282-006						
4.62A	Differential	(a) Internal open	(a) No control - actuator eventually closes.	(a) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.3920	k43a(.4), k43b(.1), k43c(.2), k43d(.3)
4.62B	Differential	(b) Short to positive.	(b) Increased output.	(b) High air flow, excess air. Possible flame out.	0.2940	k42a(.6), k42b(.3), k42c(.1)
4.62C	Differential	(c) Short to negative	(c) Decreased output.	(c) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.2940	k43a(.4), k43b(.1), k43c(.2), k43d(.3)
4.63A	Proportional Section	(a) Internal open	(a) No control - actuator eventually closes.	(a) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.9165	k43a(.4), k43b(.1), k43c(.2), k43d(.3)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.6.3	Proportional Section	(b) Short to positive	(b) Increased output.	(b) High air flow, excess air. Possible flame out.	0.6074	I(2a)(.01), I(2b)(.31), I(2c)(.31)
4.63C	Proportional Section	(c) Short to negative.	(c) Decreased output.	(c) Low air flow, low pressure Decrease in air lead F.O. Possible explosion.	0.6074	I(1a)(.01), I(1b)(.11), I(1c)(.21), I(1d)(.31)
4.64A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Air flow variation, slight loss of control.	0.2966	
4.64B	Signal Inversion Section	(b) Short to negative.	(b) Increased output.	(b) High air flow, excess air. Possible flame out.	0.2229	I(2a)(.01), I(2b)(.31), I(2c)(.31)
4.64C	Signal Inversion Section	(c) Short to positive	(c) Decreased output.	(c) Low air flow, low pressure Decrease in air lead F.O. Possible explosion.	0.2229	I(1a)(.01), I(1b)(.11), I(1c)(.21), I(1d)(.31)
4.65A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control	(a) Air flow variation, slight loss of control.	0.4170	
4.65B	Integral Gain Section	(b) Short to negative.	(b) Decreased output.	(b) Low air flow, low pressure Decrease in air lead F.O Possible explosion.	0.3127	I(1a)(.01), I(1b)(.11), I(1c)(.21), I(1d)(.31)
4.65C	Integral Gain Section	(c) Short to positive.	(c) Increased output.	(c) High air flow, excess air. Possible flame out.	0.3127	I(2a)(.01), I(2b)(.31), I(2c)(.31)
4.66A	Integrator	(a) Relays fails to open.	(a) Transfer from manual to auto causes sytem upset.	(a) Temporary air flow variations.	0.4730	
4.66B	Integrator	(b) Relays fails to close.	(b) Loss of accurate control.	(b) Air flow variations, slight loss of control.	0.2830	
4.66C	Integrator	(c) Internal open or C1 short.	(c) Loss of accurate control.	(c) Temporary air flow variations.	0.2787	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
4.66D	Integrator	(d) Open C1	(d) Output decreases.	(d) Low air flow, low pressure. Decrease in air load F.O. Possible explosion	0.1154	163a(.6), 163b(.1), 163c(.2), 163d(.3)
4.66E	Integrator	(e) Short to positive.	(e) Increased output	(e) High air flow, excess air. Possible flame out.	0.1154	162a(.6), 162b(.3), 162c(.3)
4.66F	Integrator	(f) Short to negative.	(f) Decreased output	(f) Low air flow, low pressure. Decrease in air load F.O. Possible explosion.	0.1154	163a(.6), 163b(.1), 163c(.2), 163d(.1)
4.67A	Output limiting	(a) Internal open	(a) No effect during normal operation.	(a) Could possibly give a wide air flow variation in abnormal condition--less 0.1% of time	1.1192	
4.67B	Output limiting	(b) Internal short	(b) High output.	(b) High air flow, excess air Possible flame out.	1.1192	162a(.4), 162b(.1), 162c(.1)

Hi (a) Select
Hi (a) A10100

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 1000 HRS.	CRITICAL INDEX NO.
4.68A	Input Buffer	(a) Short to positive	(a) High output	(a) High air flow, excess air. Possible flame out	1.1111	162a(.4), 162b(.1), 162c(.2), 162d(.1)
4.68B	Input Buffer	(b) Short to negative	(b) Slight output variation.	(b) Slight loss of control	1.1111	
5.08	Input Buffer	(c) Fails open	(c) Slight output variation.	(c) Slight loss of control	1.1111	
4.29A	Output Buffer	(a) Short to positive	(a) High output.	(a) High air flow, excess air Possible flame out.	1.1111	162a(.4), 162b(.1), 162c(.2), 162d(.3)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

UNIT: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL (NORM NO.)
4.69B	Output Buffer	(b) Short to negative	(b) Zero output.	(b) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	1.3131	(42a(.4), (42b(.1), (42c(.2), (42d(.3)
Manual/Auto 2F M/A A10; B PN 3F518 01 N						
4.70A	Output Buffer (Auto or Manual)	(a) Open	(a) Decreased output.	(a) Low air flow, low pressure Decrease in air lead F.O. Possible explosion.	0.10916	(43a(.4 (43b(.1 (43c(.2 (43d(.3
4.70B	Output Buffer (Auto or Manual)	(b) Short to negative	(b) Decreased output	(b) Low air flow., low pressure. Decrease in air lead F.O. Possible explosion.	0.2120	(43a(.4) (43b(.1) (43c(.2) (43d(.3)
4.70C	Output Buffer (Auto or Manual)	(c) Short to positive	(c) Increased output.	(c) High air flow, excess air Possible flame out.	0.2320	(42a(.4) (42b(.1) (42c(.2) (42d(.3)
4.71A	D to A converter (Auto Mode)	(a) Internal failure	(a) Minor output fluctuation.	[illegible] Small output offset	4.8565	
4.72A	Comparators (Auto Mode)	(a) Short to negative	(a) Output remains at point of failure in auto.	(a) Loss of control in auto.	0.43615	8C
4.72B	Comparators (Auto Mode)	(b) Short to positive	(b) Output increased.	(b) High air flow, excess air. Possible flame out.	0.4362	(42a(.4) (42b(.1) (42c(.2) (42d(.1)
4.73A	Auto clock (Auto Mode)	(a) Internal failure	(a) In auto mode locks in present point.	(a) Loss of control in auto.	0.2884	80
4.74A	Output Inverter (Manual)	(a) Internal failure	(a) Temporary process upset.	(a) Temporary instability of air flow.	0.7162	
4.75A	Manual clock circuit	(a) Internal failure.	(a) No change in output, sets at current point.	(a) Loss of control in manual.	0.2884	82

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.76A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Maintains auto control.	0.0657	82
4.76B	Control Logic (Manual)	(b) Internal failure.	(b) No increase of output signal.	(b) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.0657	143a(.4), 143b(.1), 143c(.2), 143d(.3)
4.76C	Control Logic (Manual)	(c) Internal failure.	(c) No decrease of output signal.	(c) High air flow, excess air. Possible flame out.	0.0657	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.76D	Control Logic (Manual)	(d) Internal failure.	(d) Increased output to maximum.	(d) High air flow, excess air. Possible flame out.	0.0657	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.76E	Control Logic (Manual)	(e) Internal failure.	(e) Decrease output to minimum.	(e) Low air flow, low pressure. Decrease in air lead F.O.	0.0657	143a(.4), 143b(.1), 143c(.2), 143d(.3)
4.77A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Able to use manual mode but not auto.	0.1771	80
4.77B	Control Logic (Auto)	(b) Internal failure.	(b) No increase of output signal.	(b) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.1771	143a(.4), 143b(.1), 143c(.2), 143d(.3)
4.77C	Control Logic (Auto)	(c) Internal failure.	(c) No decrease of output signal.	(c) High air flow, excess air. Possible flame out.	0.1771	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.77D	Control Logic (Auto)	(d) Internal failure.	(d) Increases to maximum.	(d) High air flow, excess air. Possible flame out.	0.1771	142a(.4), 142b(.1), 142c(.2), 142d(.3)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.77E	Control Logic (Auto)	(e) Internal failure.	(e) Decreases to minimum.	(e) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.1771	143a(.4), 143b(.1), 143c(.2), 143d(.3)
Voltage to Current Converter Module E/I-B101GR						
4.78A	All, except Reference Amp	(a) Internal open.	(a) No output signal.	(a) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	1.7008	143a(.4), 143b(.1), 143c(.2), 143d(.3)
4.78B	All, except Reference Amp	(b) Short transistor or IC to positive.	(b) Maximum output signal.	(b) High ari flow, excess air. Possible flame out.	1.7008	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.78C	All, except Reference Amp	(c) IC short to negative.	(c) Minimum output signal.	(c) Low air flow, low pressure.	1.7008	143a(.4), 143b(.1), 143c(.2), 143d(.3)
4.79A	Reference Amplifier	(a) Internal failure open.	(a) Loss of precision of control.	(a) Temporary low air flow.	0.2783	
4.79B	Reference Amplifier	(b) Internal short to positive.	(b) Output high.	(b) High air flow, excess air. Possible flame out.	0.2783	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.79C	Reference Amplifier	(c) Internal short to negative.	(c) Low output.	(c) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	0.2783	143a(.4), 143b(.1), 143c(.2), 143d(.3)
Adjustable Signal Relay, 1E AREL-B101GR						
4.80A		(a) Fails open.	(a) Loss of output.	(a) Loss of auto control.	0.0445	80

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 4.0 COMBUSTION CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
4.80B		(b) Short to negative.	(b) Loss of output.	(b) Loss of auto controls.	0.0445	80
4.80C		(c) Short to positive.	(c) High output.	(c) High fuel flow.	0.0445	43a(.6) 43b(.3) 43c(.1)
4.80D		(d) Fails to switch.	(d) Low fuel signal inhibited.	(d) Fuel flow does not decrease for light off--possible explosion.	0.0445	40
4.80E		(e) Fails to reset.	(e) Low fuel flow signal remain.	(e) Low fuel flow.	0.0445	42a(.6) 42b(.4)
	Air Flow Control I/P					
4.81A		(a) Internal failure.	(a) Fails closed.	(a) High air flow, excess air. Possible flame out.	1.84	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.81B		(b) Internal failure.	(b) Fails open.	(b) Low air flow, low presure. Decrease in air lead F.O. Possible explosion.	1.46	143a(.4), 143b(.1), 143c(.2), 143d(.3)
	Air Flow Actuator					
4.82A		(a) Stuck/bound.	(a) Open.	(a) High air flow, excess air. Possible flame out.	8.62	142a(.4), 142b(.1), 142c(.2), 142d(.3)
4.82B		(b) Stuck/bound.	(b) Closed.	(b) Low air flow, low pressure. Decrease in air lead F.O. Possible explosion.	8.62	143a(.4), 143b(.1), 143c(.2), 143d(.3)
	Fuel Oil Control Valve					
4.83A		(a) Contamination, damaged seat or worn seat.	(a) Internal leaking or fails to seat.	(a) High fuel flow, possible explosion.	16.38	43a(.6) 43b(.3) 43c(.1)
4.83B		(b) Pneumatic operator fails.	(b) Closes or fails to open.	(b) Low fuel flow or loss of flame.	16.38	42a(.6) 42b(.4)

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Drum Level Indicators Mafg-Rosamount PN 1151-DP-3E-12 LM +9 0 -9 Level In						
6. 1A		(a) Fails open.	(a) No output.	(a) High level.	2.48	34a(.9) 34b(.1)
6. 1B		(b) Short to negative.	(b) Low output.	(b) High level.	2.10	34a(.9) 34b(.1)
6. 1C		(c) Short to positive.	(c) High output.	(c) Low level.	2.10	35a(.6) 35b(.3) 35c(.1)
Steam Flow, Steam Flow Transmitter,						
6. 2A		(a) Fail open.	(a) No output.	(a) Fluctuation in level.	10.02	86
6. 2B		(b) Short to negative.	(b) Low output.	(b) Fluctuation in level.	9.64	86
6. 2C		(c) Short to positive.	(c) High output.	(c) Fluctuation in level.	9.64	86
Level Indicator						
6. 3A		(a) Internal failure.	(a) Loss of drum level gauge.	(a) No effect.		
Level Indicator Boiler Front						
6. 4A		(a) Internal failure.	(a) Loss of drum level gauge.	(a) No effect.		
Current to Voltage Converter Module I/E ND-A101GR (From Drum Level Transmitter)						
6. 5A	Input	(a) Open circuit.	(a) Low output.	(a) High drum level.	0.9436	34a(.9) 34b(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6. 5B	Input	(b) Short circuit.	(b) High output.	(b) Low drum level.	0.9436	35a(.6) 35b(.3) 35c(.1)
6. 6A	Reference Amplifier	(a) Short to negative or open.	(a) High output signal.	(a) Low drum level.	0.9436	35a(.6) 35b(.3) 35c(.1)
6. 6B	Reference Amplifier	(b) Short to positive.	(b) Decreased output signal.	(b) High drum level.	0.9436	34a(.9) 34b(.1)
6. 7A	First Stage	(a) Internal open.	(a) Decreased output.	(a) High drum level.	0.9436	34a(.9) 34b(.1)
6. 7B	First Stage	(b) Internal short to negative.	(b) Decreased output.	(b) High drum level.	0.9436	34a(.9) 34b(.1)
6. 8A	Driver	(a) Short to positive.	(a) Increased output.	(a) Low drum level.	0.9436	35a(.6) 35b(.3) 35c(.1)
Alarm Module EALM-C201GR PN C-310455-01 (to Modules Hi/Lo)						
6. 9A		(a) Internal short.	(a) False out of range signal.	(a) False alarm.	5.8850	83
6. 9B		(b) Internal open.	(b) No signal when out of range.	(b) No alarm output.	5.8850	84
Filter/Impulse (To Control) FIL/IMP-A101GR						
6.10A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
6.10B	Input Buffer	(b) Open/or short to negative.	(b) Minimum output signal.	(b) High level.	0.5763	34a(.9) 34b(.1)
6.10C	Inverter 1	(c) Short to positive.	(c) High output.	(c) Low level.	0.2470	35a(.6) 35b(.3) 35c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6.10D	Inverter 1	(d) Open/or short to positive.	(d) Loss of output signal.	(d) High level.	0.4807	34a(.9) 34b(.1)
6.10E	Inverter 1	(e) Short to negative.	(e) High output.	(e) Low level.	0.2588	35a(.6) 35b(.3) 35c(.1)
6.10F	Inverter 2	(f) Open/short to negative.	(f) Loss of output.	(f) High level.	0.5840	34a(.9) 34b(.1)
6.10G	Inverter 2	(g) Short to positive.	(g) High output.	(g) Low level.	0.3144	35a(.6) 35b(.3) 35c(.1)
	Filter/Impulse FIL/IMP-A101GR					
6.11A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
6.11B	Input Buffer	(b) Open/or short to negative.	(b) Minimum output signal.	(b) High level.	0.5763	34a(.9) 34b(.1)
6.11C	Inverter 1	(c) Short to positive.	(c) High output.	(c) Low level.	0.2470	35a(.6) 35b(.3) 35c(.1)
6.11D	Inverter 1	(d) Open/or short to positive.	(d) Loss of output signal.	(d) High level.	0.4807	34a(.9) 34b(.1)
6.11E	Inverter 1	(e) Short to negative.	(e) High output.	(e) Low level.	0.2588	35a(.6) 35b(.3)
6.11F	Inverter 2	(f) Open/short to negative.	(f) Loss of output.	(f) High level.	0.5840	34a(.9) 34b(.1)
6.11G	Inverter 2	(g) Short to positive.	(g) High output.	(g) Low level.	0.3144	35a(.6) 35b(.3) 35c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Control Module CNTRL-C101GR PN C-39282-006						
6.12A	Differential	(a) Internal open.	(a) No control--valve eventually closes.	(a) Low level.	0.3920	35a(.6) 35b(.3) 35c(.1)
6.12B	Differential	(b) Short to positive.	(b) Increased output.	(b) High level.	0.2940	34a(.9) 34b(.1)
6.12C	Differential	(c) Short to negative.	(c) Decreased output.	(c) Low level.	0.2940	35a(.6) 35b(.3) 35c(.1)
6.13A	Proportional Section	(a) Internal open.	(a) No control--valve eventually closes.	(a) Low level.	0.9165	35a(.6) 35b(.3) 35c(.1)
6.13B	Proportional Section	(b) Short to positive.	(b) Increased output.	(b) Level high.	0.6874	34a(.9) 34a(.1)
6.13C	Proportional Section	(c) Short to negative.	(c) Decreased output.	(c) Low level.	0.6874	35a(.6) 35b(.3) 35c(.1)
6.14A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Level variation--slight loss of control.	0.2966	
6.14B	Signal Inversion Section	(b) Short to negative.	(b) Increased output.	(b) Level high.	0.2225	34a(.9) 34b(.1)
6.14C	Signal Inversion Section	(c) Short to positive.	(c) Decreased output.	(c) Low level.	0.2225	35a(.6) 35b(.3) 35c(.1)
6.15A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Level oil variation, slight loss of control.	0.4170	
6.15B	Integral Gain Section	(b) Short to negative.	(b) Decreased output.	(b) Low level.	0.3127	35a(.6) 35b(.3) 35c(.1)
6.15C	Integral Gain Section	(c) Short to positive.	(c) Increased output.	(c) Increased level.	0.3127	34a(.9) 34b(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B | SUBSYSTEM: 6.0 DRUM LEVEL CONTROL One Per Boiler, Two Per Vessel | PAGE: 5

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6.16A	Integrator	(a) Relays fails to open.	(a) Transfer from manual to auto causes sytem upset.	(a) Temporary level variations.	0.4738	
6.16B	Integrator	(b) Relays fails to close.	(b) Loss of accurate control.	(b) Level variations, slight loss of control.	0.2030	
6.17C	Integrator	(c) Internal open or C3 short.	(c) Loss of accurate control.	(c) Temporary level variations.	0.2707	
6.17D	Integrator	(d) Open C3.	(d) Output decreases.	(d) Low level.	0.1354	35a(.6) 35b(.3) 35c(.1)
6.17E	Integrator	(e) Short to positive.	(e) Increased output.	(e) High level.	0.1354	34a(.9) 34b(.1)
6.17F	Integrator	(f) Short to negative.	(f) Decreased output.	(f) Low level.	0.1354	35a(.6) 35b(.3) 35c(.1)
6.18A	Summing Section	(a) Internal open.	(a) Decreased output.	(a) Low level.	3.3	35a(.6) 35b(.3) 35c(.1)
6.18B	Summing Section	(b) Short positive.	(b) Increased output.	(b) High level.	3.3	34a(.9) 34b(.1)
6.18C	Summing Section	(c) Short negative.	(c) Decreased output.	(c) Low level.	3.3	35a(.6) 35b(.3) 35c(.1)
6.19A	Output Limiting	(a) Internal open.	(a) No effect during normal operation.	(a) No effect--could possibly give a wide level variation in abnormal condition--less 0.5% of time.	1.3392	
6.19B	Output Limiting	(b) Internal short.	(b) High output.	(b) High level.	1.3392	34(.9) 34(.1)
Setpoint Module SEPT-A101GR C-22942-01-C						
6.20A		(a) Open--wiper on pos. lead/pot	(a) Decrease output.	(a) Decreased level.	0.6064	35a(.6) 35b(.3) 35c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

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REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6.20B		(b) Open--negative lead/pot	(b) Increase output.	(b) Increased level.	0.2021	34a(.9) 34b(.1)
6.20C		(c) Internal open.	(c) Decreased output.	(c) Decreased level.	0.8086	35a(.6) 35b(.3) 35c(.1)
6.20D		(d) Short to positive.	(d) Increased output.	(d) Increased level.	1.2130	34a(.9) 34b(.1)
6.20E		(e) Short to negative.	(d) Decreased output.	(e) Decreased level.	1.2130	35a(.6) 35b(.3) 35c(.1)
Current to Voltage Converter Module I/E MD-A101GR (From Steam Pressure Trans)						
6.21A	Input	(a) Open circuit.	(a) Low output.	(a) Fluctuations in level.	0.9436	86
6.21B	Input	(b) Short circuit.	(b) High output.	(b) Fluctuations in level.	0.9436	86
6.22A	Reference Amplifier	(a) Short to negative or open.	(a) High output signal.	(a) Fluctuations in level.	0.9436	86
6.22B	Reference Amplifier	(b) Short to positive.	(b) Decreased output signal.	(b) Fluctuations in level.	0.9436	86
6.23A	First Stage	(a) Internal open.	(a) Decreased output.	(a) Fluctuations in level.	0.9436	86
6.23B	First Stage	(b) Internal short to negative.	(b) Decreased output.	(f) Fluctuations in level.	0.9436	86
6.24A	Driver	(a) Short to positive.	(a) Increased output.	(a) Fluctuations in level.	0.9436	86
Filter/Impulse (To Control) FIL/IMP-A101GR						
6.25A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1735	

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6.25B	Input Buffer	(b) Open/or short to negative.	(b) Minimum output signal.	(b) High level.	0.5763	34a(.9) 34b(.1)
6.25C	Inverter 1	(c) Short to positive.	(c) High output.	(c) Low level.	0.2470	35a(.6) 35b(.3) 35c(.1)
6.25D	Inverter 1	(d) Open/or short to positive.	(d) Loss of output signal.	(d) High level.	0.4807	34a(.9) 34b(.1)
6.25E	Inverter 1	(e) Short to negative.	(e) High output.	(e) Low level.	0.2588	35a(.6) 33b(.3) 35c(.1)
6.25F	Inverter 2	(f) Open/short to negative.	(f) Loss of output.	(f) High level.	0.5840	34a(.9) 34b(.1)
6.25G	Inverter 2	(g) Short to positive.	(g) High output.	(g) Low level.	0.3144	35a(.6) 35b(.3) 35c(.1)
Square Root--Module SQRT-B101GR PNC-31563-01GR						
6.26A	Clock	(a) Internal circuit failure.	(a) Locked output.	(a) Possible high or low water during maneuvering.	0.6607	86
6.27A	Reference Amp	(a) Internal circuit failure.	(a) High or low output.	(a) Possible high or low.	1.8783	86
6.28A	D to A Converter	(a) Internal short.	(a) Max. output signaled zero.	(a) Temporary high or low during maneuvering.	7.3794	
6.29A	Counter	(a) Internal failure.	(a) Min. or error output signal.	(a) Minor water level problem.	3.4773	
6.30A	Buffer	(a) Open.	(a) Zero output.	(a) Possible high or low water during maneuvering.	1.2377	86
6.30B	Buffer	(b) Short to negative.	(b) Zero output.	(b) Possible high or low water during maneuvering.	0.9282	86
6.30C	Buffer	(c) Short to positive.	(c) High signal.	(c) High water.	0.9282	

SHIP: SHIP B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
	Adjustable Reference ADJ-REF-A-101CR					
6.31A	Reference Amplifier	(a) Open.	(a) Loss of output signal.	(a) Fluctuations in level.	0.3293	86
6.31B	Reference Amplifier	(b) Short to negative.	(b) Increased output.	(b) Fluctuations in level.	0.2470	86
6.31C	Reference Amplifier	(c) Short to positive.	(c) Loss of output signal.	(c) Fluctuations in level.	0.2470	86
6.32A	Output Amplifier	(a) Open/or short to negative.	(a) Loss of output signal.	(a) Fluctuations in level.	0.4957	86
6.32B	Output Amplifier	(b) Short to positive.	(b) Increased output.	(b) Fluctuations in level.	0.2124	86
	Manual/Auto Module M/A-A101GR PN31918-01-H					
6.32A	Output Buffer (Auto or Manual)	(a) Open.	(a) Decreased output.	(a) Decreased level.	0.3094	35a(.6) 35b(.3) 35c(.1)
6.32B	Output Buffer (Auto or Manual)	(b) Short to negative.	(b) Decreased output.	(b) Decreased level.	0.2320	35a(.6) 35b(.3) 35c(.1)
6.32C	Output Buffer (Auto or Manual)	(c) Short to positive.	(c) Increased output.	(c) Increase level.	0.2320	35a(.6) 35b(.3) 35c(.1)
6.33A	D to A Converter (Auto Mode)	(a) Internal failure.	(a) Small output offset.	(a) Small output offset.	4.8565	
6.34A	Comparators (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Loss of control in auto.	0.43615	86
6.34B	Comparators (Auto Mode)	(b) Short to positive.	(b) Output increased.	(b) High level.	0.43615	
6.35A	Auto Clock Circuit (Auto Mode)	(a) Internal failure.	(a) In auto mode locks in present point.	(a) Loss of control in auto.	0.2806	86

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Ship 8

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

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REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6.36A	Output Inverter (Manual)	(a) Internal failure.	(a) Temporary process upset.	(a) Temporary instability of level.	0.7162	
6.37A	Manual Clock Circuit	(a) Internal failure.	(a) No change in output, sets at current point.	(a) Loss of control in manual.	0.2806	83
6.38A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Maintains auto control.	0.0657	86
6.38B	Control Logic (Manual)	(b) Internal failure.	(b) No increase of output signal.	(b) Low level.	0.0657	35a(.6) 35b(.3) 35c(.1)
6.38C	Control Logic (Manual)	(c) Internal failure.	(c) No decrease of output signal.	(c) High level.	0.0657	34a(.9) 34b(.1)
6.38D	Control Logic (Manual)	(d) Internal failure.	(d) Increased output to maximum.	(d) High level.	0.0657	34a(.9) 34b(.1)
6.38E	Control Logic (Manual)	(e) Internal failure.	(e) Decrease output to minimum.	(e) Low level.	0.0657	35a(.6) 35b(.3) 35c(.1)
6.39A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Able to use manual but not auto.	0.1771	86
6.39B	Control Logic (Auto)	(b) Internal failure.	(b) No increase of output signal.	(b) Low level.	0.1771	35a(.6) 35b(.3) 35c(.1)
6.39C	Control Logic (Auto)	(c) Internal failure.	(c) No decrease of output signal.	(c) High level.	0.1771	34a(.9) 34b(.1)
6.39D	Control Logic (Auto)	(d) Internal failure.	(d) Increases to maximum.	(d) High level.	0.1771	34a(.9) 34b(.1)
6.39E	Control Logic (Auto)	(e) Internal failure.	(e) Decreases to minimum.	(e) Low level.	0.1771	35a(.6) 35b(.3) 35c(.1)
6.40A	Impulse	(a) Short to positive.	(a) High output.	(a) Fluctuations in level.	0.1771	86
6.40B	Impulse	(b) Short to negative.	(b) Low output.	(b) Fluctuations in level.	0.1771	86

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Ship B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Current to Voltage Converter Module E/I-B101GR PN 301236-01-B						
6.41A	All, except Reference Amp	(a) Internal open.	(a) No output signal.	(a) Low level.	1.7006	35a(.6) 35b(.3) 35c(.1)
6.41B	All, except Reference Amp	(b) Short transistor or IC to positive.	(b) Maximum output signal.	(b) High level.	1.7008	34a(.9) 34b(.1)
6.41C	All, except Reference Amp	(c) IC short to negative.	(c) Minimum output signal.	(c) Low level.	1.7008	35a(.6) 35b(.3) 35c(.1)
6.42A	Reference Amplifier	(a) Internal failure open.	(a) Loss of precision of control.	(a) Temporary low level.	0.2783	
6.42B	Reference Amplifier	(b) Internal short to positive.	(b) Output high.	(b) High level.	0.2733	34a(.9) 34b(.1)
6.42C	Reference Amplifier	(c) Internal short to negative.	(c) Low output.	(c) Low level.	0.2783	35a(.6) 35b(.3) 35c(.1)
Feedwater Control Valve						
6.43A		(a) Binds/stuck.	(a) Open.	(a) High level.	30.62	34a(.9) 34b(.1)
6.43B		(b) Binds/stuck.	(b) Closed.	(b) Low level.	30.24	35a(.6) 35b(.3) 35c(.1)
Filter/Impulse FIL/IMP-A101GR						
6.44A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
6.45A	Input Buffer	(a) Open/or short to negative.	(a) Minimum output signal.	(a) High level.	0.5763	34a(.9) 34b(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Ship B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
6.46A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Low level.	0.7470	35a(.6) 35b(.3) 35c(.1)
6.46B	Inverter 1	(b) Open/or short to positive.	(b) Loss of output signal.	(b) High level.	0.4807	34a(.9) 34b(.1)
6.46C	Inverter 1	(c) Short to negative.	(c) High output.	(c) Low level.	0.2588	35a(.6) 35b(.3) 35c(.1)
6.47A	Inverter 2	(a) Open/short to negative.	(a) Loss of output.	(a) High level.	0.5840	34a(.9) 34b(.1)
6.47B	Inverter 2	(b) Short to positive.	(b) High output.	(b) Low level.	0.3144	35a(.6) 35b(.3) 35c(.1)
Filter/Impulse FIL/IMP-A101GR						
6.48A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
6.49A	Input Buffer	(a) Open/or short to negative.	(a) Minimum output signal.	(a) High level.	0.5763	34a(.9) 34b(.1)
6.50A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Low level.	0.2470	35a(.6) 35b(.3) 35c(.1)
6.50B	Inverter 1	(b) Open/or short to positive.	(b) Loss of output signal.	(b) High level.	0.4807	34a(.9) 34b(.1)
6.50C	Inverter 1	(c) Short to negative.	(c) High output.	(c) Low level.	0.2588	35a(.6) 35b(.3) 35c(.1)
6.51A	Inverter 2	(a) Open/short to negative.	(a) Loss of output.	(a) High level.	0.5840	34a(.9) 34b(.1)
6.51B	Inverter 2	(b) Short to positive.	(b) High output.	(b) Low level.	0.3144	35a(.6) 35b(.3) 35c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: Ship B

SUBSYSTEM: 6.0 DRUM LEVEL CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
	Filter/Impulse FIL/IMP-A101GR					
6.52A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
6.53A	Input Buffer	(a) Open/or short to negative.	(a) Minimum output signal.	(a) High level.	0.5763	34a(.9) 34b(.1)
6.54A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Low level.	0.2470	35a(.6) 35b(.3) 35c(.1)
6.54B	Inverter 1	(b) Open/or short to positive.	(b) Loss of output signal.	(b) High level.	0.4807	34a(.9) 34b(.1)
6.54C	Inverter 1	(c) Short to negative.	(c) High output.	(c) Low level.	0.2588	35a(.6) 35b(.3) 35c(.1)
6.55A	Inverter 2	(a) Open/short to negative.	(a) Loss of output.	(a) High level.	0.5840	34a(.9) 34b(.1)
6.55B	Inverter 2	(b) Short to positive.	(b) High output.	(b) Low level.	0.3144	35a(.6) 35b(.3) 35c(.1)
	Filter/Impulse FIL/IMP-A101GR					
6.56A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
6.57A	Input Buffer	(a) Open/or short to negative.	(a) Minimum output signal.	(a) High level.	0.5763	34a(.9) 34b(.1)
6.58A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Low level.	0.2470	35a(.6) 35b(.3) 35c(.1)
6.58B	Inverter 1	(b) Open/or short to positive.	(b) Loss of output signal.	(b) High level.	0.4807	34a(.9) 34b(.1)
6.58C	Inverter 1	(c) Short to negative.	(c) High output.	(c) Low level.	0.2588	35a(.6) 35b(.3) 35c(.1)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Feedwater Hdr. Press Trans. Mafg.-Rosemount PN1144-C-2000A-12						
7. 1A		(a) Fails open.	(a) No signal.	(a) High pressure.	6.51	85
7. 1B		(b) Short to negative.	(b) Low output.	(b) High pressure.	6.13	85
7. 1C		(c) Short to positive.	(c) High output.	(c) Low pressure.	6.13	32
Current to Voltage Converter Module I/E ND-A101GR (From Feedpump Press. XMTR)						
7. 2A	Input	(a) Open circuit.	(a) Low output.	(a) High pressure.	0.9436	85
7. 2B		(b) Short circuit.	(b) High output.	(b) Low pressure.	0.9436	32
7. 3A	Reference Amplifier	(a) Short to negative or open.	(a) High output signal.	(a) Low pressure.	0.9436	32
7. 3B		(b) Short to positive.	(b) Decreased output signal.	(b) High pressure.	0.9436	85
7. 4A	First Stage	(a) Internal open.	(a) Decreased output.	(a) High pressure.	0.9436	85
7. 4B		(b) Internal short to negative.	(b) Decreased output.	(b) High pressure.	0.9436	85
7. 5A	Driver	(a) Short to positive.	(a) Increased output.	(a) Low pressure.	0.9436	32
Filter/Impulse FIL/IMP-A101GR From Drum Press. XMTR						
7. 6A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
7. 6B	Input Buffer	(b) Open/or short to negative.	(b) Minimum output signal.	(b) Low pressure.	0.5763	32

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 7.0 FEEDPUMP CONTROL
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
7. 6C	Inverter 1	(c) Short to positive.	(c) High output.	(c) High pressure.	0.2470	85
7. 6D		(d) Open/or short to positive.	(d) Loss of output signal.	(d) Low pressure.	0.4807	32
7. 6E		(e) Short to negative.	(e) High output.	(e) High pressure.	0.2588	85
7. 6F	Inverter 2	(f) Open/short to negative.	(f) Loss of output signal.	(f) Low pressure.	0.5840	32
7. 6G		(g) Short to positive.	(g) High output.	(g) High pressure.	0.3144	85
7. 7A	Pressure Indicator PI 353	(a) Internal fail-	(a) Loss of pressure.	(a) No effect.		
Drum Pressure Trans. Mafg.-Rosemount PN1144-G-1200A-12						
7. 8A		(a) Fails open.	(a) Loss of signal.	(a) Other Boiler signal used,	6.51	87
7. 8B		(b) Short to negative.	(b) Low output.	(b) Other Boiler signal used, pressure variations.	6.13	87
7. 8C		(c) Short to positive.	(c) High output.	(c) Low pressure.	6.13	32
Current to Voltage Converter Module I/E ND-A101GR (2 Modules from Drum Press. XMTR)						
7. 9A	Input	(a) Open circuit.	(a) Low output.	(a) Selects other Boiler, pressure, varies.	0.9436	87
7. 9B		(b) Short circuit.	(b) High output.	(b) Low pressure.	0.9436	32
7.10A	Reference Amplifier.	(a) Short to negative.	(a) High output signal.	(a) Low pressure.	0.9436	32
7.10B		(b) Short to positive.	(b) Decreased output signal.	(b) Selects other Boiler, pressure varies.	0.9436	87

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 7.0 FEEDPUMP CONTROL One Per Vessel | PAGE: 3

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
7.11A	First Stage	(a) Internal open.	(a) Decreased output.	(a) Selects other Boiler, pressure varies.	0.9436	87
7.11B		(b) Internal short to negative.	(b) Decreased output.	(b) Selects other Boiler, pressure varies	0.9436	87
7.11C	Driver	(c) Short to positive.	(c) Increased output.	(c) Low pressure.	0.9436	32
Filter/Impulse FIL/IMP-A101GR						
7.12A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
7.13A	Input Buffer	(a) Open/or short to negative.	(a) Minimum output signal.	(a) High pressure.	0.5763	85
7.14A	Inverter 1	(a) Short to posi-	(a) High output.	(a) Low pressure.	0.2470	32
7.14B		(b) Open/or short to positive.	(b) Loss of output signal.	(b) High pressure.	0.4807	85
7.14C		(c) Short to negative.	(c) High output.	(c) Low pressure.	0.2588	32
7.15A	Inverter 2	(a) Open/short to negative.	(a) Loss of output signal.	(a) High pressure.	0.5840	85
7.15B		(b) Short to positive.	(b) High output.	(b) Low pressure.	0.3144	32
High Signal Selector Module HI/LO-A101GR PN22936-01-8						
7.16A	Input Buffer	(a) Short to positive.	(a) High output.	(a) High pressure.	1.3131	85
7.16A		(b) Short to negative.	(b) Slight output variation.	(b) Slight pressure variation.	1.3131	
7.16C		(c) Fails open.	(c) Slight output variation.	(c) Slight pressure variation.	1.3131	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 7.0 FEEDPUMP CONTROL
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
7.17A	Output Buffer	(a) Short to positive.	(a) High output.	(a) High pressure.	1.3131	85
7.17B		(b) Short to negative.	(b) Zero output.	(b) Low pressure.	1.3131	32
7.17C		(c) Open.	(c) Zero output.	(c) Low pressure.	1.3131	32
Add/Subtract ADD/SUB-B101GR PNC-38135-01-B						
7.18A	All	(a) Fails open.	(a) Zero output.	(a) Low pressure.	1.6825	32
7.18B		(b) Short to negative.	(b) Zero output.	(b) Low pressure.	1.2619	32
7.18C		(c) Short to positive.	(c) High output.	(c) Maximum pressure.	1.2619	
Controller Module CNTRL-C101GR PNC-39282-00G (2 Modules, Aft. and Fwd. Pumps)						
7.20A	Differential	(a) Internal open.	(a) No control, valve eventually closes.	(a) Low pressure.	0.3920	32
7.20B		(b) Short to positive.	(b) Increased output.	(b) High pressure.	0.2940	85
7.20C		(c) Short to negative.	(c) Decreased output.	(c) Low pressure.	0.2940	32
7.21A	Proportional Section	(a) Internal open.	(a) No control, valve eventually closes.	(a) Low pressure.	0.9165	32
7.21B		(b) Short to positive.	(b) Increased output.	(b) Pressure high.	0.6874	85
7.21C		(c) Short to negative.	(c) Decreased output.	(c) Low pressure.	0.6974	32
7.22A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Pressure variation, slight loss of control.	0.2966	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 7.0 FEEDPUMP CONTROL
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
7.22B		(b) Short to negative.	(b) Increased outout.	(b) Pressure high.	0.2225	85
7.22C		(c) Short to positive.	(c) Decreased output.	(c) Low pressure.	0.2225	32
7.23A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Pressure variation, slight loss of control.	0.4170	
7.23B		(b) Short to negative.	(b) Decreased output.	(b) Low pressure.	0.3127	32
7.23C		(c) Short to positive.	(c) Increased output.	(c) Increased pressure.	0.3127	
7.24A	Integrator	(a) Fails to open relay.	(a) Transfer from manual to auto causes system upset.	(a) Temporary pressure variations.	0.4738	
7.24B		(b) Fails to close relay.	(b) Loss of accurate control.	(b) Pressure variations, slight loss of control.	0.2030	
7.24C		(c) Internal open or C3 short.	(c) Loss of accurate control.	(c) Temporary pressure variations.	0.2707	
7.24D		(d) Open C3.	(d) Output decreased.	(d) Low pressure.	0.1354	32
7.24E		(e) Short to positive.	(e) Increased output.	(e) High pressure.	0.1354	85
7.24F		(f) Short to negative.	(f) Decreased output.	(f) Low pressure.	0.1354	32
7.25A	Output Limiting	(a) Internal open.	(a) No effect during normal operations.	(a) No effect, could possibly give a wide temperature variation in abnormal condition, less than 0.5% of time.	1.3392	
7.25B		(b) Internal short.	(b) High output.	(b) High pressure.	1.3392	85
Man/Auto Module M/A-A101GR PN 31918-01-H (2 Modules Fwd. and Aft.)						
7.26A	Output Buffer (Auto or Manual)	(a) Open.	(a) Decreased Output.	(a) Decreased pressure.	0.30936	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 7.0 FEEDPUMP CONTROL
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
7.26B		(b) Short to negative	(b) Decreased output.	(b) Decreased pressure.	0.2320	
7.26C		(c) Short to positive.	(c) Increased output.	(c) Increased pressure.	0.2320	
7.27A	D to A Converter (Auto Mode)	(a) Internal failure.	(a) Minor output fluctuation.	(a) Small output offset.	4.8565	
7.28A	Comparators (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Loss of control in auto.	0.8723	87
7.29A	Auto Clock Circuit (Auto Mode)	(a) Internal failure.	(a) In auto mode locks in present point.	(a) Loss of control in auto.	0.2806	87
7.30A	Output Inverter	(a) Internal failure.	(a) Temporary process.	(a) Temporary instability of pressure.	0.2806	
7.31A	Manual Clock Circuit	(a) Internal failure.	(a) No change in output, sets at current point.	(a) Loss of control in manual.	0.2806	82
7.32A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Maintains auto control.	0.0657	82
7.32B		(b) Internal failure.	(b) No increase of output signal.	(b) Low pressure.	0.0657	32
7.32C		(c) Internal failure.	(c) No decrease of output signal.	(c) High pressure.	0.0657	85
7.32D		(d) Internal failure.	(d) Increased output to maximum.	(d) High pressure.	0.0657	85
7.32E		(e) Internal failure.	(e) Decreased output to minimum.	(e) Low pressure.	0.0657	32
7.33A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Able to use manual but not auto.	0.1771	87
7.33B		(b) Internal failure.	(b) No increase of output signal.	(b) Low pressure.	0.1771	32
7.33C		(c) Internal failure.	(c) No decrease of output signal.	(c) High pressure.	0.1771	85

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 7.0 FEEDPUMP CONTROL One Per Vessel |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
7.33D		(d) Internal failure.	(d) Increases to maximum.	(d) High pressure.	0.1771	85
7.33E		(e) Internal failure.	(e) Decreases to minimum.	(e) Low pressure.	0.1771	32
Voltage to Current Converter Module E/I-B101GR PN-301236-01-B						
7.34A	All, Except Reference Amplifier	(a) Internal open.	(a) No output signal.	(a) Low pressure.	1.7008	32
7.34B		(b) Short transistor or IC to positive.	(b) Maximum output signal.	(b) High presure.	1.7008	85
7.34C		(c) IC short to negative.	(c) Minimum output signal.	(c) Low pressure.	1.7008	32
7.35A	Reference Amplifier	(a) Internal failure.	(a) Loss of precision of control.	(a) Temporary low pressure.	0.2783	
7.35B		(b) Internal short to positive.	(b) Output high.	(b) High pressure.	0.2783	85
7.35C		(c) Internal short to negative.	(c) Low output.	(c) Low pressure.	0.2783	32
7.36A	Feedpump Control I/P (2 Fwd. and Aft.)	(a) High output.	(a)	(a) High pressure.	1.46	85
7.36B		(b) Low output or open to field.	(b)	(b) Low pressure.	1.84	32

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 8.0 FEEDWATER RECIRCULATION VALVE CONTROL
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
	Feedwater Flow Transmitter Mafg.-Rosemount PN1151-DP-4-E-12LM					
8. 1A		(a) Fails open.	(a) No signal.	(a) Valve opens.	10.02	27
8. 1B		(b) Short to negative.	(b) Low signal.	(b) Valve opens.	9.64	27
8. 1C		(c) Short to positive.	(c) High signal.	(c) Valve closes.	9.64	28
	Current to Voltage Converter I/END-A101GR					
8. 2A	Input	(a) Open circuit.	(a) Low output.	(a) Valve closes.	0.9436	28
8. 2B		(b) Short circuit.	(b) High output.	(b) Valve opens.	0.9436	27
8. 3A	Reference Amplifier	(a) Short to negative or open.	(a) High output signal.	(a) Valve opens.	0.9436	27
8. 3B		(b) Short to positive.	(b) Decreased output signal.	(b) Valve closes.	0.9436	28
8. 4A	First Stage	(a) Internal open.	(a) Decreased output.	(a) Valve closes.	0.9436	28
8. 4B		(b) Internal short to negative.	(b) Decreased output.	(b) Valve closes.	0.9436	28
8. 5A	Driver	(a) Short to posi-	(a) Increased output.	(a) Valve opens.	0.9436	27
	Voltage Comparator Alarm EALM-C201GR					
8. 6A		(a) Internal short.	(a) False out of range signal.	(a) False alarm.	5.8850	83
8. 6B		(b) Internal open.	(b) No signal when out of range.	(b) Loss of alarm.	5.8850	84
8. 7A	Feedpump Recirc. Valve	(a) Contamination, damaged seat or worn seat.	(a) Internal leaking or fails to seat.	(a) Valve opens or cannot completely close.	16.38	27
8. 7B		(b) Pneumatic operator fails.	(b) Fails to open.	(b) Valve closed or cannot open.	16.38	28

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 9.0 SUPERHEATER STEAM TEMPERATURE CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Windbox/Air Flow Transmitter.						
9. 1A		(a) Fails open.	(a) Loss of output signal.	(a) Low temperature.	10.02	60
9. 1B		(b) Short to negative.	(b) Low output.	(b) Low temperature.	9.64	60
9. 1C		(c) Short to positive.	(c) High output.	(c) High temperature.	9.64	61
Current to Voltage I/END-A101GR						
9. 2A	Input	(a) Open circuit.	(a) Low output.	(a) Low temperature.	1.7008	60
9. 2B		(b) Short circuit.	(b) High output.	(b) High temperature.	1.7008	61
9. 3A	Reference Amplifier	(a) Short to negative or open.	(a) High output signal.	(a) High temperature.	1.7008	61
9. 4A	First Stage	(a) Internal open.	(a) Decreased output.	(a) Low temperature.	0.2783	60
9. 4B		(b) Internal short to negative.	(b) Decreased output.	(b) Low temperature.	0.2783	60
9. 5A	Driver	(a) Short to positive.	(a) Increased output.	(a) High temperature.	0.2783	61
Filter FIL1/IMP-A101GR						
9. 6A	Resistance Ladder Input Buffer	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
9. 6B		(b) Open/or short to negative.	(b) Minimum output signal.	(b) Small effect.	0.5763	
9. 7A	Inverter 1	(a) Short to positive.	(a) High output.	(a) High temperature.	0.2470	61
9. 7B		(b) Open/or short to positive.	(b) Loss of output signal.	(b) Low temperature.	0.4807	60
9. 7C		(c) Short to negative.	(c) High output.	(c) High temperature.	0.2588	61

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
9. 8A	Inverter 2	(a) Open/short to negative.	(a) Loss of output signal.	(a) Low temperature.	0.5840	60
9. 8B		(b) Short to positive.	(b) High output.	(b) High temperature.	0.3144	61
Square Root SQRT-8101GR						
9. 9A	Clock	(a) Internal circuit failure.	(a) Locked output.	(a) Loss of control.	0.6607	88
9.10A	Reference Amplifier	(a) Internal circuit failure.	(a) High or low output.	(a) High or low temperature.	1.8783	88
9.11A	D to A Converter	(a) Internal short	(a) Maximum output signal or zero.	(a) Low temperature.	7.3794	60
9.12A	Counter	(a) Internal failure.	(a) Minor error in output signal.	(a) Minor temperature variation.	3.47733	
9.13A	Buffer	(a) Open.	(a) Zero output.	(a) Low temperature.	1.0314	60
9.13B		(b) Short to negative.	(b) Zero output.	(b) Low temperature.	1.0314	60
9.13C		(c) Short to positive.	(c) High signal.	(c) High temperature.	1.0314	61
Alarm BALM-C201GR						
9.14A	All (2 Modules Hi/Lo)	(a) Internal short.	(a) False out of range signal.	(a) False hi/lo alarm.	5.885	83
9.14B		(b) Internal open.	(b) No signal when out of range.	(b) Loss of hi/lo alarm.	5.885	84
Add/Subtract ADD/SUB-8101GR						
9.15A	All	(a) Fails open.	(a) Zero output.	(a) High temperature temporary.	1.6825	61
9.15B		(b) Short to negative.	(b) Zero output.	(b) High temperature temporary.	1.2619	61

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 9.0 SUPERHEATER STEAM TEMPERATURE CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
9.15C		(c) Short to positive.	(c) High output.	(c) Low temperature.	1.2619	60
High Signal Selector HI/LO-A101GR						
9.16A	Input Buffer	(a) Short to positive.	(a) High output.	(a) Low temperature.	1.3131	60
9.16B		(b) Short to negative.	(b) Slight output variation.	(b) Slight temperature variation.	1.3131	
9.16C		(c) Fails open.	(c) Slight output variation.	(c) Slight temperature variation.	1.3131	
9.17A	Output Buffer	(a) Short to positive.	(a) High output.	(a) Low temperature.	1.3131	60
9.17B		(b) Short to negative.	(b) Zero output.	(b) High temperature.	1.3131	61
9.17C		(c) Open.	(c) Zero output.	(c) High temperature.	1.3131	61
Adjustable Reference ADJ REF-A101GR						
9.18A	Reference Amplifier	(a) Open.	(a) Loss of output signal.	(a) High temperature.	0.3293	61
9.18B		(b) Short to negative.	(b) Increased output.	(b) Low temperature.	0.2470	60
9.18C		(c) Short to positive.	(c) Decreased output.	(c) High temperature.	0.2470	61
9.19A	Output Amplifier	(a) Open or short to negative.	(a) Loss of output signal.	(a) Low temperature.	0.4957	60
9.19B		(b) Short to positive.	(b) Increased output.	(b) High temperature.	0.2124	61
9.20A	Superheat Temp. RTD	(a) Open, primary leads.	(a) No output.	(a) High temperature and loss of HI alarm.	1.46	61, 84
9.20B		(b) Open, reference lead.	(b) Slight output variation.	(b) Temperature slightly high.	1.08	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 9.0 SUPERHEATER STEAM TEMPERATURE CONTROL
One Per Boiler, Two Per Vessel

PAGE: 4

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
9.20C		(c) Short to positive.	(c) High output.	(c) Temperature low.	1.08	60
9.21A	PRTD-A201GR All	(a) Short to negative.	(a) Low signal--closes valve.	(a) High temp., no HI alarm.	2.2208	61, 84
9.21B		(b) Open.	(b) System signal out of controller high.	(b) Low temperature.	5.5076	60
9.21C		(c) Oscillates.	(c) Output signal varies.	(c) Temperature variation.	1.1548	88
Controller CNTRL-C101GR						
9.22A	Differential	(a) Internal open.	(a) No control, valve eventually opens.	(a) Low temperature.	0.3920	60
9.22B		(b) Short to positive.	(b) Increased output.	(b) Low temperature.	0.2940	60
9.22C		(c) Short to negative.	(c) Increased output.	(c) Low temperature.	0.2940	60
9.23A	Proporational Section	(a) Internal open.	(a) No control, valve eventually opens.	(a) Low temperature.	0.9165	60
9.23B		(b) Short to positive.	(b) Increased output.	(b) Low temperature.	0.6874	60
9.23C		(c) Short to negative.	(c) Decreased Output.	(c) High temperature.	0.6874	61
9.24A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Temperature varies.	0.2966	88
9.24B		(b) Short to negative.	(b) Increased output.	(b) Low temperature.	0.2225	60
9.24C		(c) Short to positive.	(c) Decreased output.	(c) High temperature.	0.2225	61
9.25A	Integral Gain	(a) Internal open.	(a) Loss of accurate control.	(a) Temperature varies.	0.4170	88
9.25B		(b) Short to negative.	(b) Decreased output.	(b) Temperature varies.	0.3127	88

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 9.0 SUPERHEATER STEAM TEMPERATURE CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
9.25C		(c) Short to positive.	(c) Increased output.	(c) Low temperature.	0.3127	60
9.26A	Integrator	(a) Relay fails to open.	(a) Transfer from manual to auto causes system upset.	(a) Temperature variation.	0.4738	88
9.26B		(b) Relay fails to close.	(b) Loss of accurate control.	(b) Temperature variation.	0.2030	88
9.26C		(c) Internal open or C3 short.	(c) Loss of accurate control.	(c) Temperature variation.	0.2707	88
9.26D		(d) Open C3.	(d) Output decreased.	(d) High temperature.	0.1354	61
9.26E		(e) Short to positive.	(e) Increased output.	(e) Low temperature.	0.1354	60
9.26F		(f) Short to negative.	(f) Decreased output.	(f) High temperature.	0.1354	61
9.27A	Summing Section	(a) Internal open.	(a) Decreased output.	(a) High temperature.	0.30	61
9.27B		(b) Short to positive.	(b) Increased output.	(b) Low temperature.	0.30	60
9.27C		(c) Short to negative.	(c) Decreased output.	(c) High temperature.	0.30	61
9.27D	Output Limiting	(d) Internal open.	(d) No effect during normal operation.	(d) No effect.	1.3392	
9.27E		(e) Internal short.	(e) High output.	(e) Low temperature.	1.3392	60
Man/Auto M/A-A101GR						
9.28A	Output Buffer (Auto or Manual)	(a) Open.	(a) Decreased output.	(a) High temperature.	0.30936	61
9.28B		(b) Short to negative.	(b) Decreased output.	(b) High temperature.	0.2320	61
9.28C		(c) Short to positive.	(c) Increased output.	(c) Low temperature.	0.2320	60

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 9.0 SUPERHEATER STEAM TEMPERATURE CONTROL
One Per Boiler, Two Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
9.29A	D to A Converter (Auto Mode)	(a) Internal failure.	(a) Minor output fluctuation.	(a) Temperature varies.	4.8565	88
9.30A	Comparator (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Temperature high or low, loss of control.	0.4362	88
9.30B		(b) Short to positive.	(b) Output increased.	(b) Low temperature.	0.4362	60
9.31A	Auto Clock Circuit (Auto Mode)	(a) Internal failure.	(a) In auto mode locks in present point.	(a) Temperature high or low, loss of control.	0.2806	88
9.32A	Output Inverter (Manual)	(a) Internal failure.	(a) Temporary process upset.	(a) Loss of control.	0.7162	88
9.33A	Manual Clock Circuit	(a) Internal failure.	(a) No change in output, sets at current point.	(a) Loss of control.	0.2806	88
9.34A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Loss of manual control.	0.0657	82
9.34B		(b) Internal failure.	(b) No increase of output signal.	(b) Low temperature.	0.0657	60
9.34C		(c) Internal failure.	(c) No decrease of output signal.	(c) Low temperature.	0.0657	60
9.34D		(d) Internal failure.	(d) Increased output to maximum.	(d) Low temperature.	0.0657	60
9.34E		(e) Internal failure.	(e) Decrease output to minimum.	(e) High temperature.	0.0657	61
9.35A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Loss of auto control.	0.1771	88
9.35B		(b) Internal failure.	(b) No increase of output signal.	(b) High temperature.	0.1771	61
9.35C		(c) Internal failure.	(c) No decrease of output signal.	(c) Low temperature.	0.1771	60
9.35D		(d) Internal failure.	(d) Increases to maximum.	(d) Low temperature.	0.1771	60

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP 3 SUBSYSTEM: 9.0 SUPERHEATER STEAM TEMPERATURE CONTROL One Per Boiler, Two Per Vessel PAGE: 7

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
9.35E		(e) Internal failure.	(e) Decreases to minimum.	(e) High temperature.	0.1771	61
Voltage to Current Converter E/I-B101GR						
9.40A	All, Except Reference Amp	(a) Internal open.	(a) No output signal.	(a) High temperature.	1.7008	61
9.40B		(b) Short transistor or IC to positive.	(b) Maximum output signal.	(b) Low temperature.	1.7008	60
9.40C		(c) IC short to negative.	(c) Minimum output signal.	(c) High temperature.	1.7008	61
9.41A	Reference Amplifier	(a) Internal failure open.	(a) Loss of precision of control.	(a) Temperature varies.	0.2783	88
9.41B		(b) Internal short to positive.	(b) Output high.	(b) Low temperature.	0.2783	60
9.41C		(c) Internal short to negative.	(c) Low output.	(c) High temperature.	0.2783	61
9.42A	Superheat Temp. Control Valve	(a) Contamination, damaged seat, or worn seat.	(a) Open, internal leaking or fails to seat.	(a) Low temperature, valve opened or cannot close.	16.38	60
9.42B		(b) Pneumatic operator fails.	(b) Fails open.	(b) Low temperature.	16.38	60

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B — SUBSYSTEM: 10.0 STEAM DUMP CONTROL, One Per Vessel —

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
10. 1A	Steam Pressure		(a) Output high.	(a) Low steam.	0.50	90
			(b) Output low.	(b) Fails to dump.	0.50	89
	Adjustable Reference ADJ REF-A101GR					
10. 2A	Reference Amplifier	(a) Open.	(a) Loss of output signal.	(a) Low steam pressure.	0.3293	90
10. 2B		(b) Short to negative.	(b) Increased output.	(b) High steam pressure.	0.2470	89
10. 2C		(c) Short to positive.	(c) Decreased output.	(c) Low steam pressure.	0.2470	90
10. 3A	Output Amplifier	(a) Open/or short to negative.	(a) Loss of output signal.	(a) Low steam pressure.	0.2470	90
10. 3B		(b) Short to positive.	(b) Increased output.	(b) High steam pressure.	0.2124	89
	Control Module CNTRL-C101GR PNC-39282-00G					
10. 4A	Differential	(a) Internal open.	(a) No control.	(a) Loss of control.	0.3920	91
10. 4B		(b) Short to positive.	(b) Increased output.	(b) Low pressure.	0.2940	90
10. 4C		(c) Short to negative.	(c) Decreased output.	(c) High pressure.	0.2940	89
10. 5A	Proportional Section	(a) Internal open.	(a) No control, valve eventually closes.	(a) Loss of control.	0.9165	91
10. 5B		(b) Short to positive.	(b) Increased output.	(b) Low pressure.	0.6874	90
10. 5C		(c) Short to negative.	(c) Decreased output.	(c) High pressure.	0.6874	89
10. 6A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Loss of control.	0.2966	91

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 10.0 STEAM DUMP CONTROL
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
10. 6B		(b) Short to negative.	(b) Increased output.	(b) Low pressure.	0.2225	90
10. 6C		(c) Short to positive.	(c) Decreased output.	(c) High pressure.	0.2225	89
10. 7A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Loss of control.	0.4170	91
10. 7B		(b) Short to negative.	(b) Decreased output.	(b) High pressure.	0.3127	89
10. 7C		(c) Short to positive.	(c) Increased output.	(c) Low pressure.	0.3127	90
10. 8A	Integrator	(a) Fails to open relay.	(a) Transfer from manual to auto causes system upset.	(a) Loss of control.	0.4738	91
10. 8B		(b) Fails to close relay.	(b) Loss of accurate control.	(b) Loss of control.	0.2030	91
10. 9C		(c) Internal open or C3 short.	(c) Loss of accurate control.	(c) Loss of control.	0.2707	91
10. 9D		(d) Open C3.	(d) Output decreases.	(d) High pressure.	0.1354	89
10. 9E		(e) Short to positive.	(e) Increased output.	(e) Low pressure.	0.1354	90
10.10A	Output Limiting	(a) Internal open.	(a) No effect during normal operation.	(a) No effect.	1.3392	
10.10B		(b) Internal short.	(b) High output.	(b) Low pressure.	1.3392	90
Voltage to Current Converter Module E/I-B101/GR PN 301236-01-B						
10.11A	All, Except for Reference Amp.	(a) Internal open.	(a) No output signal.	(a) High pressure.	1.7008	89
10.11B		(b) Short transistor or IC to positive	(b) Maximum output signal.	(b) High pressure.	1.7008	89

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
10.11C		(c) IC short to negative.	(c) Minimum output signal.	(c) High pressure.	1.7008	89
10.12A	Reference Amplifier	(a) Internal failure open.	(a) Loss of precision of control.	(a) Loss of control.	0.2783	91
10.12B		(b) Internal short to positive.	(b) Output high.	(b) Low pressure.	0.2783	90
10.12C		(c) Internal short to negative.	(c) Low output.	(c) High pressure.	0.2783	89
Aug Stem Control Valve I/P						
10.13A		(a) Low output, open.	(a) Closes valve.	(a) High pressure.	1.82	89
10.13B		(b) Stuck, max output.	(b) Opens valve.	(b) Low pressure.	1.46	90
Aug Steam Control Valve Pneumatic Operator						
10.14A		(a) Contamination damaged seat or worn seat.	(a) Internal leaking or fails to seat.	(a) Low pressure.	16.38	90
10.14B		(b) Pneumatic operator fails.	(b) Fails closed.	(b) High pressure.	16.38	89

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11. 1A	Limit Switch 1 LS339/CL Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3A-14.	(a) Loss of turb. stm. open light, no effect.	3.28	
11. 2A	Field Interface Circuit 3A-14	(a) Fails high.	(a) High signal to Inverter 2C-14.	(a) Turb. stm. open light remains off, no effect.	0.03064	
11. 2B		(b) Fails low.	(b) Low signal to Inverter 2C-14.	(b) Turb. stm. open light remains on, no effect.	0.03064	
11. 3A	Inverter 2C-14	(a) Fails high.	(a) High signal to Buffer 3F-8.	(a) Turb. stm. open light remains on, no effect.	0.13023	
11. 3B		(b) Fails low.	(b) Low signal to Buffer 3F-8.	(b) Turb. stm. open light remains off, no effect.	0.13023	
11. 4A	Buffer 3F-8	(a) Fails high.	(a) High signal to turb. indicator light.	(a) Turb. stm. open light remains off, no effect.	0.38675	
11. 4B		(b) Fails low.	(b) Low signal to turb. indicator light.	(b) Turb. stm. open light remains on, no effect.	0.38675	
11. 5A	Limit Switch 5 LS339E/CL Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3A-12.	(a) Turb. exh. light remains off, no effect.	3.28	
11. 6A	Field Interface Circuit 3A-12	(a) Fails high.	(a) High signal to Inverter 2C-12.	(a) Turb. exh. light remains off, no effect.	0.03064	
		(b) Fails low.	(b) Low signal to Inverter 2C-12.	(b) Turb. exh. light remains on, no effect.	0.03064	
11. 7A	Inverter 2C-12	(a) Fails high.	(a) High signal to Buffer 3F-7.	(a) Turb. exh. light remains on, no effect.	0.13023	
11. 7B		(b) Fails low.	(b) Low signal to Buffer 3F-7.	(b) Turb. exh. light remains off, no effect.	0.13023	
11. 8A	Buffer 3F-7	(a) Fails high.	(a) High signal to exh. valve light.	(a) Turb. exh. light remains off, no effect.	0.38675	
11. 8B		(b) Fails low.	(b) Low signal to exh. valve light.	(b) Turb. exh. light remains on, no effect.	0.38675	

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11. 9A	Limit Switch 8 LS339E/OP Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3A-10.	(a) Indicates suction valve open, could start pump with valve closed.	3.28	94
11.10A	Field Interface Circuit 3A-10	(a) Fails high.	(a) High signal to Diode 30 and to Inverter 2C-10.	(a) Same as above.	0.03064	94
11.10B		(b) Fails low.	(b) High signal to Diode 30 and Inverter 2C-10.	(b) Cannot start fwd. pump.	0.03064	
11.11A	Inverter 2C-10	(a) Fails high.	(a) High signal to Buffer 3F-9.	(a) Light indicator valve not open, no effect.	0.13023	
11.11B		(b) Fails low.	(b) Low signal to Buffer 3F-9.	(b) Light indicator valve opened, no effect.	0.13023	
11.12A	Buffer 3F-9	(a) Fails high.	(a) High signal to turb. exh. valve light.	(a) Same as above.	0.38675	
11.12B		(b) Fails low.	(b) Low signal to turb. exh. valve light.	(b) Light indicates valve closed.	0.38675	
11.13A	Limit Switch LS329S/CL Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3A-8	(a) Indicates suction valve closed, no effect.	3.28	
11.14A	Field Interface Circuit 3A-8	(a) Fails high.	(a) High signal to Inverter 2C-8.	(a) Indicates suction valve closes, no effect.	0.03064	
11.14B		(b) Fails low.	(b) Low signal to Inverter 2C-8.	(b) Indicates suction valve open, no effect.	0.03064	
11.15A	Inverter 2C-8	(a) Fails high.	(a) High signal to Buffer 3F-14.	(a) Same as above.	0.13023	
11.15B		(b) Fails low.	(b) Low signal to Buffer 3F-14.	(b) Indicates suction valve closed, no effect.	0.13023	
11.16A	Buffer 3F-14	(a) Fails high.	(a) High signal to suction valve light.	(a) Suction valve open light remains off, no effect.	0.38675	
11.16B		(b) Fails low.	(b) Low signal to suction valve light.	(b) Suction valve open light remains on, no effect.	0.38675	
11.17A	Limit Switch 17 329D/CL	(a) Fails open.	(a) No power to Field Interface Circuit 3A-6.	(a) Light indicates discharge valve closed, no effect.	3.28	

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.18A	Field Interface Circuit 3A-6	(a) Fails high.	(a) High signal to Inverter 2C-6.	(a) Light indicates discharge valve closed, no effect.	0.03064	
11.18B		(b) Fails low.	(b) Low signal to Inverter 2C-6.	(b) Light indicates discharge valve open, no effect.	0.03064	
11.19A	Inverter 2C-6	(a) Fails high.	(a) High signal to Buffer 3G-8.	(a) Same as above.	0.13023	
11.19B		(b) Fails low.	(b) Low signal to Buffer 3G-8.	(b) Light indicates discharge valve closed, no effect.	0.13023	
11.20A	Buffer 3G-8	(a) Fails high.	(a) High signal to pump disch. valve open light.	(a) Light remains off, no effect.	0.38675	
11.20B		(b) Fails low.	(b) Low signal to pump disch. valve open light.	(b) Light remains on, no effect.	0.38675	
11.21A	Limit Switch 21 LS3298O/OP Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3A-4.	(a) Indicates suction valve open, could start fwd. pump with valve closed.	3.28	94
11.22A	Field Interface Circuit 3A-4	(a) Fails high.	(a) High signal to Diode 29 and to Inverter 2C-4.	(a) Light indicates valve open, no effect and same as above.	0.03064	
11.22B		(b) Fails low.	(b) Low signal to Diode 29 and to Inverter 2C-4.	(b) Light indicates valve closed, no effect.	0.03064	
11.23A	Inverter 2C-4	(a) Fails high.	(a) High signal to Buffer 3G-7.	(a) Same as above.	0.13023	
		(b) Fails low.	(b) Low signal to Buffer 3G-7.	(b) Light indicates valve open, no effect.	0.13023	
11.24A	Buffer 3G-7	(a) Fails high.	(a) High signal to suction valve closed light.	(a) Light remains off, no effect.	0.38675	
11.24B		(b) Fails low.	(b) Low signal to suction valve closed light.	(b) Light remains on, no effect.	0.38675	
11.25A	Limit Switch 25 LS329D/OP Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3B-14.	(a) Indicates valve open, could start pump with discharge valve closed.	3.28	94
11.26A	Field Interface	(a) Fails high.	(a) High signal to Inverter 2D-12 and NAND Gate 2H-14.	(a) Same as above.	0.03064	94

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.26B		(b) Fails low.	(b) Low signal to Inverter 2D-12 and NAND Gate 2H-14.	(b) Cannot start pump, light indicates valve closes.	0.03064	
11.27A	Inverter 2D-12	(a) Fails high.	(a) High signal to Buffer 3G-9.	(a) Light indicates discharge valve closed, no effect.	0.13023	
11.27B		(b) Fails low.	(b) Low signal to Buffer 3G-9.	(b) Light indicates discharge valve open, no effect.	0.13023	
11.28A	Buffer 3G-9	(a) Fails high.	(a) High signal to pump discharge valve closed light.	(a) Light remains off.	0.38675	
11.28B		(b) Fails low.	(b) Low signal to pump discharge valve closed light.	(b) Light remains on.	0.38675	
11.31A	NAND Gate 2H-14	(a) Fails high.	(a) High signal to Inverter 2D-14.	(a) Cannot start pump.	0.148015	94
11.31B		(b) Fails low.	(b) Low signal to Inverter 2D-14.	(b) Pump can be started with valves closed.	0.148015	
11.32A	Inverter 2D-14	(a) Fails high.	(a) High signal to NAND Gate 2H-11 and NAND Gate 2H-5.	(a) Same as above.	0.13023	94
11.32B		(b) Fails low.	(b) Low signal to NAND Gate 2H-11 and to NAND Gate 2H-5.	(b) Cannot start pump.	0.13023	
11.33A	Selector Switch S329 STBY-1	(a) Fails open.	(a) No power to Field Interface Circuit 3B-12.	(a) Loss of standby pump capability.	0.46	95
11.34A	Field Interface Circuit 3B-12	(a) Fails high.	(a) High signal to NAND Gate 2I-8 and to Flipflop 2O-9.	(a) Same as above.	0.03064	95
11.34B		(b) Fails low.	(b) Low signal to NAND Gate 2I-8 and to Flipflop 2O-9.	(b) Cannot stop fwd. pump.	0.03064	
11.35A	Flipflop 2O-9	(a) Fails to set.	(a) Low output to NAND Gate 2H-11.	(a) Loss of fwd. standby pump capability.	0.29603	
11.35B		(b) Fails to reset.	(b) High output to NAND Gate.	(b) Could initiate start of fwd. pump when in use.	0.29603	
11.36A	NAND Gate 2H-11	(a) Fails high.	(a) High signal to Inverter 2D-10.	(a) Loss of fwd. standby pump capability.	0.148015	95

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.36B		(b) Fails low.	(b) Low signal to Inverter 2D-10.	(b) Could initiate start of fwd. pump when in use.	0.148015	
11.37A	Inverter 2D-10	(a) Fails high.	(a) High signal to NAND Gate 2I-14 and Buffer 3G-14.	(a) Same as above.	0.13023	
11.37B		(b) Fails low.	(b) Low signal to NAND Gate 2I-14 and Buffer 3G-14.	(b) Loss of fwd. standby pump capability.	0.13023	95
11.38A	Buffer 3G-14	(a) Fails high.	(a) High signal to standby pump ready light.	(a) Standby pump ready light remains off.	0.38675	
11.38B		(b) Fails low.	(b) Low signal to	(b) Standby pump ready light remains on.	0.38675	
11.39A	Selector Switch S329R-1	(a) Fails open.	(a) No power to Field Interface Circuit 3B-10.	(a) Cannot start fwd. pump.	0.46	
11.40A	Field Interface Circuit 3B-10	(a) Fails high.	(a) High signal to NAND Gate 2H-8 and to Flipflop 2O-4.	(a) Cannot start fwd. pump.	0.03064	
11.40B		(b) Fails low.	(b) Low signal to NAND Gate 2H-8 and to Flipflop 2O-4.	(b) Fwd. pump could inadvertently start.	0.03064	33
11.41A	NAND Gate 2H-8	(a) Fails high.	(a) High signal to Inverter 2D-8.	(a) Same as above.	0.148015	33
11.41B		(b) Fails low.	(b) Low signal to Inverter 2D-8.	(b) Could initiate start fwd. pump when in use.	0.148015	
11.42A	Inverter 2D-8	(a) Fails high.	(a) High signal to Flipflop 2O-9.	(a) Same as above.	0.13023	
11.42B		(b) Fails low.	(b) Low signal to Flipflop 2O-9.	(b) Puts fwd. pump in standby capability.	0.13023	95
11.43A	Selector Switch S329S-1 Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3B-8.	(a) Cannot stop fwd. pump.	0.10	
11.44A	Field Interface Circuit 3B-8	(a) Fails high.	(a) High signal to NAND Gate 2H-8 and NAND Gate 2I-8.	(a) Same as above.	0.03064	
11.44B		(b) Fails low.	(b) Low signal to NAND Gate 2H-8 and NAND Gate 2I-8.	(b) Stops fwd. pump.	0.03064	94

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.45A	NAND Gate 2I-8	(a) Fails high.	(a) High signal to Inverter 1E-5.	(a) Stops fwd. pump.	0.148015	94
11.45B		(b) Fails low.	(b) Low signal to Inverter 1E-5.	(b) No effect.	0.148015	
11.46A	Inverter 1E-5	(a) Fails high.	(a) High signal to Flipflop 2O-4.	(a) No effect.	0.13023	
11.46B		(b) Fails low.	(b) Low signal to Flipflop 2O-4.	(b) Stops fwd. pump.	0.13023	94
11.47A	Flipflop 2O-4	(a) Fails to set.	(a) Low output to NAND Gate 2H-5.	(a) Cannot start fwd. pump.	0.29603	
11.47B		(b) Fails to reset.	(b) High output to NAND Gate 2H-5.	(b) Inadvertent start of fwd. pump.	0.29603	33
11.48A	NAND Gate 2H-5	(a) Fails high.	(a) High signal to NAND Gate 2I-11.	(a) Cannot start fwd. pump.	0.148015	
11.48B		(b) Fails low.	(b) Low signal to NAND Gate 2I-11.	(b) Inadvertent start of fwd. pump.	0.148015	33
11.49A	NAND Gate 2I-14	(a) Fails high.	(a) High signal to NAND Gate 2I-11.	(a) Cannot start pump from stby condition.	0.148015	94
11.49B		(b) Fails low.	(b) Low signal to NAND Gate 2I-11.	(b) Inadvertent start of fwd. pump.	0.148015	33
11.50A	NAND Gate 2I-11	(a) Fails high.	(a) High signal to Time Delay 3P-5.	(a) Cannot start fwd pump.	0.148015	33
11.50B		(b) Fails low.	(b) Low signal to Time Delay 3P-5.	(b) Loss of fwd. pump.	0.148015	94
11.51A	Time Delay 3P-5	(a) Fails high.	(a) High signal to Output Circuit 3N-4.	(a) Loss of fwd. pump.	2.5108	94
11.51B		(b) Fails low.	(b) Low signal to Output Circuit 3N-4.	(b) Inadvertent start or cannot stop pump.	2.5108	33
11.52A	Output Circuit 3N-4	(a) Fails high.	(a) High signal to Relay Coil 53, R329.	(a) Same as above.	0.56454	33
11.52B		(b) Fails low.	(b) Low signal to Relay Coil 53, R329.	(b) Cannot start fwd pump.	0.56454	94

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.53A	Relay	(a) Fails to energize or contacts remain open.	(a) Fails to energize	(a) Loss of fwd. pump.	1.0646	94
11.54A	Pressure Switch PS602	(a) Fails open.	(a) No power to Field Interface Circuit 3B-6.	(a) False low pressure failure alarm, standby pump started.	11.66	
11.54B		(b) Fails closed.	(b) Continuous power to Interface Circuit 3B-6.	(b) Fail to set alarm and standby not activated.	11.28	95
11.55A	Field Interface Circuit 3B-6	(a) Fails high.	(a) High signal to NAND Gate 2I-5.	(a) False low lube oil alarm, standby pump started.	0.03064	
11.55B		(b) Fails low.	(b) Low signal to NAND Gate 2I-5.	(b) Fails to alarm when low, standby not started.	0.03064	95
11.56A	NAND Gate 2I-5	(a) Fails high.	(a) High signal to Inverter 2D-6 and NAND Gate 2M-14.	(a) Same as above.	0.148015	95
11.56B		(b) Fails low.	(b) Low signal to Inverter 2D-6 and NAND Gate 2M-14.	(b) False alarm, standby pump started.	0.148015	
11.57A	Time Delay 3O-3	(a) Fails open.	(a) Fails open to Time Delay 3P-5.	(a) Loss of all alarms and auto backup.	2.5108	95
11.57B		(b) Fails to time.	(b) Fails to time to Time Delay 3P-5.	(b) Premature alarm and start of standby.	2.5108	
11.58A	Inverter 2D-6	(a) Fails high.	(a) High signal to Buffer 3H-8.	(a) False low lube press. alarm, no effect.	0.13023	
11.58B		(b) Fails low.	(b) Low signal to Buffer 3H-8.	(b) Loss of low lube press. alarm.	0.38675	
11.59A	Buffer 3H-8	(a) Fails high.	(a) High signal to alarm.	(a) Loss of low lube press. alarm.	0.38675	
		(b) Fails low.	(b) Low signal to alarm.	(b) False low lube press. alarm.	0.38675	
11.62A	Field Interface Circuit 3B-4	(a) Fails high.	(a) High signal to NAND Gate 2J-14 and Inverter 2E-14.	(a) False pump fail alarm/standby started.	0.03064	
11.62B		(b) Fails low.	(b) Low signal to NAND Gate 2J-14 and Inverter 2E-14.	(b) Loss of alarm/standby when press. low.	0.03064	95
11.63A	NAND Gate 2J-14	(a) Fails high.	(a) High signal to NAND Gate 2M-14.	(a) Same as above.	0.148015	95

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.63B		(b) Fails low.	(b) Low signal to NAND Gate 2M-14.	(b) False pump failure alarm and standby started.	0.148015	
11.64A	NAND Gate 2M-14	(a) Fails high.	(a) High signal to Time Delay 3P-11 and Buffer 3H-7.	(a) Same as above.	0.148015	
11.64B		(b) Fails low.	(b) Low signal to Time Delay 3P-11 and Buffer 3H-7.	(b) Loss of alarm and standby pump.	0.148015	95
11.65A	Time Delay 3P-11	(a) Fails open.	(a) Fails open to Buffer 3H-7.	(a) Loss of alarm and standby pump.	2.5108	95
11.65B		(b) Fails to time.	(b) Fails to time to Buffer 3H-7.	(b) Premature alarms and standby pump.	2.5108	
11.66A	Buffer 3H-7	(a) Fails high.	(a) High signal to Alarm 67.	(a) Loss of alarm.	0.38675	
11.66B		(b) Fails low.	(b) Low signal to resistor alarm.	(b) False alarm.	0.38675	
11.68A	Limit Switch LS339/OP Wiring and Connectors	(a) Fails open.	(a) No power to Field Interface Circuit 3C-14.	(a) Indicates steam turb. valve open when closed. No pump fail alarm or standby activation.	3.28	95
11.69A	Field Interface Circuit 3C-14	(a) Fails high.	(a) High signal to Inverter 2D-4 and NAND Gate 2M-10.	(a) Same as above.	0.03064	95
11.69B	Field Interface Circuit 3C-14	(b) Fails low.	(b) Low signal to Inverter 2D-4 and NAND Gate 2M-10.	(b) False pump fail alarm and standby started.	0.03064	
11.70A	Inverter 2D-4	(a) Fails high.	(a) High signal to Buffer 3I-8 and to Inverter 2J-11.	(a) False pump fail alarm and standby started.	0.13023	
11.70B		(b) Fails low.	(b) Low signal to Buffer 3I-8 and to Inverter 2J-11.	(b) Loss of alarm and standby when when valve closed.	0.13023	95
11.71A	NAND Gate 2J-11	(a) Fails high.	(a) High signal to NAND Gate 2M-14.	(a) Same as above.	0.148015	95
11.71B		(b) Fails low.	(b) Low signal to NAND Gate 2M-14.	(b) False alarm and standby started.	0.148015	
11.72A	Buffer 3I-8	(a) Fails high.	(a) High signal to turb. stm. value closed light.	(a) Loss of light.	0.38675	
11.72B		(b) Fails low.	(b) Low signal to turb. stm. valve closed light.	(b) Light remains on.	0.38675	

FAILURE MODES AND EFFECTS ANALYSIS (FMCA)

SHIP: SHIP B

SUBSYSTEM: 11.0 FWD. FEED PUMP START/STOP CONTROL MODULE
Two Per Vessel, FWD , and AFT Controls

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
11.73A	Inverter 2E-14	(a) Fails high.	(a) High signal to NAND Gate 2M-10.	(a) Loss of feedpump stopped light when discharge press. low.	0.13023	
11.73B		(b) Fails low.	(b) Low signal to NAND Gate 2M-10.	(b) False feedpump stopped light.	0.13023	
11.74A	NAND Gate 2M-10	(a) Fails high.	(a) High signal to Buffer 3I-7 and Inverter 2E-10.	(a) Same as above.	0.148015	
11.74B		(b) Fails low.	(b) Low signal to Buffer 3I-7 and Inverter 2E-10.	(b) False feedpump running light.	0.148015	
11.75A	Buffer 3I-7	(a) Fails high.	(a) High signal to feedpump stopped light.	(a) Loss of light.	0.38675	
11.75B		(b) Fails low.	(b) Low signal to feedpump stopped light.	(b) Light remains on.	0.38675	
11.76A	Inverter 2E-10	(a) Fails high.	(a) High signal to Buffer 3I-9.	(a) Feedpump running light remains on.	0.13023	
11.76B		(b) Fails low.	(b) Low signal to Buffer 3I-9.	(b) Loss of feedpump running light.	0.13023	
11.77A	Buffer 3I-9	(a) Fails high.	(a) High signal to feedpump running light.	(a) Same as above.	0.38675	
11.77B		(b) Fails low.	(b) Low signal to feedpump running light.	(b) Feedpump running light remains on.	0.38675	
11.78A	NAND Gate 2M-6	(a) Fails high.	(a) High signal to Buffer 3J-8.	(a) False standby start alarm.	0.148015	
11.78B		(b) Fails low.	(b) Low signal to Buffer 3J-8.	(b) Loss of standby start alarm.	0.148015	
11.79A	Buffer 3J-8	(a) Fails high.	(a) High signal to standby start alarm.	(a) Loss of standby start alarm.	0.38675	
11.79B		(b) Fails low.	(b) Low signal to standby start alarm.	(b) Standby start alarm remains on.	0.38675	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 12.0 DEAERATOR LEVEL CONTROL | PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Tank Level Trans. LT310 Mafg.-Rosemount PN1151-DP4-E-12LM						
12. 1A		(a) Fail open.	(a) No signal.	(a) High deaerator level.	6.63	24
12. 1B		(b) Fails to negative.	(b) Low signal.	(b) High deaerator level.	6.25	24
12. 1C		(c) Fails to positive.	(c) High signal.	(c) Low deaerator level.	6.25	25
Level Indicator						
12. 3A		(a) Internal failure.	(a) No deaerator level indicator.	(a) No effect.		
Alarm Module EALM-C201GR PN C-310455-01 2 Modules HI/LO						
12. 4A	Alarm Module	(a) Internal failure.	(a) No alarm for HI/LO deaerator level.	(a) No effect.	5.885	
12. 4B		(b) Internal failure.	(b) False alarm.	(b) No effect.	5.885	
Filter/Impulse FIL/IMP-A101GR						
12. 5A	Resistance Ladder	(a) Internal failure.	(a) Minimum effect.	(a) No effect.	1.1795	
12. 5B	Input Buffer	(b) Open/or short to negative.	(b) Minimum output signal.	(b) High deaerator level.	0.5763	24
12. 6A	Inverter 1	(a) Short to positive.	(a) High output.	(a) Low deaerator level.	0.2470	25
12. 6B		(b) Open/or short to positive.	(b) Loss of output signal.	(b) High deaerator level.	0.4807	24
12. 6C		(c) Short to negative.	(c) High output.	(c) Low deaerator level.	0.2588	25
12. 7A	Inverter 2	(a) Open/short to negative.	(a) Loss of output.	(a) High deaerator level.	0.5840	24

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 12.0 DEAERATOR LEVEL CONTROL |

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
12. 7B		(b) Short to positive.	(b) High output.	(b) Low deaerator level.	0.3144	25
Controller Module CNTRL-C101GR PN C-39282-00E (2 Modules)						
12. 8A	Differential	(a) Internal open.	(a) No control, valve eventually closes.	(a) Low deaerator level.	0.3920	25
12. 8B		(b) Short to positive.	(b) Increased output.	(b) High level.	0.2940	24
12. 8C		(c) Short to negative.	(c) Decreased output.	(c) Low level.	0.2940	25
12. 9A	Proportional Section	(a) Internal open.	(a) No control, valve eventually closes.	(a) Low level.	0.9165	25
12. 9B		(b) Short to positive.	(b) Increased output.	(b) Level high.	0.6874	24
12. 9C		(c) Short to negative.	(c) Decreased output.	(c) Low level.	0.6874	25
12.10A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Level variation, slight loss of control.	0.2966	
12.10B		(b) Short to negative.	(b) Increased output.	(b) Level high.	0.2225	25
12.10C		(c) Short to positive.	(c) Decreased output.	(c) Low level.	0.2225	24
12.11A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Level variation, slight loss of control.	0.4170	
12.11B		(b) Short to negative.	(b) Decreased output.	(b) Low level.	0.3127	25
12.11C		(c) Short to positive.	(c) Increased output.	(c) Increased level.	0.3127	24
12.12A	Integrator	(a) Fails to open relay.	(a) Transfer from manual to auto causes system upset.	(a) Temporary level variation.	0.4738	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 12.0 DEAERATOR LEVEL CONTROL | PAGE: 3

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
12.12B		(b) Fails to close	(b) Loss of accurate control.	(b) Level variations, slight loss of control.	0.2030	
12.12C		(c) Internal open	(c) Loss of accurate control.	(c) Temporary level variations.	0.2707	
12.12D		(d) Open C3.	(d) Output decreased.	(d) Low level.	0.1354	25
12.12E		(e) Short to positive.	(e) Increased output.	(e) High level.	0.1354	24
12.12F		(f) Short to negative.	(f) Decreased output.	(f) Low level.	0.1354	25
12.12G	Output Limiting	(g) Internal open.	(g) No effect during normal operation.	(g) No effect, could possibly give a wide level variation in abnormal conditions, less than 0.5% of time.	1.3392	
12.12H		(h) Internal short.	(h) High output.	(h) High level.	1.3392	24
Man/Auto Module M/A-A101GR PN 31918-01-H (2 Modules)						
12.13A	Output Buffer (Auto or Manual)	(a) Open.	(a) Decreased output.	(a) High level.	0.30936	24
12.13B		(b) Short to negative.	(b) Decreased output.	(b) High level.	0.2320	24
1..13C		(c) Short to positive.	(c) Increased output.	(c) Low level.	0.2320	25
12.14A	D to A Converter (Auto Mode)	(a) Internal failure.	(a) Minor output fluctuation.	(a) Small output offset.	4.8565	
12.15A	Comparator (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Loss of control in auto.	0.43615	92
12.15B		(b) Short to positive.	(b) Output increased.	(b) Low level.	0.43615	25
12.16A	Auto Clock Circuit (Auto Mode)	(a) Internal failure.	(a) In auto mode locks in present point.	(a) Loss of control in auto.	0.2806	92

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 12.0 DEAERATOR LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
12.17A	Output Inverter (Manual)	(a) Internal failure.	(a) Temporary process upset.	(a) Temporary instability of level.	0.7162	
12.18A	Manual Clock Circuit	(a) Internal failure.	(a) No change in, output sets at current point.	(a) Loss of control in manual.	0.2806	82
12.19A	Control Logic (Manual)	(a) Internal failure.	(a) Stays in auto.	(a) Maintains auto control.	0.0657	82
12.19B		(b) Internal failure.	(a) No increase of output signal.	(a) High level.	0.0657	24
12.19C		(c) Internal failure.	(c) No decrease of output signal.	(c) Low level.	0.0657	25
12.19D		(d) Internal failure.	(d) Increased output to maximum.	(d) Low level.	0.0657	25
12.19E		(e) Internal failure.	(e) Decreased output to minimum.	(e) High level.	0.0657	24
12.20A	Control Logic	(a) Internal failure.	(a) Stays in manual mode.	(a) Able to use manual but not auto.	0.1771	92
12.20B		(b) Internal failure.	(b) No increase of output signal.	(b) High level.	0.1771	24
12.20C		(c) Internal failure.	(c) No decrease of output signal.	(c) Low level.	0.1771	25
12.20D		(d) Internal failure.	(d) Increases to maximum.	(d) Low level.	0.1771	25
12.20E		(e) Internal failure.	(e) Decreased to minimum.	(e) High level.	0.1771	24
Adjustable Reference ADJ REF-A101CR (2 Modules)						
12.21A	Reference Amplifier	(a) Open.	(a) Loss of output signal.	(a) Low level.	0.3293	25
12.21B		(b) Short to negative.	(b) Increased output.	(b) Increased level.	0.2470	24

SHIP: SHIP B   SUBSYSTEM: 12.0 DEAERATOR LEVEL CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
12.21C		(c) Short to positive.	(c) Decreased output.	(c) Decreased level.	0.2470	25
12.22A	Output Amplifier	(a) Open/or short to negative.	(a) Loss of output signal.	(a) Low level.	0.4957	25
12.22B		(b) Short to positive.	(b) Increased output.	(b) Increased level.	0.2124	24
Current to Voltage Converter Module I/END-A201GR PN C-22930-01-C						
12.23A	Input	(a) Open circuit.	(a) Low output.	(a) High tank level.	0.9436	24
12.23B		(b) Short circuit.	(b) High output.	(b) Low tank level.	0.9436	25
12.24A	Reference Amplifier	(a) Short to negative or open.	(a) High output signal.	(a) Low tank level.	0.9436	25
12.24B		(b) Short to positive.	(b) Decreased output signal.	(b) High tank level.	0.9436	24
12.25A	First Stage	(a) Internal open.	(a) Decreased output.	(a) High tank level.	0.9436	24
12.25A		(b) Internal short to negative.	(b) Decreased output.	(b) High tank level.	0.9436	24
12.26A	Driver	(a) Short to positive.	(a) Increased output.	(a) Low tank level.	0.9436	25
12.27A	Condensate Make-up Control Valve	(a) Binds/stuck open.		(a) Low tank level.	16.38	25
12.27B		(b) Binds/stuck closed.		(b) High tank level.	16.38	24
12.28A	Condensate Spell Control Valve	(a) Binds/stuck open.		(a) High tank level.	16.38	24
12.28B		(b) Binds/stuck closed.		(b) High tank level.	16.38	24

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 13.0 FUEL OIL HEADER TEMPERATURE
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Temp Transducer						
13. 1A		(a) Open, primary leads.	(a) Close valve.	(a) Low temperature.	2.00	44
13. 1B		(b) Open, reference lead.	(b) Valve slightly closed.	(b) Temperature slightly lower.	1.62	
Platinum Resistance Temperature Detector PRTD-A201GR						
13. 2A	All	(a) Short to negative.	(a) Low signal, open valve.	(a) High temperature.	2.2208	46
13. 2B		(b) Open.	(b) System signal out of controller high, valve open.	(b) High temperature.	5.5076	46
13. 2C		(c) Oscillates.	(c) Output signal varies.	(c) Loss of temperature control.	1.1548	93
Controller CNTRL-C101GR						
13. 3A	Differential	(a) Internal open.	(a) No control, valve eventually closes.	(a) Low temperature.	0.3920	44
13. 3B		(b) Short to positive.	(b)Increased output.	(b) High temperature.	0.2940	46
13. 3C		(c) Short to negative.	(c) Decreased output.	(c) Low temperature.	0.2940	44
13. 4A	Proportional Section	(a) Internal open.	(a) No control, valve eventually closes.	(a) Low temperature.	0.9165	44
13. 4B		(b) Short to positive.	(b) Increased output.	(b) Temperature high.	0.6874	46
13. 4C		(c) Short to negative.	(c) Decreased output.	(c) Low temperature.	0.6874	44
13. 5A	Signal Inversion Section	(a) Internal open.	(a) Loss of accurate control.	(a) Temp. variation, slight loss of control.	0.2966	
13. 5B		(b) Short to negative.	(b) Increased output.	(b) Temperature high.	0.2225	46

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
13. 5C		(c) Short to positive.	(c) Decreased output.	(c) Low temperature.	0.2225	44
13. 6A	Integral Gain Section	(a) Internal open.	(a) Loss of accurate control.	(a) Temperature variation, slight loss of control.	0.4170	
13. 6B		(b) Short to negative.	(b) Decreased output.	(b) Low temperature.	0.3127	44
13. 6C		(c) Short to positive.	(c) Increased output.	(c) Increased temperature.	0.3127	46
13. 7A	Integrator	(a) Relay fails to open.	(a) Transfer from manual to auto causes system upset.	(a) Temporary temperature variations.	0.4738	
13. 7B		(b) Relay fails to close.	(b) Loss of accurate control.	(b) Temperature variations, slight loss of control.	0.2030	
13. 7C		(c) Internal open or C3 short.	(c) Loss of accurate control.	(c) Temporary temperature variations.	0.2707	
13. 7D		(d) Open C3.	(d) Output decreased.	(d) Low temperature.	0.1354	44
13. 7E		(e) Short to positive.	(e) Increased output.	(e) High temperature.	0.1354	46
13. 7F		(f) Short to negative.	(f) Decreased output.	(f) Low temperature.	0.1354	44
13. 8A	Summing Section	(a) Internal open.	(a) Decreased output.	(a) Low temperature.	0.30	44
13. 8B		(b) Short to positive.	(b) Increased output.	(b) High temperature.	0.30	46
13. 8C		(c) Short to negative.	(c) Decreased output.	(c) Low temperature.	0.30	44
13. 9A	Output Limiting	(a) Internal open.	(a) No effect during normal operation.	(a) No effect, could possibly give a wide temperature variation in abnormal condition, less than 0.5% of time.	1.3392	
13. 9B		(b) Internal short.	(b) High output.	(b) High temperature.	1.3392	46

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 13.0 FUEL OIL HEADER TEMPERATURE
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Setpoint SETPT-A101GR						
13.10A	All	(a) Open, wire on positive lead/pot.	(a) Decreased output.	(a) Decreased temperature.	0.6064	44
13.10B		(b) Open negative lead/pot.	(b) Increased output.	(b) Increased temperature.	0.20214	46
13.10C		(c) Internal open.	(c) Decreased output.	(c) Decreased temperature.	0.8086	44
13.10D		(d) Short to positive.	(d) Increased output.	(d) Increased temperature.	1.21284	46
13.10E		(e) Short to negative.	(e) Decreased output.	(e) Decreased temperature.	1.21284	44
Man/Auto M/A-A101GR						
13.11A	Output Buffer (Auto or Manual)	(a) Open.	(a) Decreased output.	(a) Decreased temperature.	0.30936	44
13.11B		(b) Short to negative.	(a) Decreased output.	(a) Decreased temperature.	0.2320	44
13.11C		(c) Short to positive.	(c) Increased output.	(c) Increased temperature.	0.2320	46
13.12A	D to A Converter (Auto Mode)	(a) Internal failure.	(a) Minor output fluctuation.	(a) Small output offset.	4.8565	
13.13A	Comparators (Auto Mode)	(a) Short to negative.	(a) Output remains at point of failure in auto.	(a) Loss of ocntrol in auto.	0.43615	93
13.13B		(b) Short to positive.	(b) Output increased.	(b) Increase in temperature.	0.43615	46
13.14A	Auto Clock Circuit (Auto Mode)	(a) Internal failure.	(a) In auto mode, locks in present point.	(a) Loss of control in auto.	0.2806	93
13.14B	Output Inverter (Manual)	(b) Internal failure.	(b) Temporary process upset.	(b) Temporary instability of temp.	0.7162	

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 13.0 FUEL OIL HEADER TEMPERATURE
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
13.15A	Manual Clock Circuit	(a) Internal failure.	(a) No change in output sets at current point.	(a) Loss of control in manual.	0.2806	82
13.15B		(b) Internal failure.	(b) No increase of output signal.	(b) Maintains auto control.	0.0657	82
13.15C		(c) Internal failure.	(c) No decrease of output signal.	(c) High temperature.	0.0657	46
13.15D		(d) Internal failure.	(d) Increased output to maximum.	(d) High temperature.	0.0657	46
13.15E		(e) Internal failure.	(e) Decrease output to minimum.	(e) Low temperature.	0.0657	44
13.16A	Control Logic (Auto)	(a) Internal failure.	(a) Stays in manual mode.	(a) Able to use manual but not auto.	0.1771	93
13.16B		(b) Internal failure.	(b) No increase of output signal.	(b) Low temperature.	0.1771	44
13.16C		(c) Internal failure.	(c) No decrease of output signal.	(c) High temperature.	0.1771	46
13.16D		(d) Internal failure.	(d) Increases to maximum.	(d) High temperature.	0.1771	46
13.16E		(e) Internal failure.	(e) Decreases to minimum.	(e) Low temperature.	0.1771	44
Voltage to Current Converter E/I-B101GR						
13.17A	All, Except Reference Amp.	(a) Internal open.	(a) No output signal.	(a) Low temperature.	1.7008	44
13.17B		(b) Short transistor or IC to positive.	(b) Maximum output signal.	(b) High temperature.	1.7008	46
13.17C		(c) IC short to negative.	(c) Minimum output signal.	(c) Low temperature.	1.7008	44
13.18A	Reference Amplifier	(a) Internal failure open.	(a) Loss of precision of control.	(a) Temporary low temperature.	0.2783	

FAILURE MODES AND EFFECTS ANALYSIS (FMECA)

SHIP: SHIP B

SUBSYSTEM: 13.0 FUEL OIL HEADER TEMPERATURE
One Per Vessel

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
13.18B		(b) Internal short to positive.	(b) Output high.	(b) High temperature.	0.2783	46
13.18C		(c) Internal short to negative.	(c) Low output.	(c) Low temperature.	0.2783	44
13.19A	Fuel Oil Temp. Control Valve I/P	(a) Stuck, binds open.	(a) High steam flow.	(a) High temperature.	0.97	46
13.19B		(b) Stuck, binds closed.	(b) Low steam flow.	(b) Low temperature.	0.97	44
13.19C		(c) Loss of input signal.	(c) Valve closes.	(c) Low temperature.	1.35	44
	Fuel Oil Temp. Control Value					
13.20A		(a) Contamination, damaged seal or worn seat.	(a) Internal leaking or full to seat.	(a) Valve open or cannot completely close, high temperature.	16.38	46
13.20B		(b) Pneaumater operative fails.	(b) Fails closed.	(b) Low temp.	16.38	44

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B | SUBSYSTEM: 14.0 FUEL OIL RECIRCULATION CONTROL | PAGE: 1

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
Manual Loader Wiring and Connectors						
14. 1A		(a) Open.	(a) Loss of set point.	(a) High pressure.	0.50	39
Indicator						
14. 2A		(a) Internal fail-	(a) Loss of indication of fuel oil pressure valve setting.	(a) No effect.	0.50	
Setpoint Module SETPT-A101GR PN C-22942-01-C						
14. 3A	All	(a) Open wire on positive lead/pot.	(a) Decreased output.	(a) Increased pressure.	0.40428	39
14. 3B		(b) Open negative lead pot.	(b) Increased output.	(b) Decreased pressure.	0.40428	38a(.6) 38b(.4)
14. 3C		(c) Internal open.	(c) Decreased output.	(c) Increased pressure.	0.80856	39
14. 3D		(d) Short to positive.	(d) Increased output.	(d) Decreased pressure.	1.2128	38a(.6) 38b(.4)
14. 3E		(e) Short to negative.	(e) Increased output.	(e) Decreased pressure.	1.2128	38a(.6) 38b(.4)
Voltage to Current Converter Module E/I-B101GR PN-301236-01-B						
14. 4A	All, Except Reference Amp.	(a) Internal open.	(a) No output signal.	(a) High pressure.	1.7008	39
14. 4B		(b) Short transistor or IC to positive	(b) Maximum output signal.	(b) High pressure.	1.7008	39
14. 4C		(c) IC short to negative.	(c) Minimum output signal.	(c) High pressure.	1.7008	39
14. 5A	Reference Amplifier	(a) Internal failure open.	(a) Loss of precision of control.	(a) Temporary high pressure.	0.2783	
14. 5B		(b) Internal short to positive.	(b) Output high.	(b) Low pressure.	0.2783	38a(.6) 38b(.4)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 14.0 FUEL OIL RECIRCULATION CONTROL

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
14. 5C		(c) Internal short to negative.	(c) Low output.	(c) High pressure.	0.2783	39
	Fuel Oil Pressure Control Valve					
14. 6A		(a) Loss of Control Air	(a) Valve closes.	(a) High pressure.	0.30	39
14. 6B		(b) Fails to close.	(b) Oil recirculates	(b) Low pressure.	0.30	38a(.6) 38b(.4)
14. 6C		(c) Fails to open.	(c) Oil does not recirculate.	(c) High pressure.	0.30	39
	Air Flow I/P Converter					
14. 7A		(a) Inter failure.	(a) High output.	(a) High pressure.	1.46	39
14. 7B		(b) Loss of input signal as output.	(b) Low output.	(b) Low pressure.	1.84	38a(.6) 38b(.4)
	Fuel Oil Pressure Regulating Valve PN E-30397-01					
14. 8A		(a) Bound/stuck.	(a) Open.	(a) High pressure.	16.38	39
14. 8B		(b) Bound/stuck.	(b) Closed.	(b) Low pressure.	16.38	38a(.6) 38b(.4)

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 15.0 LUBE OIL PUMP CONTROLS
Two Per Vessel, FWD and AFT

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
15. 1A	LS605S Suction Valve Switch, Wiring and Connections	(a) Fails open when valve closed.	(a) No signal to 3A-14 Input Circuit.	(a) False L.O. Suction Valve open light.	3.28	
15. 1B		(b) Fails open when valve open.	(b) No signal to 3A-12 Input Circuit.	(b) False L.O. Suction Valve closed light, loss of standby ready light and loss of automatic standby function.	3.28	96
15. 2A	LS605D Discharge Valve Switch, Wiring and Connections	(a) Fails open when valve closed.	(a) No signal to 3A-10 Input Circuit.	(a) False L.O. Discharge Valve open light.	1.83	
15. 2B		(b) Fails open when valve open.	(b) No signal to 3A-8 Input Circuit.	(b) False L.O. Discharge Valve closed light, loss of standby ready light and loss of standby pump.	1.45	96
15. 3A	Input Circuits 3A-14, 3A-10	(a) Fails high.	(a) High signal to Buffer 2A-8 and 2A-9.	(a) L.O. Pump Valve always indicates open.	0.03064	
		(b) Fails low.	(b) Low signal to Buffer 2A-8 and 2A-9.	(b) L.O. Pump Valve always indicates closed.	[illegible].03064	
15. 4A	Buffer Circuit 2A-8, 2A-9	(a) Fails high.	(a) No light circuit to ground.	(a) Loss of indicating lights.	0.[illegible]8675	
		(b) Fa[illegible] low.	(b) Shorts light circuit to ground.	(b) Loss of indicating lights.	0.38685	
15. 5A	Input Circuits 3A-12, 3A-8	(a[illegible] [illegible]ails high.	(a) High signal to Buffer 2A-7 and Inverter 1C-14.	(a) L.O. Pump Suction or Discharge Valve light always indicates and loss of automatic changeover.	0.03064	96
15. 5B		(b) Fails low.	(b) Low signal to Buffer 2A-7 and Inverter 1C-14.	(b) L.O. Pump Suction or Discharge Valve light never indicates open and primary or standby pumps could be activated with valve closed.	0.03064	
15. 6A	Buffers 2A-7, 2A-14	(a) Fails high.	(a) Opens light circuit to ground.	(a) Light never indicates valve closed.	0.38675	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B   SUBSYSTEM: 15.0 LUBE OIL PUMP CONTROLS Two Per Vessel, FWD and AFT

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
15. 6B		(b) Fails low.	(b) Light circuit to ground.	(b) Valve always indicates closed.	0.38675	
15. 7A	Inverters 1C-14, 1C-12	(a) Fails high.	(a) High signal to NAND Gate 1F-14.	(a) Could allow standby pump to be activated with valve closed.	0.13023	
15. 7B		(b) Fails low.	(b) Low signal to NAND Gate 1F-14.	(b) Loss of automatic standby capability.	0.13023	96
15. 8A	NAND Gate 1F-14	(a) Fails high.	(a) High signal to Inverter 1C-10.	(a) Same as 7(b).	0.148015	96
15. 8B		(b) Fails low.	(b) Low signal to Inverter 1C-10.	(b) Same as 7(a).	0.148015	
15. 9A	Inverter 1C-10	(a) Fails high.	(a) High signal to NAND Gate 1F-11.	(a) Same as 7(a).	0.13023	
		(b) Fails low.	(b) Low signal to NAND Gate 1F-11.	(b) Same as 7(b).	0.13023	96
15.10A	S605 Standby Switch, Connectors and Wiring	(a) Fails open.	(a) No signal to Input Circuit 3A-6.	(a) Loss of automatic standby function and cannot shut down primary pump	1.83	96
15.10B		(b) Fails closed.	(a) 24 volt signal to Input Circuit 3A-6.	(b) Loss of primary pump.	1.45	50
15.11A	Input Circuit 3A-6	(a) Fails high.	(a) High signal to Flipflop 3G-9 and NAND Gate 1G-14.	(a) Loss of standby function.	0.03064	96
15.11B		(b) Fails low.	(b) Low signal to Flipflop 3G-9 and NAND Gate 1G-14.	(b) Loss of primary pump.	0.03064	50
15.12A	S605R Run Switch	(a) Fails open.	(a) No signal to Input Circuit 3A-4.	(a) Loss of primary start mode.	0.23	
15.12B		(b) Fails closed.	(b) Continuous signal to Input Circuit 3A-4.	(b) Loss of standby function and and ready light.	0.23	96
15.13A	Input Circuit 3A-4	(a) Fails high.	(a) High signal to input of NAND Gate 1F-8 and Output Circuit 3E-4.	(a) Same as 12(a).	0.03064	
15.13B		(b) Fails low.	(b) Low signal to input and to NAND Gate 1F-8 and Output Circuit 3E-4.	(b) Same as 12(b).	0.03064	96

SHIP: SHIP B

SUBSYSTEM: 15.0 LUBE OIL PUMP CONTROLS
Two Per Vessel, FWD and AFT

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES: SUBSYSTEM	FAILURE MODES: SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
15.14A	NAND Gate 1F-8	(a) Fails high.	(a) High signal to Inverter Cir- Circuit 1C-6	(a) Same as 12(b).	0.148015	96
15.14B		(b) Fails low.	(b) Low signal to Inverter Circuit 1C-6.	(b) Loss of primary pump function.	0.148015	
15.15A	Inverter 1C-6	(a) Fails high.	(a) High signal to Flipflop 3G-9.	(a) Same as 14(b).	0.13023	
15.15B		(b) Fails low.	(b) Low signal to Flipflop 3G-9.	(a) Same as 12(b).	0.13023	96
15.16A	Flipflop 3G-9	(a) Fails high.	(a) High signal to NAND Gate 1F-11.	(a) Same as 14(b).	0.29603	
15.16B		(b) Fails low.	(b) Low signal to NAND Gate 1F-11.	(b) Same as 12(b).	0.29603	96
15.17A	NAND Gate 1F-11	(a) Fails high.	(a) High signal to Inverter Cir- cuit 1C-8.	(a) Same as 12(b).	0.148015	96
15.17B		(b) Fails low.	(b) Low signal to NAND Gate 1F-11.	(b) Same as 14(b).	0.148015	
15.18A	Inverter 1C-8	(a) Fails high.	(a) High signal to Buffer 2B-8 and NAND Gate 1G-11.	(a) Same as 14(b).	0.13023	
15.18B		(b) Fails low.	(b) Low signal to Buffer 2B-8 NAND Gate 1G-11.	(b) Same as 12(b).	0.13023	96
15.19A	Buffer 2B-8	(a) Fails high.	(a) Open light circuit to ground.	(a) L.O. Pump standby pump light remains on.	0.38675	
15.19B		(b) Fails low.	(b) No light circuit to ground.	(b) Standby Pump not indicated ready.	0.38675	
15.20A	NAND Gate 1G-11	(a) Fails high.	(a) High signal to Output Cir- cuit 3E-3.	(a) Loss of Standby Pump.	0.148015	96
15.20B		(b) Fails low.	(b) Low signal to Output Cir- cuit 3E-3.	(b) Pump activated by Standby Coil.	0.148015	
15.21A	Output Circuit 3E-3	(a) Fails high.	(a) 24 volts to Standby Coil R605.	(a) Same as 20(b).	0.56454	
15.21B		(b) Fails low.	(b) No input to Standby Coil R605.	(b) Same as 20(a).	0.56454	96

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 15.0 LUBE OIL PUMP CONTROLS
Two Per Vessel, FWD and AFT

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
15.22A	Relay R605 Standby	(a) Fails to set.	(a) Contact 1/3 fails to close.	(a) Loss of Standby Pump.	0.53	96
15.22B		(b) Fails to reset.	(b) Contact 1/3 fails to open.	(b) Pump runs continuously.	0.53	
15.23A	Stop Switch S605-1D Connectors and Wiring	(a) Fails closed.	(a) Signal to Input Circuit 3B-14.	(a) Loss of both primary and standby for one pump.	0.23	96
15.23B		(b) Fails open.	(b) No signal to Input Circuit 3B-14.	(b) Cannot shut down pump.	0.23	
15.24A	Input Circuit 3B-14	(a) Fails high.	(a) High signal to NAND Gates 1F-8 and 1G-14.	(a) Same as 23(b).	0.03064	
15.24B		(b) Fails low.	(b) Low signal to NAND Gates 1F-8 and 1G-14.	(b) Same as 23(a).	0.03064	96
15.25A	NAND Gate 1G-14	(a) Fails high.	(a) High signal to Inverter 1D-14.	(a) Same as 23(a).	0.148015	96
15.25B		(b) Fails low.	(b) Low signal to Inverter 1D-14.	(b) Same as 23(b).	0.148015	
15.26A	Inverter 1D-14	(a) Fails high.	(a) High signal to Outpout Circuit 3E-5.	(a) Same as 23(b).	0.13023	
15.27A	Output Circuit 3E-5	(a) Fails high.	(a) 24 volts to Reset Coil R605.	(a) Same as 23(a).	0.56454	96
15.27B		(b) Fails low.	(b) No input to Reset Coil R605.	(b) Same as 23(b).	0.56454	
15.28A	Output Circuit 3E-4	(a) Fails high.	(a) 24 volts to run Coil R605.	(a) Primary runs continuously.	0.56454	
15.28B		(b) Fails low.	(b) No input to run Coil R605.	(b) Loss of primary function.	0.56454	50
15.29A	Pressure Switch	(a) Fails closed.	(a) Signal to Input Circuit 3B-12.	(a) Loss of aft. Standby Pump function, L.O. Pump running light remains on, no alarm.	11.66	96
15.29B		(b) Fails open.	(b) No signal to Input Circuit 3B-12.	(b) Standby started, alarm on, L.O. Pump running light out.	11.28	
15.30A	Input Circuit 3B-12	(a) Fails high.	(a) High signal to NAND Gate 1F-5 and Inverter 1D-12.	(a) Same as 29(b).	0.03064	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 15.0 LUBE OIL PUMP CONTROLS
Two Per Vessel, FWD and AFT

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
15.30B		(b) Fails low.	(b) Low signal to NAND Gate 1F-5 and Inverter 1D-12.	(b) Same as 29(a).	0.03064	96
15.31A	Inverter 1D-12	(a) Fails high.	(a) High signal to Inverter 2B-7.	(a) L.O. Pump running light remains on.	0.13023	
15.31B		(b) Fails low.	(b) Low signal to Inverter 2B-7.	(b) No L.O. Pump running light.	0.13023	
15.32A	Buffer 2B-7	(a) Fails high.	(a) No circuit to ground.	(a) Same as 31(b).	0.13023	96
15.32B		(b) Fails low.	(b) Open circuit to ground.	(b) Same as 31(a).	0.38675	
15.33A	NAND Gate 1F-5	(a) Fails high.	(a) High signal to Inverter 1C-4.	(a) Loss of standby switching function and alarm on.	0.148015	96
15.33B		(b) Fails low.	(b) Low signal to Inverter 1C-4.	(b) Standby activated and alarm on.	0.148015	
15.34A	Inverter 1C-4	(a) Fails high.	(a) High signal to Timer 2F-5 and Buffer 2C-8.	(a) Same as 32(b).	0.13023	
15.34B		(b) Fails low.	(b) Low signal to Timer 2F-5 and and Buffer 2C-8.	(b) Same as 32(a).	0.13023	96
15.35A	Timer 2F-5	(a) Fails to time.	(a) Premature signal to Gate 1G-5.	(a) Standby activated.	2.5108	
15.35B		(b) Fails open.	(b) No signal to Gate 1G-5.	(b) Loss of standby.	2.5108	96
15.36A	Buffer 2C-8	(a) Fails high.	(a) No circuit to ground.	(a) Loss of alarm.	0.38675	
15.36B		(b) Fails low.	(b) Open circuit to grouond.	(b) Alarm activated.	0.38675	
15.37A	L.O. Pump Stopped Function, Inverter 3B-10, Buffer 2B-14, Buffer 2B-9	(a) Fails true.	(a) Incorrect signals when pump stopped.	(a) Loss of L.O. Pump, stopped high.	0.80414	50
15.37B		(b) Fails false.	(b) Incorrect signals when pump running.	(b) False L.O. Pump stopped light.	0.80414	
15.38A	Input Circuit 3B-8	(a) Fails high.	(a) High signal to Inverter 1D-10.	(a) Loss of standby switching function.	0.03064	96
15.38B		(b) Fails low.	(b) Low signal to Inverter 1D-10.	(b) Alarm activates.	0.03064	

FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

SHIP: SHIP B

SUBSYSTEM: 15.0 LUBE OIL PUMP CONTROLS
Two Per Vessel, FWD and AFT

REF. NO.	ITEM NOMENCLATURE FUNCTION	FAILURE MODE/S	FAILURE MODES SUBSYSTEM	FAILURE MODES SYSTEM	FAILURES/ 10E6 HRS.	CRITICAL INDEX NO.
15.39A	Inverter 1D-10	(a) Fails high.	(a) High signal to 1F-5.	(a) Same as 37(b).	0.13023	
15.39B		(b) Fails low.	(b) Low signal to 1F-5.	(b) Same as 37(a).	0.13023	50