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12

COST EFFECTIVENESS STUDY OF WASTEWATER MANAGEMENT SYSTEMS FOR SELECTED U.S. COAST GUARD VESSELS

Volume V - Characteristics and Cost Estimates of Selected Marine Sanitary Devices

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FINAL REPORT

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16. Abstract

A full characterization is presented of five Marine Sanitary Devices (MSDs) which were hybridized to form the subsystems of 18 candidate Wastewater Management System (WMS) concepts considered in this study. The five MSDs considered are: Jered Sewage Disposal System, GATX Evaporative Toilet System, Chrysler "Aqua-Sans" Recirculating Oil System, Grumman Flow Through System, and a Collection, Holding, Transfer (CHT) System. All of the generic MSD data required for the development of the 18 candidate WMS configurations as a function of vessel, the effectiveness assessment of each viable candidate system/vessel combination, and the development of life-cycle cost estimates for each viable candidate system/vessel combination have been developed.

All MSD data are presented on an MSD subsystem level (and within subsystem by different available model type or equipment capacity), corresponding to the manner in which the MSDs were hybridized to form the candidate WMS configurations. The MSD data presented include the following: system description and physical characteristics; MSD related effectiveness attribute data which include the following characteristics: Adaptability for Shipboard Installation, Performance, Operability, Personnel, Safety, Habitability, Reliability, and Maintainability; acquisition costs, operating/maintenance characteristics and cost estimates including the following: operation, preventive maintenance, corrective maintenance, and overhaul.

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Volume V. Characteristics and Cost Estimates of Selected Marine Sanitary Devices

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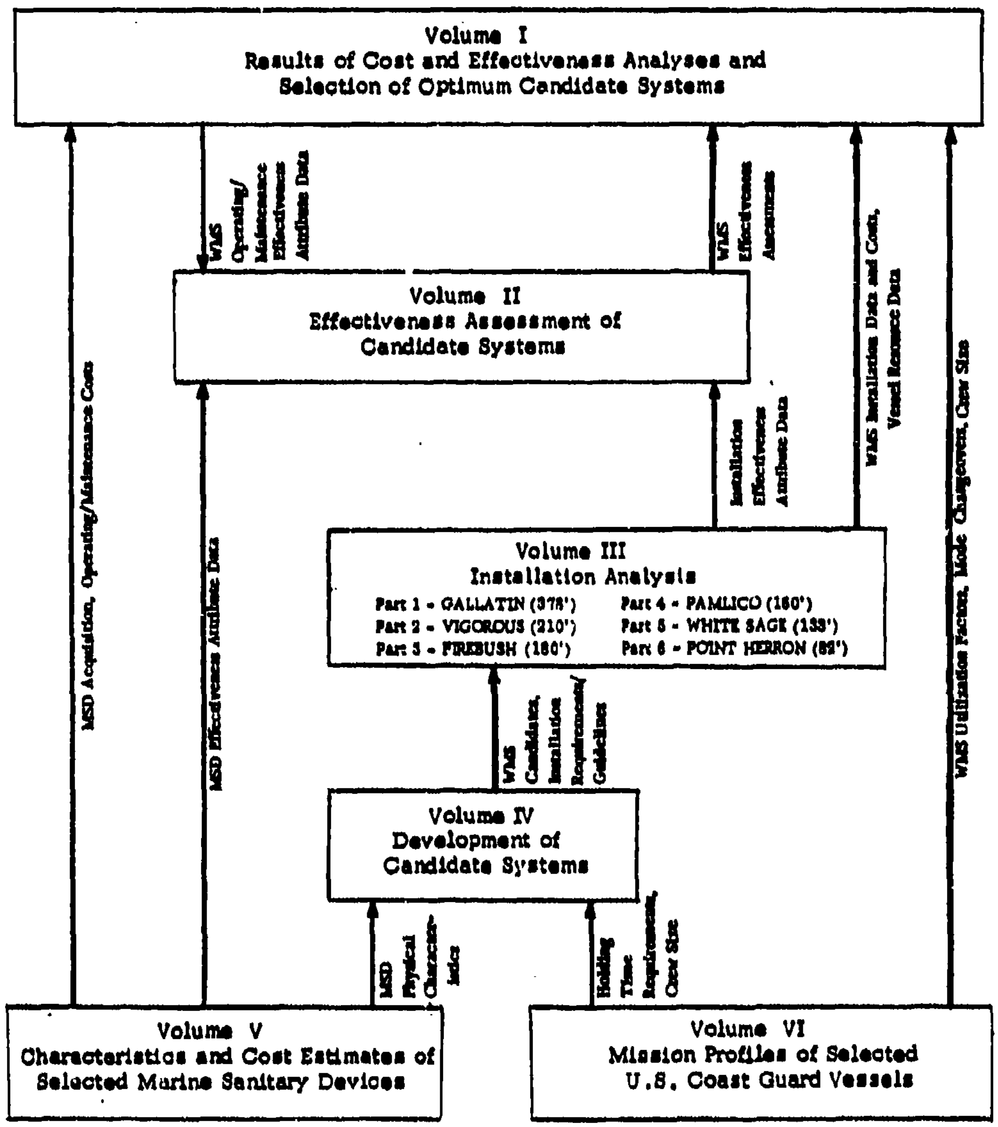
The cooperation of the following MSD equipment manufacturers in providing requested product literature, technical data and cost information is greatly appreciated, namely; Chrysler, GATX, Grumman, Jered, and Thiokol.

PREFACE

The relationship among the volumes of the report is depicted below. This relationship does not convey all the information contained within each volume.



METRIC CONVERSION FACTORS

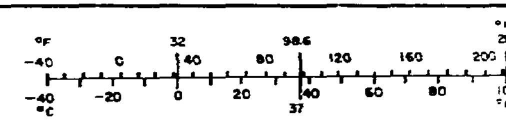
Approximate Conversions to Metric Measures

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



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INTRODUCTION

OBJECTIVES

The objective of this volume is to present a full characterization of the five Marine Sanitary Devices (MSDs) which were hybridized to form the subsystems of the 18 candidate Wastewater Management System (WMS) configurations included in this study. The purpose of this characterization is to develop the various types of generic MSD data necessary for the following phases of this study:

- Development of the 18 candidate WMS concepts and the corresponding configurations suitable for each vessel included in this study, as well as the associated installation requirements.
- Quantification of the effectiveness of each viable candidate system/vessel combination.
- Development of life cycle cost estimates for each viable candidate system/vessel combination.

In order to fulfill this objective it is necessary that all MSD data be presented on a subsystem level (as opposed to the overall MSD system level) corresponding to the manner in which the MSDs were hybridized to form the WMS candidates for managing the black (sewage and garbage grinder slurry) and gray (galley and turbid) wastewaters aboard the six U.S. Coast Guard vessels included in this study. Generally, each MSD needs to be viewed as consisting of two major subsystems namely, the waste Collection/Transport subsystem and the waste Treatment/Disposal subsystem MSDs whose Treatment/Disposal subsystems consist of waste treatment equipment and an incinerator to dispose of the residues of such waste treatment (Chrysler and Grumman MSDs), need to be further broken down for purposes of this study into two separate subsystems, in order to fulfill the data requirements of the WMS concepts which consider the substitution of a holding tank for the incinerator.

In addition, MSD subsystem data are required for the different equipment sizes and model types available from the manufacturers, in order to facilitate the development of the most suitable WMS configuration for each vessel.

The specific types of MSD data required on a subsystem level include the following:

. MSD description, including the following:

.. Principle of operation

.. Method of implementing principle of operation

.. Physical characteristics including:

- Weights
- Volumes
- Dimensions (including maximum height)
- Pipe connection specifications

.. Vessel resource hook up requirements (e.g., fuel, electric power, fresh water, compressed air, cooling water, ventilation, and ambient air).

The above information is required for the development of the candidate WMS concepts and the specific WMS configurations suitable for each vessel included in this study, as well as the associated installation requirements (see Volume IV).

. MSD related effectiveness attribute data, including the following types of information:

.. Installation characteristics

.. Performance characteristics

.. Operability characteristics

.. Personnel safety characteristics

.. Habitability characteristics

.. Reliability characteristics

.. Maintainability characteristics

The above information, in combination with other types of information, is required as input to the effectiveness rating functions which, in turn, is used to quantify the effectiveness of every viable candidate system vessel combination (see Volume II).

. MSD costs, including the following:

.. Acquisition (including initial spares parts)

.. Operation and maintenance, including the following:

- Consumables
- Repair parts
- Labor (number of men, man-hours, skills, frequency of tasks)
- Vessel resources (fuel, electric power, fresh water, compressed air, etc.)

.. MSD installation costs are not considered in this volume. Instead, installation data for each viable candidate WMS for each vessel is presented in Volume III of this report.

The above information is required as input to the development of life cycle cost estimates for each viable candidate system/vessel combination (see Volume I).

SCOPE OF MSD ANALYSIS

The MSDs to be included in this study were specified by the U.S. Coast Guard. The selection of specific MSDs was based on two considerations. First, inclusions of representatives of the different MSD concepts currently in use or under evaluation namely, reduced volume vacuum and pumped collection; recirculation; flow through; and CHT (collection, holding and transfer). Second, inclusion of a representative from each of the above concepts which has the most extensive history of actual use and/or development and testing.

MSDs Considered

The five MSDs that were included in this study were far enough along in their development to be seriously considered for installation aboard operational vessels. In order to accommodate the need for systems of various capacities for which the cited MSDs are not particularly appropriate, other selected sizes and types of equipment from the same manufacturers were included, even though the development or testing was not as extensive as for the MSDs originally selected. In order to qualify for inclusion in this study, different sizes and models of MSD subsystems had to satisfy at least one of the following requirements.

- Be operational
- Be fabricated
- Be designed (catalog item)
- Be technically supported or endorsed by the manufacturer

The following five MSDs were considered for this study:

- JERED reduced volume vacuum flush collection/incineration, Model V85003 as installed on the USS Kraus (DD 848). For reduced capacity requirements, Jered's Small Boat Sewage Collection System was considered.
- GATX reduced volume flush pumped transfer collection/evaporation, as installed on the Navy service craft MONOB (YAG-61). For reduced capacity requirements, smaller evaporators which are catalog items from the evaporator supplier, but which have not yet had the GATX modifications designed for them, were considered.
- Chrysler recirculating oil full volume flush collection/incineration, Aqua-Sans Models A, A/B and B, plus waste Holding Tank and Incinerator for Model C.

- Grumman flow through/incineration, modified version of prototype installed on USCGC Red Beech (WLM-686). The major modification is the substitution of a Thiokol Corporation incinerator subsystem in place of the Grumman incinerator. Other modifications are described further (see Grumman System Description) and in Volume IV.
- Collection, Holding and Transfer (CHT) system. The CHT System is not proprietary to any one manufacturer, and is generally custom fitted in each installation. Therefore, tank sizes, pumps and miscellaneous functions are generalized in this document.

Candidate Wastewater Management Systems Considered

The manner in which the above MSDs were hybridized to form the 18 candidate Wastewater Management System (WMS) concepts is indicated in Figure 1. The specific MSD equipments used as the building blocks for synthesizing each viable candidate WMS configuration which is suitable for handling black and gray wastewaters on board each of the six vessels included in this study are indicated in Table 1. The holding tank capacities indicated reflect the results of shipchecks and are necessarily those required to fulfill the holding time requirements. The indicated percentages for black and gray wastewater holding times indicate the percentages of the required black and gray wastewater holding tank capacities which could be fitted on the vessel due to space restrictions.

Limitations

The MSD analysis procedures used to develop the data in this document are considered to be fairly general, and applicable for study purposes of this type. However, the data presented in this document has been developed specifically for use as inputs to the cost and effectiveness analyses of the WMS candidates included in this study, and are subject to the stated assumptions and limitations.

- Management of shipboard black (sewage and garbage grinder output) and grey (galley and turbid) wastewater streams
- Separate drain lines for sewage, galley, and turbid wastewaters
- Garbage grinder output is considered sewage (black water) and is assumed to be operationally separable from galley wastewater
- Deck drains are connected to galley and turbid drain lines
- Galley and turbid drain lines are always gravity operated

Treatment/Disposal (Bk & Gr) / Sewage Collection	NO DISCHARGE					FLOW THROUGH (Grumman)					
	HOLDING TANKS	INCINERATOR	EVAPORATOR	OIL RECIRCULATION (Chrysler)		WITH SLUDGE HOLDING TANK			WITH SLUDGE INCINERATOR (Thiokol)		
						CENTRIFUGE FEED			CENTRIFUGE FEED		
				With Hold Tank	With Incinerator	Black Only	Black & Gray	Gray Only	Black Only	Black & Gray	Gray Only
GRAVITY DRAINAGE	BLACK Sewage and garbage grinder output to Holding Tank GRAY Galley/Turbid to separate Holding Tank 1			BLACK Chrysler oil recirculation system for sewage Settled sewage & garbage grinder output to Sludge Holding Tank GRAY Galley/Turbid to separate Holding Tank 2	BLACK Chrysler oil recirculation system for sewage Settled sewage and garbage grinder output to Incinerator (Chrysler) GRAY Galley/Turbid to Holding Tank 3	BLACK Sewage and garbage grinder output to Grumman via influent surge tank Sludge to Holding Tank GRAY Galley/Turbid to separate Holding Tank 4	BLACK&GRAY Sewage, garbage grinder output, Galley/Turbid to Grumman via influent surge tank Sludge to Holding Tank 5	BLACK Sewage and garbage grinder output to Holding Tank GRAY Galley/Turbid to Grumman via influent surge tank Sludge to (either separate or sewage) Holding Tank 6	BLACK Sewage and garbage grinder output to Grumman via influent surge tank Sludge to Incinerator (Thiokol) GRAY Galley/Turbid to Holding Tank 7	BLACK & GRAY Sewage, garbage grinder output, Galley/Turbid to Grumman via influent surge tank Sludge to Incinerator (Thiokol) 8	
REDUCED VOLUME FLUSH COLLECTION: VACUUM COLLECTION (JERED)	BLACK Vacuum collection of sewage in VCT Sewage transfer to Holding Tank or held in large VCT Garbage grinder output to VCT or directly to Holding Tank by gravity GRAY Galley/Turbid to separate Holding Tank 9	BLACK Vacuum collection of sewage in VCT Sewage and garbage grinder output to Incin. (Jered or Thiokol) GRAY Galley/Turbid to Holding Tank 10	BLACK Vacuum collection of sewage in VCT Sewage and garbage grinder output to GATX Evaporator GRAY Galley/Turbid to Holding Tank 11					BLACK Vacuum collection of sewage in VCT Sewage transfer to Holding Tank or held in large VCT Garbage grinder output to VCT or directly to Holding Tank by gravity GRAY Galley/Turbid to Grumman via influent surge tank Sludge to (separate or sewage) Holding Tank 12			BLACK Vacuum collection of sewage in VCT Sewage & garbage grinder output to Incin. (Thiokol) GRAY Galley/Turbid to Grumman via influent surge tank Sludge to Incin. (Thiokol) 13
MACERATOR/TRANSFER PUMP COLLECTION (GATX)	BLACK M/T Pump collection of sewage Sewage and garbage grinder output to Holding Tank GRAY Galley/Turbid to separate Holding Tank 14	BLACK M/T Pump collection of sewage Sewage and garbage grinder output to Incin. (Jered or Thiokol) GRAY Galley/Turbid to Holding Tank 15	BLACK M/T Pump collection of sewage Sewage and garbage grinder output to GATX Evaporator GRAY Galley/Turbid to Holding Tank 16					BLACK M/T Pump collection of sewage Sewage and garbage grinder output to Holding Tank GRAY Galley/Turbid to Grumman via influent surge tank Sludge to (separate or sewage) Holding Tank 17			BLACK M/T collection of sewage Sewage and garbage grinder output to Incin. (Thiokol) via surge tank GRAY Galley/Turbid to Grumman via influent surge tank Sludge to Incin. (Thiokol) 18

Figure 1

WMS CONCEPTS FOR SHIPBOARD BLACK AND GRAY WASTEWATERS

Table 1
WMS EQUIPMENT REQUIREMENTS

Vessel GALLATIN (378')

WMS Number	WMS Acceptability: For Installation (Yes/No)	WMS Acceptability: Holding Time (%) Black	WMS Acceptability: Holding Time (%) Gray	WMS Acceptability: Safety (Yes/No) (1)	Number of Fixtures: Commodes (2)	Number of Fixtures: Urinals (3)	JERED: Number of VCT's (Sized by Gallons) Small Boat 30	JERED: VCT Small Boat 60	JERED: VCT Small Boat 120	JERED: VCT Large Boat 200	JERED: VCT Large Boat 250	JERED: Number of Incinerators Jered	JERED: Number of Incinerators Thiokol	JERED: Number of M/T Pumps	GATX: Number of Evaporators (Sized by Gallons) 20	GATX: Evaporators 40	GATX: Evaporators 60	GATX: Evaporators 80	GATX: Number of Vapor Treatment Sections	GRUMMAN: Number of Treatment Subsystems	GRUMMAN: Number of Thiokol Incinerators	CHRYSLER Collection and Recircul. Subsystem: Number of Separator Tanks Model A	Separator Tanks Model A/B	Separator Tanks Model B	Number of P&FM Packages Model A	P&FM Packages Model B	Number of Sludge Surge Tanks Model B	Sludge Surge Tanks Model C	CHRYSLER Incinerator Subsystem: Number of Incinerators Model A	Incinerators Model C	Tanks (4): Black (Gallons Each Tank) FWD	Black AFT	Gray (Gallons Each Tank) FWD	Gray AFT
1	Yes	100	19	Yes	28S	16S																									5184B	2596B	1750B	2424B
2	Yes	100	18	Yes	28S	10S																	3		3						965C	487C	1571B	2424B
3	Yes	100	13	Yes	28S	10S																	3		3			1		2			539B	2424B
4	Yes	100	17	Yes	28S	10S														2											528A, 434C	265A, 217C	1750B	2020B
5	No																																	
6	No																																	
7	Yes	100	17	Yes	28S	10S														2	2										258A	265A	1750B	2020B
8	No																																	
9	Yes	100	21	Yes	28J	10S/9J			1	1																					1533B	763B	2244B	2424B
10	Yes	100	21	Yes	28J	10S/9J			1	1		2																					2244B	2424B
11	Yes	100	17	Yes	28J	10S/9J			1	1								6	6														1346B	2424B
12	No																																	
13	No																																	
14	Yes	100	30	Yes	28G	10S/10G								18																	1668B	830B	2693B	3994B
15	Yes	100	33	Yes	28G	10S/10G						1		18																			2693B	4668B
16	Yes	100	17	Yes	28G	10S/10G								18				6	6														1346B	2424B
17	No																																	
18	No																																	

WMS = Wastewater Management System
P&FM = Pressurization and Fluid Maintenance
(1) Does WMS meet all applicable safety standards?
(2) Letter following entered number means: S = Standard, J = JERED, G = GATX
(3) Letters following entered numbers mean: S = Standard urinal only, S/J = Standard urinals with indicated number of Jered urinal discharge valves, S/G = Standard urinals with indicated number of GATX flushometers.
(4) Letter following entered gallonage denotes tank usage: A = Influent Surge, B = Wastewater holding, C = Sludge holding, D = Intermediate tank not supplied with MSD.

WMS No.	1, 2	4, 14	9
Tank Height	6'0" (FWD and AFT)	5'-0" (FWD and AFT)	6'-0" (FWD) and 5'-6" (AFT)

Table 1

WMS EQUIPMENT REQUIREMENTS

Vessel VIGOROUS (210')

WMS NUMBER	WMS ACCEPTABILITY: For Installation (Yes/No)	WMS ACCEPTABILITY: Holding Time (%): Black	WMS ACCEPTABILITY: Holding Time (%): Gray	WMS ACCEPTABILITY: Safety (Yes/No) (1)	NUMBER OF FIXTURES: Commodes (2)	NUMBER OF FIXTURES: Urinals (3)	JERED: NUMBER OF VCT's (Sized By Gallons): Small Boat: 30	JERED: VCT's: Small Boat: 60	JERED: VCT's: Small Boat: 120	JERED: VCT's: Large Boat: 200	JERED: VCT's: Large Boat: 250	JERED: NUMBER OF INCINERATORS: Jered	JERED: NUMBER OF INCINERATORS: Thiokol	JERED: Number of M/T Pumps	GATX: NUMBER OF EVAPORATORS (Sized By Gallons): 20	GATX: EVAPORATORS: 40	GATX: EVAPORATORS: 60	GATX: EVAPORATORS: 80	GATX: Number of Vapor Treatment Sections	GATX: Number of Treatment Subsystems	GRUMMAN: Number of Thiokol Incinerators	GRUMMAN: Number of Separator Tanks: Model A	CHRYSLER: COLLECTION AND RECIRCUL. SUBSYSTEM: Number of Separator Tanks: Model A/B	CHRYSLER: Separator Tanks: Model B	CHRYSLER: Number of PSFM Packages: Model A	CHRYSLER: PSFM Packages: Model B	CHRYSLER: Number of Sludge Surge Tanks: Model B	CHRYSLER: Sludge Surge Tanks: Model C	CHRYSLER: INCINERATOR SUBSYSTEM: Number of Incinerators: Model A	CHRYSLER: Incinerators: Model C	TANKS (4): BLACK (Gallons Each Tank)	TANKS (4): GRAY (Gallons Each Tank)
1	Yes	40	1	Yes	17S	3S																									2154B	120B
2	Yes	53	1	Yes	17S	3S																	1		1						538C	120B
3	No																															
4	No																															
5	No																															
6	No																															
7	No																															
8	No																															
9	Yes	48	1	Yes	17J	3S/5J					1																				740B	120B
10	Yes	100	1	Yes	17J	3S/5J					1	1																				120B
11	No																															
12	No																															
13	No																															
14	Yes	100	1	Yes	17G	3S/3G								9																	1742B	120B
15	Yes	100	3	Yes	17G	3S/3G						1		9																		538B
16	Yes	100	1	Yes	17G	3S/3G								9			3		3													120B
17	No																															
18	No																															

WMS = Wastewater Management System
P&FM = Pressurization and Fluid Maintenance
(1) Does WMS meet all applicable safety standards?
(2) Letter following entered number means: S = Standard, J = JERED, G = GATX
(3) Letters following entered numbers mean: S = Standard urinal only, S/J = Standard urinals with indicated number of Jered urinal discharge valves, S/G = Standard urinals with indicated number of GATX flushometers.
(4) Letter following entered gallonage denotes tank usage: A = Influent Surge, B = Wastewater holding, C = Sludge holding, D = Intermediate tank not supplied with MSD.

WMS No.	1, 2, 9	14
Tank Height	6'-0"	5'-0"

Table i

WMS EQUIPMENT REQUIREMENTS

Vessel FIREBUSH (130')

WMS Number	WMS Acceptability: For Installation (Yes/No)	WMS Acceptability: Holding Time (%) Black	WMS Acceptability: Holding Time (%) Gray	WMS Acceptability: Safety (Yes/No) (1)	Number of Fixtures: Commodes (2)	Number of Fixtures: Urinals (3)	JERED: Number of WCT's (Sized By Gallons) Small Boat 30	Small Boat 60	Small Boat 120	Large Boat 200	Large Boat 250	JERED: Number of Incinerators: Jered	Thiokol	Number of M/T Pumps	GATX: Number of Evaporators (Sized By Gallons) 20	40	60	80	Number of Vapor Treatment Sections	Number of Treatment Subsystems	GRUMMAN: Number of Thiokol Incinerators	CHRYSLER: Collection and Recircul. Subsystem: Number of Separator Tanks Model A	Model A/B	Model B	Number of PSFM Packages Model A	Model B	Incinerator Subsystem: Number of Sludge Surge Tanks Model B	Model C	Number of Incinerators Model A	Model C	Tanks (4): Black (Gallons Each Tank)	Tanks (4): Gray (Gallons Each Tank)
1	Yes	100	0	Yes	6S	1S																									7295B	0
2	Yes	100	0	Yes	6S	1S																	1		1						1361C	0
3	Yes	100	12	Yes	6S	1S																	1		1		1			1		2395B
4	Yes	100	22	Yes	6S	1S														1											261A, 680C	4495B
5	Yes	100	100	Yes	6S	1S														2											1029A, 2345C	
6	Yes	100	100	Yes	6S	1S														2											9032B	768A
7	Yes	100	29	Yes	6S	1S														1	1										261A	6109B
8	Yes	100	100	Yes	6S	1S														2	2										1029A	
9	Yes	100	13	Yes	6J	1S/2J					1																				2145B	2737B
10	Yes	100	35	Yes	6J	1S/2J					1	1																				7295B
11	Yes	100	35	Yes	6J	1S/2J					1							2	2													7295B
12	Yes	100	100	Yes	6J	1S/2J					1									2											2145B	768A, 1737C
13	Yes	100	100	Yes	6J	1S/2J					1									1	3											768A
14	Yes	100	13	Yes	6G	1S/1G								4																	2345B	2693B
15	Yes	100	35	Yes	6G	1S/1G						1		4																		7295B
16	Yes	100	35	Yes	6G	1S/1G								4				2	2													7295B
17	Yes	100	100	Yes	6G	1S/1G								4						2											2345B	768A, 1737C
18	Yes	100	100	Yes	6G	1S/1G								4						1	3										101D	768A

WMS = Wastewater Management System

PSFM = Pressurization and Fluid Maintenance

(1) Does WMS meet all applicable safety standards?

(2) Letter following entered number means: S = Standard, J = JERED, G = GATX

(3) Letters following entered numbers mean: S = Standard urinal only, S/J = Standard urinals with indicated number of Jered urinal discharge valves, S/G = Standard urinals with indicated number of GATX flushometers.

(4) Letter following entered gallonage denotes tank usage: A = Influent Surge, B = Wastewater holding, C = Sludge holding, D = Intermediate tank not supplied with MSD.

WMS No.	1	2, 5	4	6	9, 12	14, 17
Tank Height	8'-3"	5'-0"	4'-0"	11'-1"	7'-6"	6'-9"

NOTES: (a) WMS No. 6 - Combined sewage/sludge holding tank.
(b) WMS No. 18 - Intermediate tank used as influent surge tank.

Table 1

WMS EQUIPMENT REQUIREMENTS

Vessel PAMLICO (160')[5] - New Construction

Sheet 4 of 6

WMS NUMBER	WMS Acceptability: For Installation (Yes/No)	WMS Acceptability: Holding Time (%) Black	WMS Acceptability: Holding Time (%) Gray	WMS Acceptability: Safety (Yes/No) (1)	Number of Fixtures: Commodes (2)	Number of Fixtures: Urinals (3)	JERED: Number of VCT's (Sized By Gallons) Small Boat 30	Small Boat 60	Small Boat 120	Large Boat 200	Large Boat 250	JERED: Number of Incinerators Jered	JERED: Number of Incinerators Thiokol	Number of M/T Pumps	GATX: Number of Evaporators (Sized By Gallons) 20	40	60	80	GATX: Number of Vapor Treatment Sections	GATX: Number of Treatment Subsystems	GRUMMAN: Number of Thiokol Incinerators	CHRYSLER Collection and Recircul. Subsystem: Number of Separator Tanks Model A	Model A/B	Model B	Number of P&FM Packages Model A	Model B	Number of Sludge Surge Tanks Model B	Model C	CHRYSLER Incinerator Subsystem: Number of Incinerators Model A	Model C	TANKS(4): BLACK (Gallons Each Tank)	TANKS(4): GRAY (Gallons Each Tank)
1	Yes	100	55	Yes	4S	1S																									3419B	5385B
2	Yes	100	64	Yes	4S	1S																1			1						638C	6283B
3	Yes	100	64	Yes	4S	1S																1			1				1			6283B
4	Yes	100	64	Yes	4S	1S														1											268A, 285C	6283B
5	Yes	100	100	Yes	4S	1S														1											268A,	1099C
6	Yes	100	100	Yes	4S	1S														1											4233B	200A
7	Yes	100	64	Yes	4S	1S														1	1										68A	6283B
8	Yes	100	100	Yes	4S	1S														1	1										268A	
9	Yes	100	64	Yes	4J	1S/2J	1																								1070B	6283B
10	Yes	100	64	Yes	4J	1S/2J			1				1																			6283B
11	Yes	100	64	Yes	4J	1S/2J	1									1			1													6283B
12	Yes	100	100	Yes	4J	1S/2J	1													1											1070B	200A, 814C
13	Yes	100	100	Yes	4J	1S/2J	1													1	1											200A
14	Yes	100	64	Yes	4G	1S/1G								3																	1099B	6283B
15	Yes	100	64	Yes	4G	1S/1G							1	3																		6283B
16	Yes	100	64	Yes	4G	1S/1G								3		1			1													6283B
17	Yes	100	100	Yes	4G	1S/1G								3						1											1099B	200A, 814C
18	Yes	100	100	Yes	4G	1S/1G								3						1	1										26D	200A

WMS - Wastewater Management System

P&FM - Pressurization and Fluid Maintenance

(1) Does WMS meet all applicable safety standards?

(2) Letter following entered number means: S = Standard, J = JERED, G = GATX

(3) Letters following entered numbers mean: S = Standard urinal only, S/J = Standard urinals with indicated number of Jered urinal discharge valves, S/G = Standard urinals with indicated number of GATX flushometers.

(4) Letter following entered gallonage denotes tank usage: A = Influent Surge, B = Wastewater holding, C = Sludge holding, D = Intermediate tank not supplied with MSD.

(5) Pamlico is currently outfitted with a Colt Industries 450-gallon VCT and no wastewater holding tank. Systems 9, 10, 11, 12 and 13 are configured with smaller VCT's and associated treatment/holding tank arrangements in accordance with the guidelines established for this study. It will be assumed, however, that these systems would be adequately served by the existing 450-gallon VCT plus appropriate treatment subsystems (i.e., incinerator/evaporator) with cost/effectiveness assessments treated accordingly.

WMS No.	1, 9, 12, 14, 17	2, 4	5, 6
Tank Height	6'-0"	4'-3"	5'0"

NOTES: (a) WMS No. 6 - Combined sewage/sludge holding tank.

(b) WMS No. 18 - Intermediate tank used as influent surge tank.

Table I

Vessel WHITE SAGE (133')

WMS EQUIPMENT REQUIREMENTS

WMS Number	WMS Acceptability: For Installation (Yes/No)	Holding Time (%): Black	Holding Time (%): Gray	Safety (Yes/No) (1)	Number of Fixtures: Commodes (2)	Number of Fixtures: Urinals (3)	JERED: Number of VCT's (Sized by Gallons) Small Boat 30	60	120	Large Boat 200	250	Number of Incinerators: Jered	Thiokol	GATX: Number of M/T Pumps	Number of Evaporators (Sized by Gallons) 20	40	60	80	Number of Vapor Treatment Sections	Number of Treatment Subsystems	GRUMMAN: Number of Thiokol Incinerators	CHRYSLER Collection and Recircul. Subsystem: Number of Separator Tanks Model A	A/B	B	Number of PSFM Packages Model A	B	Incinerator Subsystem: Number of Sludge Surge Tanks Model B	C	Number of Incinerators Model A	C	Tanks (4): Black (Gallons Each Tank)	Gray (Gallons Each Tank)
1	Yes	100	100	Yes	4S	1S																									722B	2063B
2	Yes	100	100	Yes	4S	1S																1			1						135C	2063B
3	Yes	100	100	Yes	4S	1S																1			1				1			2063B
4	Yes	100	100	Yes	4S	1S														1											110A, 60C	2063B
5	Yes	100	100	Yes	4S	1S														1											432A, 232C	
6	Yes	100	100	Yes	4S	1S														1											722B	323A, 172C
7	Yes	100	100	Yes	4S	1S														1	1										110A	2063B
8	Yes	100	100	Yes	4S	1S														1	1										432A	
9	Yes	100	100	Yes	4J	1S/2J	1																								200B	2063B
10	Yes	100	100	Yes	4J	1S/2J			1				1																			2063B
11	Yes	100	100	Yes	4J	1S/2J	1											1	1													2063B
12	Yes	100	100	Yes	4J	1S/2J	1													1											200B	172C, 323A
13	Yes	100	100	Yes	4J	1S/2J	1													1	1											323A
14	Yes	100	100	Yes	4G	1S/1G								3																	232B	2063B
15	Yes	100	100	Yes	4G	1S/1G							1	3																		2063B
16	Yes	100	100	Yes	4G	1S/1G								3				1	1													2063B
17	Yes	100	100	Yes	4G	1S/1G								3						1											232B	323A, 172C
18	Yes	100	100	Yes	4G	1S/1G								3						1	1										43D	323A

WMS - Wastewater Management System

PSFM - Pressurization and Fluid Maintenance

(1) Does WMS meet all applicable safety standards?

(2) Letter following entered number means: S = Standard, J = JERED, G = GATX

(3) Letters following entered numbers mean: S = Standard urinal only, S/J = Standard urinals with indicated number of Jered urinal discharge valves, S/G = Standard urinals with indicated number of GATX flushometers.

(4) Letter following entered gallonage denotes tank usage: A = Influent Surge, B = Wastewater holding, C = Sludge holding, D = Intermediate tank not supplied with MSD.

WMS No.	1, 5, 14	2, 9, 12	4	6	17
Tank Height	5'-6"	3'-0"	2'-0"	6'-0"	5'-0"

NOTE: WMS No. 18 - Intermediate tank used as influent surge tank.

Table 1

WMS EQUIPMENT REQUIREMENTS

Vessel POINT HERRON (82') Sheet 6 of 6

WMS NUMBER	For Installation (Yes/No)	WMS Acceptability: Holding Time (2) Black	WMS Acceptability: Holding Time (2) Gray	WMS Acceptability: Safety (Yes/No) (1)	Number of Fixtures: Commodes (2)	Number of Fixtures: Urinals (3)	JERED: Number of VCT's (Sized By Gallons) Small Boat 30	JERED: VCT Small Boat 60	JERED: VCT Small Boat 120	JERED: VCT Large Boat 200	JERED: VCT Large Boat 250	JERED: Number of Incinerators Jered	JERED: Number of Incinerators Thiokol	JERED: Number of M/T Pumps	GATX: Number of Evaporators (Sized By Gallons) 20	GATX: Evaporators 40	GATX: Evaporators 60	GATX: Evaporators 80	GATX: Number of Vapor Treatment Sections	Number of Treatment Subsystems	Number of Thiokol Incinerators	CHRYSLER: Collection and Recircul. Subsystem: Number of Separator Tanks Model A	Separator Tanks Model A/B	Separator Tanks Model B	Number of P&FM Packages Model A	P&FM Packages Model B	Number of Sludge Surge Tanks Model B	Sludge Surge Tanks Model C	Incinerator Subsystem: Number of Incinerators Model A	Incinerators Model C	Tanks (4): BLACK (Gallons Each Tank)	Tanks (4): GRAY (Gallons Each Tank)
1	Yes	58	0	Yes	2S	0																									242B	0
2	No																															
3	No																															
4	No																															
5	No																															
6	No																															
7	No																															
8	No																															
9a	Yes	100	20	Yes	2J	0S/1J	1																								105B	242B
10	No																															
11	Yes	100	20	Yes	2J	0S/1J	1									1			1												0	242B
12	No																															
13	No																															
14	Yes	100	20	Yes	2G	0								2																	134B	242B
15	No																															
16	Yes	100	20	Yes	2G	0								2		1			1												0	242B
17	No																															
18	No																															

WMS = Wastewater Management System
P&FM = Pressurization and Fluid Maintenance
(1) Does WMS meet all applicable safety standards?
(2) Letter following entered number means: S = Standard, J = JERED, G = GATX
(3) Letters following entered numbers mean: S = Standard urinal only, S/J = Standard urinals with indicated number of Jered urinal discharge valves, S/G = Standard urinals with indicated number of GATX flushometers.
(4) Letter following entered gallonage denotes tank usage: A = Influent Surge, B = Wastewater holding, C = Sludge holding, D = Intermediate tank not supplied with MSD.

WMS No.	1	9	14
Tank Height	2'-10"	2'-6"	3'-0"

It is noted that most of the data presented in this document have not been validated due to the lack of extensive usage of these MSDs. (especially the different models considered here) in marine environments. Unit and parts costs were obtained from manufacture's whenever possible. Other types of data, including equipment failure rates, some of the operating and maintenance activity times, and effectiveness attribute data (safety, habitability, reliability, etc.) represent estimates and judgments by Bradford personnel.

Although an attempt was made to present all MSDs at the same level of detail, those MSDs which have been longest in service may, unfortunately, be analyzed at a greater level of detail. There is also a tendency to inadvertently penalize a MSD having the most detailed Operation and Maintenance manual by including a disproportionate number of activities compared to an MSD for which there is a dearth of information.

As a result of the above limitations, caution is advised in attempting to use this data directly for systems and/or vessels specifically included in this study.

ASSUMPTIONS

A number of assumptions and Coast Guard guidelines were used in the course of developing the MSD data presented in this volume. Most of these assumptions and guidelines pertain to the operation and maintenance of the MSDs included in this study and are presented below.

Maintenance Policy

The maintenance analysis of the MSDs included in this study was governed by the following two U.S. Coast Guard guidelines:

- To the extent possible, all MSD maintenance, including overhauls, would be performed at dockside (at the vessel's home port) by vessel personnel while on board the vessel (as opposed to maintenance in a shipyard).

- To the extent possible, repair of equipment is preferred to replacement (with subsequent repair in a depot or by the manufacturer).

The above guidelines served as the basis for defining the level at which the MSD maintenance analysis should be conducted, as well as the type of maintenance activities to be included. Although it was attempted to accommodate the above guidelines by including maintenance activities which deal with repairs which could reasonably be accomplished by vessel personnel, the determination of the level of repair (as well as which repairs to include) remains somewhat arbitrary and is a matter of judgement by the analyst.

Overhaul Intervals

Definitive overhaul policies could not be obtained from all MSD manufacturers. As a result, an interval of two years between overhauls was assumed for purposes of estimating MSD (life cycle) overhaul costs.

Cost of Labor

Personnel aboard U.S. Coast Guard vessels are in principle available for duty while on board and are not paid on an hourly basis or on the basis of specific equipments which they operate and maintain. However, in order to estimate the share of the vessel's manpower resources which would be consumed by the MSD when installed on such vessels, it is convenient to have an hourly labor rate for different skill levels of Coast Guard shipboard personnel. Such hourly labor rates can then be readily related to MSD operating and maintenance task requirements.

Since hourly labor rates are not readily available for Coast Guard personnel, such labor rates were developed for purposes of this study on the basis of available data on Coast Guard personnel qualifications and annual billet costs. In lieu of regularly defined work schedules which are not available for Coast Guard shipboard personnel, an eight hour day, five days per week, work schedule was assumed for purposes of this study.

yielding 2,080 work hours per year. Hourly labor rates were then obtained by dividing the annual billet cost for a given skill level by 2080 (see page 18, APPROACH). Estimates of labor costs were based on skill requirements for MSD operation and maintenance, rather than on personnel skill availabilities on board a given vessel.

Cost of Vessel Resources

Although resources available aboard a vessel already exist to support other functions and are generally not installed for the sole purpose of supporting an MSD, it is nevertheless important to estimate the cost of such resources which would be attributable to an MSD when installed on board the vessel. Another reason for estimating these resource requirements is that such an estimate will help determine whether an MSD installation would strain vessel resources and perhaps require upgrading of the available storage or generation capacity. Furthermore, it is noted that, except for fresh water which is stored on board some vessels (as opposed to generating it by an evaporator), all vessel resources derive from conversion of fuel (see Appendix B for derivations), and hence constitute a direct cost item.

For purposes of this study the cost of vessel resources is assumed to be as follows:

- 39¢/gallon of fuel oil
- 3¢/kwh of electric power
- 70¢/1000 gallons of fresh water, if taken from shore supply
- $20/1000 gallons (2¢/gallon) of fresh water, if generated on board vessel by an evaporator
- 1.83¢/1000 gallons for the cost of electric power to pump flushing fluid
- $[6.1227 (14.7 + p)^{0.1419} - 8.9898]$ [V] is the annual cost of compressed air in cents, where p is pressure in psig and V is the flow in standard cubic feet per day.

Miscellaneous

The following additional assumptions were made, affecting the cost of MSD operation and maintanance:

- The cost of lubricating oil and grease is assumed to be negligible with the differential costs between MSDs to be insignificant.
- The standard and high wattage heating elements in all sizes of GATX evaporators are assumed to be equal in cost to the standard heaters in the currently used 80 gallon evaporator. End connections of heating elements are a significant portion of the element cost and is fairly constant for all wattages used. This tends to minimize cost variations.
- Grumman MSDs are assumed to have the same operating and maintenance characteristics and costs regardless of the type of waste input, i.e., combined black and gray, standard flush black water or gray water only. Variations due to differences of influent flow rate will be accounted for later on in the utilization factor applicable to a given vessel (see Volume 1). Variations due to type of waste are too difficult and uncertain to ascertain and are therefore ignored.
- Electrical and electronic controls and the electrical portions of motors and solenoid valves are assumed to warrant corrective maintenance only, i.e., they are always run to failure. Preventive maintenance is considered generally impossible or impractical on board the vessel for these items. Replacement or repair during overhaul will not be performed as a preventive measure but will be done for those devices that have exhibited intermittent or temporary failures.
- The times specified for maintenance are intrinsic repair times and do not include logistic delay times such as the time to gather tools, draw parts from stock, extensive cleanup, parts ordering, or time to get to the compartment in which the equipment is located.

- Corrective maintenance includes diagnostic time to detect and isolate a fault as well as checkout time after repair.

- Equipment in parallel, e.g., dual/redundant pumps, are assumed to wear or fail at equal rates.

- Where multiple units are involved, e.g., commodes, parallel pumps, multiples of relays, operation (OP) preventive maintenance (PM) and overhaul (OH) apply to all units. Corrective maintenance (CM) is assumed to apply only to the one unit that failed.

- Where multiple items are involved, the failure rate of a single item (as well as the number of spare parts used and costs thereof) is multiplied by the number of multiple units.

- Where a number of corrective maintenance actions are listed for a component and preparative time, i.e., isolation, disassembly, drainage, etc. is required for any of the actions, then the preparative time is included for each action. For preventative maintenance and overhaul, the preparative time is included only once, regardless of the number of actions subsequently taken.

- The pressure generated by a pump that supplies flush fluid is assumed to be 50 psig on all vessels. For pumping other liquids, the pressure used for calculation is the known pressure requirement. If not known, 50 psig is generally assumed.

- The pressure used for calculating compressed air power or costs is that which is required by the end use item. Although normal practice calls for compression to some higher level and reduction through a regulator, this energy is ignored.

- Labor costs are assumed for the minimum skill level or pay grade that can execute the required action, regardless of the availability of such personnel on board a given vessel.

- All data entries assume that the MSD is in usage all the time, i.e., the system and subsystem are available round the clock (100% utilization factor). This does not mean that every device operates continuously, but only when called for in the normal course of operation.
- Where the load on an electrical motor cannot readily be calculated, the load is assumed to be equal to the full horsepower rating.
- Changeover in mode of operating a WMS is assumed to be in full cycles, i.e., after changing from primary WMS mode of operation to either overboard dumping or discharging to a pier connection, the WMS is restored to primary mode operating status.

APPROACH

The approach used in the development of the MSD data presented in this volume is discussed below.

Sources of Data

The following sources of data were utilized in the development of the MSD information presented in this volume:

- Visits to Coast Guard, Army, Navy, and commercial vessels on which the MSDs included in this study have been installed and are either operational or are under evaluation. These visists provided an opportunity to inspect the installation of these systems and to obtain information on the operation, maintenance, performance, habitability and other related aspects of these MSDs.
- MSD Operating and Maintenance Manuals.
- MSD manufacturer personnel and literature.
- Navy MSD test and evaluation reports.
- Navy personnel conducting MSD test and evaluation studies.
- Navy Maintenance Requirements Cards (MRCs) for Jered and GATX MSDs.

- U.S. Coast Guard personnel conducting MSD test and evaluation studies.
- Engineering judgements by Bradford personnel.

Whenever practical, the source of data or estimates have been indicated in footnotes. In order to acquire the most realistic data, preference was given to information obtained from operational experience, i.e., from personnel running operating equipment or demonstration tests. The hands-on experience by manufacturers was ranked second but was tempered by the supposition of inherent bias. Where inconsistent data were obtained from two or more equally ranked sources, the most penalizing, credible data were used. This is compatible with the case of a manufacturer recommending more preventive maintenance than was performed by operating personnel. The assumption is that the personnel were too busy or lax and had not yet seen the results of their failure to provide adequate preventive maintenance.

MSD Descriptions and Physical Characteristics

MSD descriptions and physical characteristics were derived from MSD O&M Manuals, manufacturer literature and personnel, and Bradford personnel familiarity with some of the MSDs included in this study. It is noted that since CHT systems are not standard MSD systems marketed as such by MSD manufacturers, but instead are custom fitted for a vessel, specific CHT physical characteristics (such as weight and volume) cannot be given. Physical characteristics of CHT systems are presented in Volume III of this report as part of the WMS installation analysis.

MSD Effectiveness Attribute Data

The MSD effectiveness attribute data represents generic MSD characteristics which are specifically of interest in assessing the overall effectiveness of the candidate WMS configurations for each vessel. These data were developed on the basis of the MSD analyses, available information, and judgements by Bradford personnel. Wherever considered appropriate, the data are supported by footnotes to explain the reasoning that led to specific results or judgements.

The MSD effectiveness attribute data are geared to the objective of fulfilling the input requirements of the structure of the effectiveness model and the associated effectiveness rating functions developed in Volume 2. These effectiveness attribute data are organized by MSD and within each MSD are subdivided by Measure of Effectiveness (M/E). There are seven M/Es which essentially are intended to evaluate different aspects or characteristics of the MSDs. The seven M/Es or types of characteristics are as follows:

- I - ADPATABILITY FOR SHIPBOARD INSTALLATION
- II - PERFORMANCE
- III - OPERABILITY
- IV - PERSONNEL SAFETY
- V - HABITABILITY
- VI - RELIABILITY
- VII - MAINTAINABILITY

Within each M/E the effectiveness attribute data are organized by elementary factor/subfactor which are identified by a unique number. These elementary factors/subfactors address specific MSD characteristics or attributes, some of which are subjective in nature.

In order to fulfill the objectives of this study, the effectiveness attribute data are presented on an MSD subsystem level in accordance with the manner in which these MSDs are hybridized to form the 18 candidate WMS concepts included in this study. The relationship between effectiveness attribute data at the MSD subsystem level and the WMS level is presented in Tables 2 and 3, which indicate cross-references between

Table 2

WMS/MSD CROSS REFERENCE FOR EFFECTIVENESS ATTRIBUTE DATA

WMS No.	Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem	
		Black	Gray
1	CHT	CHT	CHT
2	Chrysler	Chrysler with Holding Tank	CHT
3	Chrysler	Chrysler with Incinerator	CHT
4	Grumman	Grumman with Holding Tank	CHT
5	Grumman	Grumman with Holding Tank	
6	CHT	CHT	Grumman with Holding Tank
7	Grumman	Grumman with Incinerator	CHT
8	Grumman	Grumman with Incinerator	
9	Jered (1)	CHT	CHT
10	Jered (1)	Jered/Thiokol Incinerator (2)	CHT
11	Jered (1)	GATX	CHT
12	Jered (1)	CHT	Grumman with Holding Tank
13	Jered (1)	Thiokol Incinerator (3)	Grumman with Incinerator
14	GATX	CHT	CHT
15	GATX	Jered/Thiokol Incinerator (3)	CHT
16	GATX	GATX	CHT
17	GATX	CHT	Grumman with Holding Tank
18	GATX	Thiokol Incinerator (3)	Grumman with Incinerator

(1) Large or small boat system, depending on vessel. Effectiveness attribute data based on large boat system.

(2) Jered or Thiokol incinerator, depending on vessel. Effectiveness attribute data based on Jered incinerator.

(3) Thiokol incinerator used in conjunction with the Grumman MSD treating the gray water stream. Effectiveness attribute data based on Jered incinerator.

Table 3

MSD/WMS CROSS REFERENCE FOR EFFECTIVENESS ATTRIBUTE DATA

JERED	
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem (Black)
9, 10, 11, 12, 13	10*, 13**, 15*, 18**

GATX	
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem (Black)
14, 15, 16, 17, 18	11, 16

CHRYSLER		
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem (Black)	
	With Holding Tank	With Incinerator
2, 3	2	3

GRUMMAN				
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem			
	With Holding Tank		With Incinerator	
	Black	Gray	Black	Gray
4, 5, 7, 8.	4, 5	5, 6, 12, 17	7, 8	8, 13, 18

CHT		
Collection/Transport Subsystem (Black)	Treatment/Disposal Subsystem	
	Black	Gray
1, 6	1, 6, 9, 12, 14, 17	1, 2, 3, 4, 7, 9, 10, 11, 14, 15, 16

* Jered or Thiokol incinerator. Effectiveness attribute date based on Jered incinerator.

** Thiokol incinerator. Effectiveness attribute data based on Jered incinerator.

WMS No. and MSD subsystem and vice versa. Table 2, in effect, indicates how the 18 WMS concepts (see Figure 1) have been formed as hybrid combinations of the MSD subsystems. The manner in which effectiveness attribute data at the MSD subsystem level is combined to form effectiveness attribute data at the WMS level (sometimes in combination with other types of attribute data, e.g., WMS installation related attribute data) is documented by each effectiveness rating function for the correspondingly numbered elementary factor or subfactor (see effectiveness rating functions in Volume 2 of this report).

Acquisition Costs

Acquisition costs were obtained from MSD manufacturers. Exceptions were the Grumman MSD, and the Thiokol incinerator used with the Grumman. Estimated acquisition costs for these two subsystems were provided by the Coast Guard. Since CHT systems are not standard MSD systems marketed as such by MSD manufacturers, but instead are custom fitted for a vessel, a CHT system is assumed to have no acquisition cost. A CHT system is assumed to have an installation cost only, i.e., the cost of required materials to fabricate the tanks, and the cost of associated pumps are considered to be part of the installation cost (operating and maintenance associated with CHT systems are treated in the same manner as other MSDs).

In accordance with the objectives of this study, acquisition costs were solicited from MSD manufacturers on a subsystem level (rather than on an overall MSD level), corresponding to the manner in which the MSDs have been hybridized to form the 18 WMS candidate concepts.

Accordingly, data forms were prepared for each MSD in which each subsystem, including all different equipment sizes and model types of interest, were individually listed. The MSD manufacturer was requested to provide an acquisition cost for each listed subsystem or equipment on the basis of 1976 costs and a production run of up to 100 units. In addition, cost estimates were requested for initial spares packages required to support each listed subsystem, together with estimates of how many subsystems can reasonably be supported by one initial spares package.

Labor Rates for MSD Operation and Maintenance

Guidance for selection of skill level was furnished by a Coast Guard Manual[1] which does not give qualifications for ratings below E4. Abstracts of skill level abilities are given in Table 4. Labor costs for various skill levels were obtained from a Coast Guard study[2] which reflects total costs to the government including such often neglected items as cost of education and training, severance pay, pensions, etc. Annual billet cost was converted to hourly rates by using the Coast Guard assumed working time as 2080 hours per year. These rates are presented in Table 5. The apparent discrepancy in pay rates between an electrician's mate and a machinery technician is primarily due to the difference in the median years of service.

Conversion of labor grades of Navy personnel, prescribed for maintenance actions on MRCs, was made by equating a Fireman as an E2, and EM3, and EN3 as an E3.

(1) Enlisted Qualification Manual CG-311 (1975) DOT, USCG.
(2) USCG Military and Civilian Manpower Billet and Life Cycle Costing, July 1975.

Table 4

RATINGS AND SKILLS OF USCG ENLISTED PERSONNEL

Ratings*

Chief Petty Officer - E7
Petty Officer 1st class - E6
Petty Officer 2nd class - E5
Petty Officer 3rd class - E4

Skills

E4 Electricians Mate or Electronics Technician EM or ET

Knowledge to replace motor bearings
Knowledge of common motor faults
Testing of miscellaneous appliances

E4 Machinery Technician MK

Change dehydrator in refrigeration system
Operate halogen leak detector
Repack compressor stuffing boxes
Line up, start, operate and secure miscellaneous auxiliary equipment, eg: air compressors
environmental pollution control system

E5 Electrician's Mate or Electronic Technician EM or ET

Rewind controller solenoids
Replace heating units, thermostats, relays, switches
IC equipment maintenance
Assist in repair and adjustment of electric motors and associated equipment

E5 Machinery Technician MK

Chemically remove scale from distilling plant
Change/add oil to refrigeration compressor
Determine wear and overhaul pump
Adjust automatic regulating valves

E6 Electricians' Mate or Electronics Technician EM or ET

Adjust time-sequence relay
Trouble shoot electrical control circuits and follow corrective procedures

E6 Machinery Technician MK

Test and renew oil seals in refrigeration compressor
Major repairs on refrigeration system

* From DOT USCG Enlisted Qualifications Manual CG-311 (1975)

Table 5

LABOR RATES*

Pay Grade	Electricians Mate (EM)		Machinery Technician (MK)	
	Annual+ ($)	Hourly Rate ($/hour)	Annual+ ($)	Hourly Rate ($/hour)
E-2	11,332	5.45	13,038	6.27
E-3	12,396	5.96	14,235	6.84
E-4	13,522	6.50	15,425	7.42
E-5	15,023	7.22	16,911	8.13
E-6	20,240	9.73	23,215	11.16

+ Source of annual billet costs - USCG Military and Civilian Manpower Billet and Life Cycle Costing, July 1975.

* Hourly rate based on annual billet costs and assumed 2080 hours per year.

Analysis and Classification of Operating and Maintenance Tasks

Analysis of MSD operating and maintenance requirements provides data for estimating the WMS life cycle costs of the recurring expenditures (as opposed to the fixed costs of acquisition and installation). However, besides providing cost information, a lot of added useful information can be gleaned from such an analysis if the data are recorded and organized in an orderly and systematic manner. Specifically, the type of information which can be obtained from such an analysis (some of which constitutes effectiveness attribute data) includes the following:

- Man-hour resource utilization, including the following:
  - Number of men required
  - Skill level requirements
  - Total man-hour requirements
  - Periodicity and duration of operating/maintenance tasks
- Consumable requirements
- Spare and repair parts logistic requirements
- Vessel resource requirements (fuel, electric power, fresh water, compressed air, etc.).

In order to proceed with this analysis in an orderly fashion, all activities associated with MSDs were divided into two main categories, namely:

- Operation
- Maintenance

MSD maintenance was then subdivided into the following three subcategories:

- Preventive (scheduled) maintenance
- Corrective (unscheduled) maintenance
- Overhaul

It is noted that such categorization not only facilitates analysis of MSD operation and maintenance, but it can also yield some important information and direction for MSD improvement programs. Some examples of this are:

- If operating requirements are unduly severe, automation of the operation might be considered.
- If the corrective maintenance burden is too severe, relief might be sought along the lines of equipment/system reliability improvement, or inclusion of additional or better fault detection and/or isolation devices.
- If the preventive maintenance burden is considered to be too great, it might be alleviated by substitution of materials which require less maintenance, by redesign, by adoption of different maintenance procedures or schedules, by parts substitution, etc.
- If overhauls are considered to take too long, thus making the equipment (and perhaps the vessel) unavailable for unacceptably long periods of time, progressive maintenance might be considered. Progressive maintenance, an approach utilized by the Navy, calls for modularization of the system in such a way that overhauls are in effect stretched out over time (as opposed to complete overhaul at one time). This is accomplished by substituting a major system module (which takes comparatively little time) with one taken from a pool of such modules which have been overhauled prior to the ship's arrival at the yard. During each ship visit, a different module is interchanged. In time, the entire system will have undergone overhaul.

Before the analysis of MSD operating and maintenance requirements could proceed, it was necessary to ensure that the above categorization of task types was well defined and unambiguous. Corrective maintenance tasks arise as a result of random equipment failures and hence are not scheduled tasks. Overhauls are scheduled after extended system operation and are intended to restore systems to their original status, to make major modifications or improvements, and generally to counteract the effects of wearout, so as to prevent major system breakdowns.

However, operation and preventive and maintenance tasks are both scheduled and a priori prescribed activities, and the distinction between them is not always obvious. Certain activities clearly fall into one or the other category. For example, removing ashes from an incinerator or adding chemicals to a waste treatment system are clearly operating activities. Similarly, greasing bearings is clearly a preventive maintenance activity. But, how should one classify an activity such as replacing a filter? Is it an operating activity or is it a preventive maintenance activity? The answer is not a priori obvious, nor are there well established definitions of tasks which would help one to decide one way or another.

To resolve such ambiguities, a rule had to be established against which ambiguous tasks could be tested in order to determine whether it is to be categorized as an operating activity or a preventive maintenance activity. The rule adopted is based on the following conventions:

- A task is classified as an <u>operating</u> activity if the following two conditions apply:
  - Failure to perform this task may degrade the performance of the system so that it is longer in conformance with specifications or it may become unacceptable (e.g., a reduction in the rate of processing wastes, or an increase in odor).

.. However, failure to perform this task will not result in system/subsystem/equipment failures or accelerated wear-out of any system component.

- A task is classified as a preventive maintenance activity if the following two conditions apply:

.. Failure to perform this task may result in a system/subsystem/equipment failure, or the accelerated wearout of one or more system components.

.. However, failure to perform this task will not result in the performance of the system to be degraded so that it no longer conforms to specifications or becomes unacceptable.

The above rule can be used to resolve the question raised earlier whether replacement of a filter constitutes an operating or a preventive maintenance task. The answer depends on the type, or the function, of the filter in question. If the filter is used to purify wastes, replacement of the filter is an operating activity. On the other hand, if the filter is used to purify lubricating oil, replacement of the filter is a preventive maintenance activity. Further discussion and definitions of operating and maintenance task categories appear in Appendix B.

Treatment of Dependencies Inherent in Operating/Maintenance Data

In accordance with the objectives of this analysis, it is necessary to present MSD operating and maintenance data on a subsystem level (as opposed to the overall MSD level) corresponding to the manner in which the MSD are hybridized to form the candidate WMS configurations. This requirement poses special problems in the development and presentation of operating and maintenance data.

These problems arise from the fact that the data to be presented should be generic and general MSD data which are applicable for evaluating any WMS configuration on any given vessel. However, some of the data depend on other factors, such as vessel type, crew size, installation, etc. As a result, when such dependencies occur, explicit data cannot be provided. Instead, the data (i.e., quantities or costs) have to be expressed in terms of one or more variables which depend on the vessel, the installation, mission profiles, etc. Only when the context and specifics of a given WMS configuration on a given vessel become known can values be assigned to these variables and the data (at the WMS level not the MSD subsystem level) can be made explicit.

Examples of such dependencies and the manner in which they are treated include the following:

- Operation/maintenance activities, part requirements, and vessel resource utilization of fixtures, pumps, etc., depend on the number of such units for any candidate system/vessel combination. As a result, data have to be given on a per unit basis rather than on a per system or subsystem basis.

- Vessel resource utilization and certain replacement part (e.g., Jered and Chrysler incinerator liners) requirements are a function of crew size. As a result, such data are given on a per capita basis rather than on a per system or subsystem basis.

- Labor and costs for mode changeovers (from primary mode to overboard discharge or pierside connection, and vice versa) depend on vessel mission profiles (i.e., the number of 3-mile limit crossings and the number of pier dockings). As a result, such data are given on a per mode changeover basis rather than on a system or subsystem basis.

- The cost of fresh water depends on the type of vessel on which the WMS is installed, i.e., the source of fresh water-whether taken from shore and stored or whether generated on board the vessel by an evaporator. This is due to the large difference in cost of fresh water depending on source (70¢/1000 gallons for stored water versus $20/1000 gallons for generated water). As a result, two different costs are given for fresh water.

- The electric power consumption and cost for compressed air depends on both the rate of usage and the pressure at which it is used. If compressed air is used by an MSD subsystem at a known pressure, then the cost of this vessel resource can be calculated on a per subsystem basis. However, compressed air used to aerate a black water holding tank depends on both the volume and the maximum height of the holding tank, since this height will determine the pressure at which compressed air is used. However, tank dimensions are vessel installation dependent and hence are variables. As a result, compressed air consumption and cost are given in terms of the two variables: rate of consumption and pressure, rather than on a system or subsystem basis.

Presentation of Operating/Maintenance Data

Data for operating and maintenance tasks were recorded on the data sheets shown in Figures 2, 3, 4 and 5 for operating, preventive maintenance, corrective maintenance and overhaul tasks, respectively. The data are presented on an MSD basis and within an MSD in the sequence: operation, preventive maintenance, corrective maintenance, and overhaul. The data presented in the four sections are grouped by MSD subsystem and sometimes by sub-subsystem. The groupings are consistent for each MSD. These separations permit assessment of a hybrid WMS which, for example, utilizes

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD ____________ Page ___ of ___

	LABOR						VESSEL RESOURCES USED										MATERIALS CONSUMED				TOTAL
							Resource Usage Rate					Annual Cost of Resource Consumed									
Operational Requirement	Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs-Min)	Number Operators/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing water (kwh/day)	Compressed Air (SCF/day @ P)	Electric Power (@ 3¢/kwh)	Fuel Oil (@ 35¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.83¢/1000 gal)	Compressed Air (see footnote)	Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	Annual Operating Cost ($)

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

Compressed Air Cost in ¢/Year $= \left(6.12268\ (14.7 + p)^{0.1429} - 8.9898\right)\left(\text{SCF/day}\right)$ where p is in psig

SCF = standard cubic feet at 14.7 psi and 70°F

Figure 2

DATA SHEET FOR MSD OPERATION

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD ______________________ Page______of______

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)

Figure 3

DATA SHEET FOR MSD PREVENTIVE MAINTENANCE

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD ____________

Page ____ of ____

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)

Figure 4

DATA SHEET FOR MSD CORRECTIVE MAINTENANCE

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD ____________

Page ______ of ______

LABOR							PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

Figure 5

DATA SHEET FOR MSD OVERHAUL

the collection subsystem from one MSD with the treatment subsystem from a different MSD. Where the MSD manufacturer has established more than one size (or capacity) component, equipment or subsystem, the different sizes are included.

Every MSD operating or maintenance activity that would have a reasonably significant impact on labor, vessel resources, material consumption or spare parts was included on these forms. For example, fixture flushing by users has no effect on labor for operation or maintenance but has an effect on vessel resource consumption (electric power and, for Jered and GATX collection subsystem, fresh water).

Sources of data for the activities included the manufacturer's O&M manual, Navy MSD test reports, preliminary Navy Maintenance Requirement Cards (MRC) for GATX and Jered MSDs, and recommendations by the Manufacturer, Coast Guard personnel, demonstration vessel personnel and the engineering judgment of Bradford personnel. Data were obtained from these sources in addition to calculated information. Calculations for vessel resource utilization were based on equations furnished by the Coast Guard, and are detailed in Appendix B.

Much of the data giving the time required to carry out an action was estimated by Bradford personnel using their own personal experience as well as the similarities to actions observed, tested for and prescribed by others. The time given for execution of the action is usually without allowance for time to get to the scene of the action, gathering tools, withdrawing parts from stock, extensive cleanup or procedures for replacement of stock.

The skill level required for a stated activity is the assumed minimum level. A system is not penalized if manpower availability aboard the vessel dictates the use of more skilled operating or maintenance personnel than is necessary.

Operation and maintenance on MSD can be provided with only two ratings: Machinery Technician (MK) and Electricians Mate (EM). The few simple electronic tasks are assumed to be within the electricians mate's capability and the pay differences are within 10%. The pay grades and skill type are combined for simplicity of presentation, e.g., MK2 is an E-2 machinery technician; EM5 is an E-5 electrician's mate.

Estimated time required for a given activity is given in hours-minutes. The following examples explain the method of representation. Twenty minutes is shown as -20, seventy five minutes as 1-15, and one hundred and twenty minutes as 2-.

Electrical controls are treated in the data forms with the subsystem or sub-subsystem (component) to which they are related. The power and cost of automatic operation are included with those for the component or subsystem. Power consumption data reflect the integrated value for items that do not operate continuously or at constant rates.

Multiple units are indicated by a number in parentheses following the item name in the activity description whenever the number of units is known. Operation, preventive maintenance and overhaul apply to all of the multiples. Corrective maintenance applies only to the one failed unit but the estimated frequency of failure, as well as the number/cost of spares used, takes the population into account.

Wherever practical, the data shown are dependent only on the MSD being operational, e.g., an exhaust blower that runs continuously whenever the system is on. However, some data are clearly dependent on the number of men using the system, e.g., power to pump flush fluid. These data are given in per capita form. Where characteristics and costs are dependent partly on the MSD and partly on crew size, a judgment was made as to the significance and difficulty of calculation and a selection was made of the method of calculation to be used. Labor costs to switch the MSD mode of operation from treatment to off loading or to pumping overboard are mission profile dependent. These data are given in per cycle form, where a cycle includes the reversal of mode changeover. Vessel dependent data, in these tables, are found in the cost of fresh water which is contingent upon the source, i.e., generated on board or storage of shoreside supply. The resulting water costs are shown both ways. Installation dependence occurs in instances where the number of multiple units is variable within an MSD, i.e., number of commodes, urinals, transfer pumps, etc. Cost figures are given per unit or per pump. In summary, dependent data are presented in one of the following forms:

- Data reflecting both MSD and per capita influence, are shown in the form (X.XX + Y.YY/capita).
- Data that are not dependent only upon an MSD are presented in one of the following appropriate forms:
  - x.xx/c = value per capita
  - x.xx/cy = value per (changeover) cycle
  - x.xx/unit = value per unit, i.e., per commode, per flushometer
  - x.xx/pump = value per pump

Data entries frequently have superscript letters to indicate the general origin of the entry. The coding for these letters (which omit the i and l characters) are:

a. Manufacturer's Operation and Maintenance (O&M) Manual
b. Manufacturer's catalog/literature/letter
c. Manufacturer's report
d. Manufacturer's personnel
e. Demonstration vessel personnel
f. U.S. Coast Guard report
g. U.S. Coast Guard personnel
h. U.S. Navy report
j. U.S. Navy personnel
k. Bradford calculation
m. Bradford personnel judgment or estimate
n. Navy Maintenance Requirement Card (MRC) (possibly preliminary)
p. U.S Coast Guard demonstration vessel data log

The first three columns of each data form present then (1) time between repetition of the activity, (2) time for execution of the activity and (3) the number and labor category of personnel required. Since so many entries in these columns were the result of Bradford personnel judgment, the superscript 'm' was omitted for clarity and easier reading. Other sources of input are always indicated. Obvious calculations such as annual hours, annual labor costs, total material costs and the sum of material and labor costs were performed by Bradford but the data are entered without superscript. The superscript 'k' indicates that the data were from another source but manipulated or converted by Bradford to conform to the column heading format. Data from another source that was manipulated by Bradford personnel, having to make judgments in the process, received an 'm' as the superscript.

JERED SEWAGE DISPOSAL SYSTEM

PRINCIPLES OF OPERATION

The Jered MSD is based on the use of vacuum collection of human wastes from proprietary, reduced flush commodes. Wastes from standard urinals are also collected by the vacuum drains by means of a special interface valve. The collected sewage is incinerated in a vortex incinerator. It is the only MSD considered in this study that provides motive power for transport of sewage at the central collection site.

The primary Jered MSD under consideration is the model V85003 that was installed as a test system on the USS Kraus. The system has the capacity to handle a maximum of 200 men on a 24-hour basis. In order to examine a vacuum collection system that is practical for significantly fewer users, the Jered Small Boat Collection System was included in this study. The small boat system is essentially a collection and holding system; it does not include an incinerator. Available information on this system is much less extensive that for the 200-man system. The small boat system is available in different capacities. In the description of it below, prospective minor modifications are discussed which would be expected if the system is to be adapted for use with a small incineration subsystem, possibly by another manufacturer. Currently, Jered has only one size incinerator.

The 200-man MSD is an automatic system but requires an operator for periodic ash removal from the incinerator. However, the system is quite complex and requires a fair amount of operator and preventive maintenance actions.

A function block diagram of the Jered Large Boat Sewage Disposal System is presented in Figure 6. A functional block diagram of the Jered Small Boat Waste Collection System appears in Figure 7.

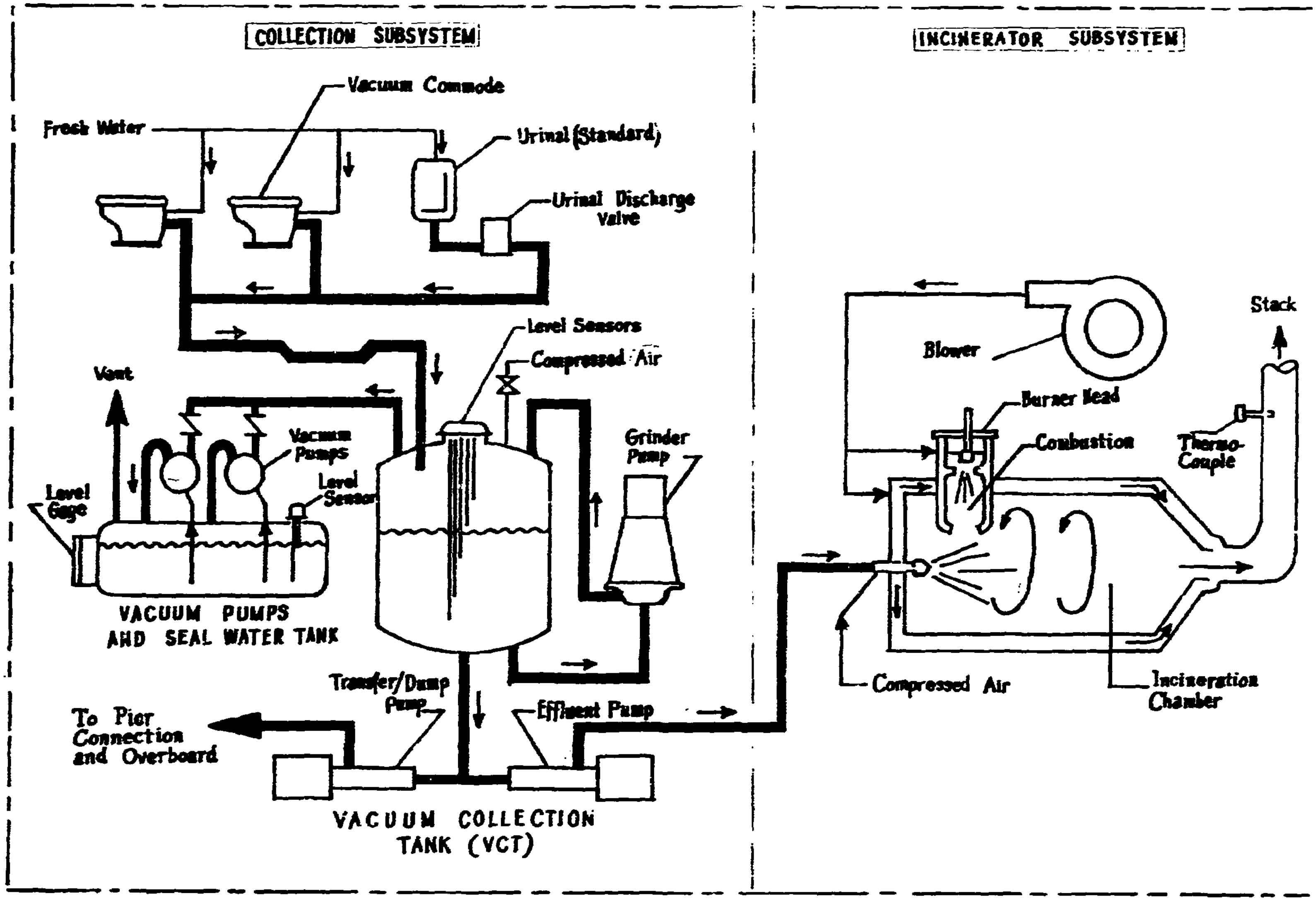

Figure 6

JERED LARGE BOAT SEWAGE DISPOSAL SYSTEM

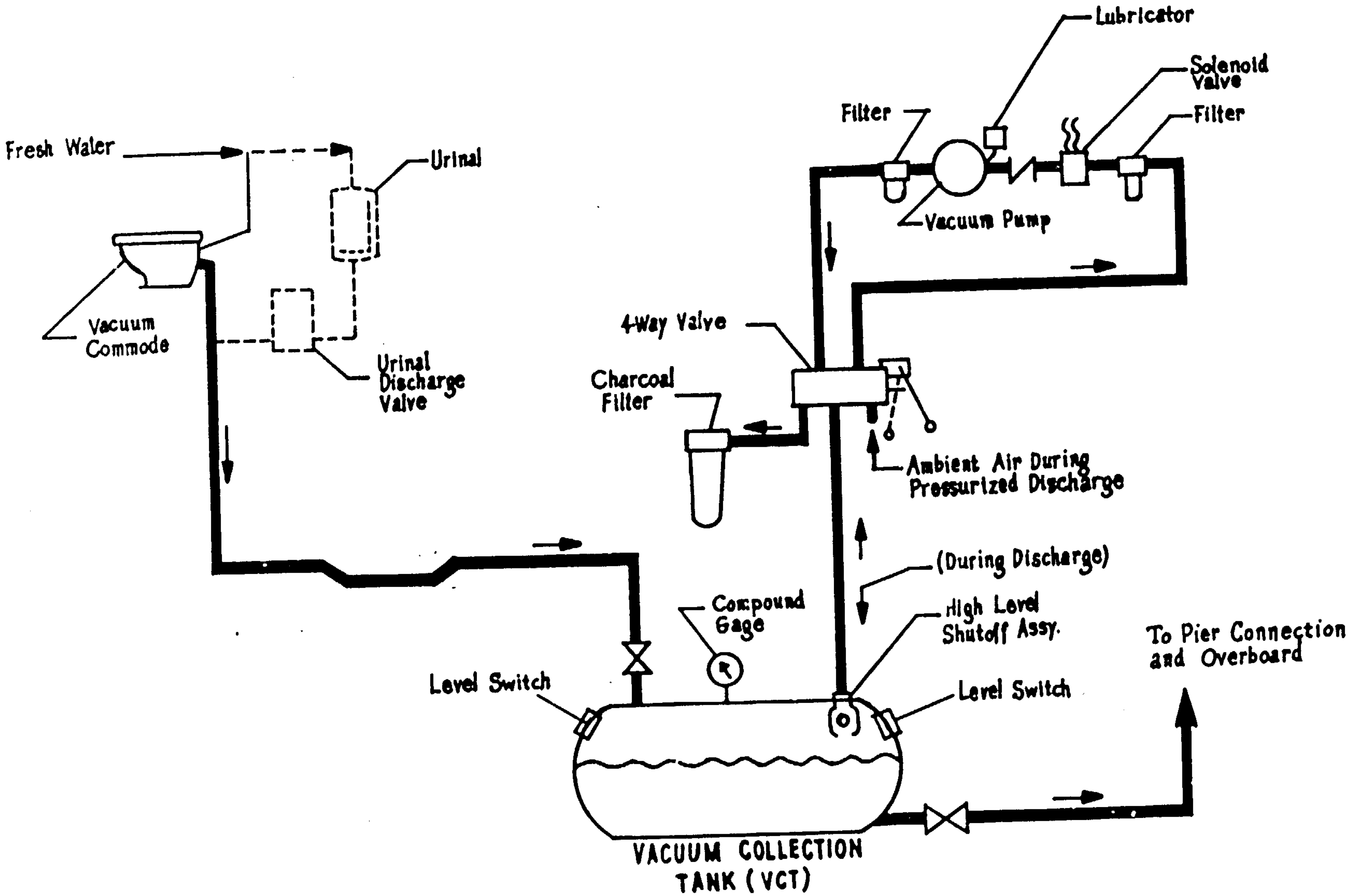

Figure 7

JERED SMALL BOAT WASTE COLLECTION SYSTEM

SYSTEM DESCRIPTION

The more detailed description will basically address the 200-man MSD. Description of the small boat system, which uses the same type of plumbing fixtures and drain piping, will be given after the description for the 200-man MSD, both for the collection and incinerator subsystems.

Collection Subsystem (200-man MSD)

The collection subsystem is comprised of:

- Vacuum operated commodes
- Standard urinals with vacuum interface valve
- Vacuum drain pipes
- Vacuum collection tank (VCT) assembly

A. Vacuum Operated Commodes

The vacuum toilet is shaped like a domestic toilet but is made of porcelain coated steel. The outlet for wastes, a 1 1/2" hole at the bottom of the bowl, is sealed from underneath by a Sewage Discharge Valve. At the top rear of the unit is a diaphragm covered push button. When flushing is required, the user depresses the push button. Within seconds, the flushing sequence occurs. Flush water from the vessel's fresh water supply starts to rinse the walls of the bowl. The discharge valve opens the bowl outlet. Vacuum vigorously sucks the waste, rinse water and air into the drain line for a second or two. A small amount of rinse water is retained after the discharge valve closes. This water helps to effect a seal against the vacuum. The entire cycle takes about six seconds.

Located inside the commode, between the bowl and the external housing, are six control assemblies that are operated by the vacuum existing in the drain pipe. They are:

- Activation Valve - This is the valve that starts the flush sequence when the user depresses its push button. If the vacuum is insufficient to properly flush the commode, the valve remains cocked until the vacuum is adequate and then starts the sequence.

- Gravity Timer - This assembly controls the timing of the various sequences by means of cam operated valves. It is adjustable.

- Vacuum-Dispensing Valve - This valve acts as a pneumatic amplifier or power relay. The small valves in the gravity timer actuate the vacuum dispensing valve which allows a large, rapid flow of air from the piston actuator in the sewage dispensing valve.

- Sewage-Dispensing Valve - This valve seals the bowl from the vacuum in the drain pipe until called upon to open during the flush sequence.

- Check Valve Assembly - This assembly helps operate the four assemblies above.

- Water-Dispensing Valve - This valve releases fresh water to the flush ring in the commode for rinsing the bowl.

The timing is set to draw the wastes, flush water (about two pints) and about 3.5 standard cubic feet of air each time the flush mechanism is actuated.

B. Urinals and Vacuum Interface Valves (Urinal Discharge Valves)

The urinals are standard, existing units with standard flushometers accurately adjusted to deliver about one pint of rinse water per flush. The urinals in one vessel compartment are piped to a single gravity drained line leading to an interface valve (each interface valve can accommodate up to 5 urinals). The valve, called a Urinal Discharge Valve, isolates the gravity-drained line from the vacuum drain line. The valve opens when it detects a quantity of urine and flush water exerting a static pressure on a float. Little or no air passes through the valve into the vacuum drain line during operation.

C. Vacuum Drain Pipes

The vacuum drain pipes are small diameter lines: 1 1/2 inch at the commode, and 2 inch from the junction of individual commode drains to the collection tank. The air that enters the line through the commode during a flush operation is approximately 3.5 cubic feet in volume. The sewage sucked into the drain line will travel in the form of a slug for over 150 linear feet by the time the commode valve closes. The entrapped air expands to about seven cubic feet at the collection tank pressure of half an atmosphere. This volume of air is sufficient to drive the slug of sewage 300 feet in a two-inch line. Thus, the output of sewage from a commode can be expected to reach the collection tank in one action taking only a few seconds.

Since the drain pipe cross section is always filled, with either the slug of sewage (about 17 inches long) or air, the pipes need not be sloped for drainage. In fact, the water can be made to flow vertically upward for a distance of six to eight feet or up an incline of a few degrees. At regular intervals, the drain pipe is bent into a shallow dip so that water adhering to the pipe walls, or the urine and flush water that enters the vacuum pipe through the urine discharge valve, will collect in these depressions to form slugs. The next flush action will sweep the collected slugs ahead of the incoming sewage.

D. Vacuum Collection Tank Assembly (200-man unit)

The 200-man vacuum collection tank (VCT) assembly is skid mounted and contains the following items:

- VCT
- Dual vacuum pumps and seal water tank
- Grinder pump
- Effluent pump
- Transfer/dump pump
- Fluid instruments, valves, and controls
- Electrical instruments and controls

a. VCT

The VCT is an upright cylinder with disked heads top and bottom, approximately 3.5 feet in diameter and four feet high. It holds 224 gallons to the high level shut-down point. The unit installed on the USS Kraus and possibly those on the Spruance class destroyers had a vertical baffle that divided the tank into two compartments. The first compartment (coarse side) received incoming sewage. The second compartment (fine side) received sewage that had passed through the grinder pump once. Current design uses no baffle so that the sewage can recirculate through the grinder pump for a statistical average of seven times.

The tank normally operates at 14 to 20 inches of mercury vacuum (Hg Vac). A vacuum relief valve prevents stronger vacuums. The tank is constructed to withstand an internal pressure of 50 psig and is protected by a pressure relief valve. The pressure capability permits the tank to be evacuated by using compressed air to drive the sewage out during emergency conditions.

The tank has multiple probes that sense liquid level by conductance. Upon contact with sewage a small current flow triggers a sensitive transistor relay. The original design of a two-compartment tank has ten probes, five in each half, with one on each side acting as a common ground. With an unbaffled tank, only five probes (indicating four distinct levels) will be necessary.

b. Vacuum Pumps and Seal Water Tank

Dual vacuum pumps, direct coupled to electric motors, are installed in parallel, atop the seal water tank. They are water ring seal pumps, drawing fresh water from the tank and discharging the air-water mixture back into the tank for separation. Air leaves the tank through a vent line. The heat of air compression is absorbed by the water in the seal tank. If the water temperature is too high, pumping efficiency drops and operators sometimes replace the water just to lower the temperature. The water is periodically replaced to avoid corrosion by the gases absorbed in it.

Two vacuum switches control the operation of the pumps. As the absolute pressure rises to 6.86 psia* (16 in. Hg Vac.) the "run" pump starts up and continues until the pressure reaches 4.9 psia (20 in. Hg Vac.) If system usage is heavy enough so that the one vacuum pump is inadequate, the "standby" pump is started when the absolute pressure rises to 7.84 psia (14 in. Hg. Vac.). It, too, shuts off at 20 in. Hg Vac. Periodically, the run-standby designations are reversed by a manually operated switch in order to give equal wear to the pumps. If either one or both pumps operate continuously for more than 20 minutes, an alarm is given to indicate a probable vacuum leak somewhere in the system.

c. Grinder Pump

The grinder pump is a macerating centrifugal pump, known by the trade name Maz-O-Rator, which recirculates collected sewage in the VCT. It is mounted vertically near the tank with piping to and from it. Pumping capacity is at least 45 gpm. For systems where the VCT had two compartments, the grinder pump operation was controlled by the liquid level sensors. Pump control action in an unbaffled VCT is not known at present.

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*psia = pounds per square inch absolute.
Atmospheric pressure is 14.7 psia.

d. Effluent Pump

The effluent pump is the normal means of transferring sewage from the VCT to the incinerator. It is a progressing-cavity pump, often referred to by the trade name, Moyno, and is operated at low speed to produce a 0.5 gpm flow. The original drive was by V-belt, but it now uses a chain drive.

e. Transfer/Dump Pump

The transfer/dump pump is a progressing-cavity pump, similar to the effluent pump but operated at higher speed to yield a seven gallons per minute transfer rate. Its original purpose was to dump the VCT contents overboard while the tank was still under vacuum or to transfer the contents to the second VCT on a vessel with two MSDs (two MSDs are employed on the USS Spruance). For purposes of this study, the transfer/dump pump will be considered to be a backup for the éffluent pump, and vice versa.

f. Fluid Instruments, Valves and Controls

In addition to the level sensor probes and vacuum switches already mentioned, the VCT assembly employs a liquid level gage and a level sensor on the seal water tank, sight plugs on the VCT, pressure/vacuum gages, manual valves and check valves.

g. Electrical Instruments and Controls

Electrical instruments and controls include:

- Indicator lights, for status monitoring and alarm indication
- Elapsed time meters, for status monitoring
- Switches, for manual control and mode of operation
- Logic relays including automatic shutdown and alarm sequence
- Power relays, including overload relays
- Audible alarm

Incinerator Subsystem (200 man MSD)

The incinerator subsystem consists primarily of a packaged incinerator and an ancillary fuel oil day tank. Since the fuel tank is custom designed for the installation, once the (daily) capacity is specified, the subsystem description will be essentially that of the incinerator. This unit is skid mounted and contains:

- An Incineration chamber with burner head and sludge nozzle
- A blower
- A fuel pump and fuel filter
- Instruments and controls, both fluid and electrical

A. Combustion Chamber

The incineration chamber is a horizontal cylinder, with a vertically-downward-firing burner head mounted tangentially to the chamber near one end. Through the end wall near the burner, a pneumatic nozzle, using compressed air to atomize the sewage, sprays the sewage along the centerline of the cylinder. Combustion gases form a vortex, spiralling through the chamber to the exhaust outlet at the center of the far wall. The chamber shell is cooled by air taken from the blower, so that external temperatures do not present a personnel hazard.

Since the sewage is sprayed along the centerline of the vortex (and the chamber), liquid and solid particles have to pass through the hot combustion gases before they can reach the wall. The design is such that liquids are vaporized, and the combustible vapors and solids are burned in the combustion gases, leaving only particulate ash to reach the wall. Centrifugal forces keep the heavier ash particles in the chamber and prevent them from leaving with the flue gas.

The burner head consists of a fuel nozzle, ceramic vaporizing tube (to vaporize the oil), ignition spark plug, combustion chamber, and flame scanner. Fuel is completely burned in the combustion chamber before the combustion gases enter the larger incineration chamber. The flame scanner prevents continued fuel injection in the event that ignition does not take place or the flame goes out.

Ash removal is through a small cleanout access panel at the bottom of the door, through which the sludge nozzle is installed.

B. Blower

The incinerator blower is a high pressure blower capable of producing 740 SCFM at 16 psig. In addition to providing combustion air for the fuel, it provides cooling air for the combustion chamger, the incinerator chamber door, the incinerator exterior, and the exhaust gases. The air that cools the combustion chamber and door also serves as combustion air for the organic matter in the sewage. A motorized valve controls the amount of air flowwing to the fuel-fired combustion chamber.

C. Fuel Pump and Fuel Filter

The fuel pump and filter are located under the incinerator chamber. The pump is a fixed, positive-displacement gear pump directly driven by a motor. The filter is a cartridge type.

D. Instruments and Controls

The instrumentation and controls are rather complex and only the highlights will be presented here. For greater detail, the O&M Manual should be consulted. Operator interfacing instruments and controls, (e.g., manual switches, indicating lights, elapsed time meter) are located in a control panel box mounted on the side of the incinerator. A temperature controller is separately mounted. Other items are located within pipes in the processing units.

Primary incinerator control is provided by the temperature controller, which is an indicating type that receives signals from a thermocouple in the exhaust stack. The proportional band control is nullified so that on-off control around a set point of 700°F is maintained, using a variable frequency of cycling. The controller also activates low and high temperature alarms.

A simplified sequence of automatic operation of the incinerator is as follows. Upon signal from the VCT, indicating a sufficiently high level of contained sewage, the incinerator blower is activated. A combustion air pressure switch senses blower operation and permits a programmed startup sequence to occur. After a timed interval during which the air purges potentially explosive vapors from the incinerator chamber and establishes movement of gas up the exhaust stack, the burner begins to fire (46 seconds). The spark plug ignites the fuel under the watchful (fire) eye of the flame scanner. If ignition does not occur within seven seconds, fuel valves close. When stack temperature reaches 650-675°F, the incinerator feed pump (VCT effluent pump) starts pumping, providing compressed air is flowing to the sludge nozzle, as determined by a pressure switch. When the VCT is satisfied that sufficient sewage has been withdrawn (and incinerated) the fuel flow is cut off to the burner. The blower continues to supply compressed air for the duration of a time interval empirically preset by a time-delay relay. The incinerator may be restarted during this post purge period.

Small Boat Collection Subsystem

The Jered small boat MSD is a special type of Collection, Holding and Transfer (CHT) system, there being neither an incinerator as in the Jered 200-man MSD, nor any other treatment process. It is included with the discussion of the Jered MSD not only because of similar collection methods, but because the adaptations and hybridization anticipated for it will make it similar to that of the larger MSD.

The small boat vacuum collection subsystem (SBCS) uses the same principles of vacuum transport as the 200-man system. In fact, it uses the same commodes. If a urinal were to be installed on a small boat, the fixture and urine discharge valve would be the same.

The type of equipment used in the SBCS is similar to components found in household appliances. They are fairly reliable and long lasting but for continual use on board a Coast Guard vessel, some of them would be upgraded in quality. A prime example is the piping. The flexible plastic tubing and plastic fittings in the current design would be replaced by rigid metal piping and fittings.

The major components of the SBCS, other than the commode, are:

- Vacuum collection tank (VCT)
- Vacuum pump(s) and ancillaries
- Instruments and controls

A. Vacuum Collection Tank

The VCT is available in four sizes, 30, 60, 120 and 200 gallons. They are horizontal cylinders with disked heads. The sewage connections are through two inch ball valves, in on top and out the end, at the bottom. The small line to the vacuum source is protected against sewage inflow by a float-operated High-Level-Shutoff Assembly. Liquid level switches at either end of the tank operate a remote ght that indicates high level. An external level sight gage and a compound pressure gage complete the instrumentation.

The current method of evacuation is through the use of compressed air to blow the contents out. If the SBCS is hybridized with an incinerator or even an evaporator, a recirculating macerator/transfer pump might be added. This pump would provide the primary or backup method of evacuation.

B. Vacuum Pump and Ancillaries

The vacuum pump is an oil-lubricated rotary vane pump close-coupled to an electric motor. It can be used as a compressor as well, and is the source of compressed air required during VCT blowout. Inlet and outlet filters are provided with the pump, as well as an oil reservoir/feeder.

The filters have porous stone elements housed within glass jars. The glass jars would probably be replaced by metal units for use on a Coast Guard vessel

A starting switch and a vacuum switch control the vacuum pump operation. When the pump is shut down because of adequate vacuum in the tank, a check valve prevents air and oil from leaking through the pump and into the VCT. A charcoal filter cartridge deodorizes the air evacuated from the tank by the pump. It is replaced when saturated, as determined by the detection of odor.

One vacuum pump of a single size is supplied for all sizes of SBCS tanks. The larger tanks simply provide more holding capacity in terms of man-days. Redundant pumps would most likely be installed for use on board Coast Guard vessels. If the VCT were employed in a system that has subsequent processing, the tank would be used for its vacuum function only, with the holding function replaced by some process, e.g., incineration, evaporation. In this event, increased vacuum pumping capacity in conjunction with one of the larger tanks would be suitable for serving bigger crews. A larger vacuum pump of the same style, made by the same manufacturer, is available with a very slight increase in physical dimensions.

C. Instruments and Controls

In addition to the instruments and controls already discussed, one more item is required and is basic to the subsystem, i.e., the mode valve. The mode valve is a five-part, four-way valve that reverses the direction of air flow (into or out of the VCT) without requiring any change to the vacuum pump. This is accomplished by connecting the discharge or suction side of the pump to the tank. The valve is a spool valve with sliding O-Ring Seals, manually operated by a lever. A possible modification for this valve is to have its operation automated, controlled by a level sensing device.

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COMPONENT PHYSICAL CHARACTERISTICS

Component	Weight (lbs)		Volume	Dimensions (inches)		
	Dry	Filled	cu ft	Height	Length	Width
Commode	30	31	3.1	16.3	20.3	16 dia
Urine Dischg. Valve	7	8	0.2	12.4	-	5.6 dia
Vac. Collect. Tank *						
30 gal	100	266	4.4	-	38	16 dia
60 gal	175	591	8.7	-	48	20 dia
120 gal	350	1183	18.1	-	69	24 dia
200 gal	530	2100	33.5	-	72	32 dia
Vacuum Pump						
0822	43	-	1.0	18	10	10
1022	47	-	1.1	19	10	10
Recirc. Macer. Pump**	125	127	1.0	10	25	7
Incin. Feed Pump **	144	147	2.5	16	30	9
Vac. Coll. Tank Assy.						
250 gal	5000	6900	165	66	72	60
Incinerator	2000	-	102	63	77	36

* Includes tank and auxiliary components except for vacuum pump(s).
** Included in 250 gal VCT Assembly.

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COMPONENT PIPE CONNECTION SIZES

Commode	Outlet Pipe: Water Supply:	1 1/2-inch IPS 1/2-inch ID Hose
Urinal Discharge Valve	Inlet and Outlet:	1 1/2-inch IPS
Vacuum Tanks		
Small boat VCT	Inlet and Outlet: Vacuum Connection	2-inch NPT
250 gal	See JERED Dwg. H20118C001 (3 sheets)	
Vacuum Pump		
0822 and 1022	Inlet and Outlet:	3/8-inch IPS
Recirc. Macerator Pump	Inlet: Outlet:	3-inch NPT 1 1/4-inch NPT
Incinerator Feed Pump	Vertical: Horizontal (Flow in either direction)	1 1/2-inch NPT 1 1/4-inch NPT
Incinerator (JERED)		
Sludge Connection	1/2-inch NPT	
Compressed Air	1/4-inch NPT	
Stack	8-inch 150-lb steel flange*	

* Stack may vary in size depending upon installation.

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COMPONENT VESSEL RESOURCE REQUIREMENTS

Component	HP	Watts	Volts	Phase	Hertz	Amp.	Ambient Air SCFM	Compressed Air SCFM	Fuel Oil gph
Vacuum Pump *									
0822	1/2		120/240	1	60				
1022	3/4		120/240	1	60				
Vacuum Collection Assy.									
Vacuum Pump *	3		440	3	60				
Overboard Pump	3		440	3	60				
Effluent Pump	1/2		440	3	60				
Controls		250 est.	120	1	60				
Recirc. Macerator Pump	1 1/2		440	3	60				
Incinerator (JERED)						10 max		15	
			110	1	60	1.0			
Blower	5		440	3	60		2700 **		
Oil Pump	1/3		440	3	60				7.5 est.
Controls		250 est.	110	1	60				

* Dual vacuum pumps frequently run at the same time.

** Combustion blower withdraws 720 SCFM. Compartment ventilation required is 2700 SCFM (per incinerator)

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD JERED

Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data Collect./Transp. Subsystem Large Boat	Collect./Transp. Subsystem Small Boat	Treat./Disposal Subsystem
12	MSD materials disallowed or not recommended.(1)			
	(a) No disallowed or not recommended materials present(2) in MSD subsystem.	a	a	a
	(b) Some disallowed or not recommended materials present in MSD subsystem, but resultant problems can be solved or compensated for.			
	(c) Presence of disallowed or not recommended materials in MSD subsystem presents problems with no feasible solutions.			
13	Extent of additional support systems or equipment required to accommodate MSD(3)			(6)
	Identification of support system requirements for MSD subsystem.			
21	Extent of fixture modifications required for MSD installation.	(7)	(7)	
	(a) MSD uses standard commodes and urinals.			
	(b) MSD uses non-standard commodes and special equipment is associated with the urinals.	b	b	N/A
	(c) MSD uses non-standard commodes, special equipment is associated with the urinals and each fixture has additional hook-up requirements.			
22	Extent of flush medium supply modifications required for MSD installation.			
	(a) MSD uses sea water for flushing fixtures.			
	(b) MSD uses fresh water for flushing fixtures.	b	b	N/A
	(c) MSD uses a non-aqueous for flushing fixtures.			
231	Hookup requirements(4) for MSD Collection/Transport subsystem installation.	(8)	(9)	
	(a) MSD uses standard Collection/Transport subsystem.			
	(b) MSD uses recirculating Collection/Transport subsystem.(5)			
	(c) MSD uses non-standard and centralized Collection/Transport subsystem.	c	c	N/A
	(d) MSD uses non-standard and non-centralized Collection/Transport subsystem.(6)			

(1) As specified in subchapters J&F of Merchant Marine Code and C.G. MSD regulations.
(2) For purposes of this study, C.G. directs choice (a) for all MSDs.
(3) Examples:
- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(4) Drain piping; electric cables for connecting commodes, M/T pump and control panel, compressed air, etc.
(5) In existing gravity drain system.
(6) Includes conversion from reduced flush vacuum collection to a standard gravity drain system with or without recirculation.

(7) Fire protection equipment; ventilation.
(8) Urinal discharge valves required (at least one for every 5 urinals).
(9) Cables for electric power and controls (control panel, VCT), compressed air, vacuum lines, fresh water.
(10) Electric power, electrical controls, fresh water; vacuum lines (has own compressed air).

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I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD JERED | Sheet 2 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
232	Routing flexibility for drain piping modifications[1] associated with MSD Collection/Transport subsystem installation[2] (a) Routing of MSD Collection/Transport piping is highly flexible. (b) Routing of MSD Collection/Transport piping is moderately flexible with some restrictions. (c) Routing of MSD Collection/Transport piping is highly inflexible.	(3) a	(3) a	N/A
233	Space requirements for MSD Collection/Transport subsystem installation (a) Space required for MSD Collection/Transport subsystem is little or no greater than that required for standard Collection/Transport subsystem. (b) Space required for MSD Collection/Transport subsystem is moderately increased over that required for standard Collection/Transport subsystem. (c) Space required for MSD Collection/Transport subsystem is much greater than that required for standard Collection/Transport subsystem.	(4) c	(5) c	N/A
234	Modularity of MSD Collection/Transport subsystem (as it affects installation). (a) Collection/Transport subsystem is highly modular. (b) There is an option for some decentralization of the MSD Collection/ Transport subsystem. (c) The MSD Collection/Transport subsystem is highly centralized.	c	c	N/A
235	Vent requirements for MSD Collection/Transport subsystem installation. (a) MSD Collection/Transport subsystem requires no vents. (b) MSD Collection/Transport subsystem requires few vents. (c) MSD Collection/Transport subsystem requires many vents.	(6) b	(7) b	N/A

(1) Of the three relevant categories of routing lines (piping, ventilation, electrical), piping is the most important for assessing ease of MSD installation.

(2) Notes:

- With gravity drainage, lines must always slope downward and require venting.
- Smaller size lines are inherently more flexible.
- With pump or vacuum Collection/Transport subsystem, sharp bends, risers and long runs can be accommodated in piping.

(3) Restriction on vertical risers: 6-8 ft.

(4) VCT and vacuum pump with seal water tank.

(5) Requires less space; two vacuum pumps and valves are relatively small.

(6) Vent required for VCT (connected to seal water tank).

(7) Vented only in compartment.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD JERED Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	Attribute Data Collect./Transp. Subsystem Large Boat	Small Boat	Treat./Disposal Subsystem
242	Hookup requirements[1] for MSD waste Treatment/Disposal subsystem installation (a) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are minimal. (b) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are moderate. (c) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are extensive.	N/A		(5) b
243	Degree of modularity of MSD waste Treatment/Disposal subsystems (as it affects installation)[2] (a) MSD Treatment/Disposal subsystem is highly modular. (b) There is an option for some decentralization of the MSD Treatment/Disposal subsystem. (c) MSD Treatment/Disposal subsystem is highly centralized.	N/A		(6) c
244	Vent requirements for MSD waste Treatment/Disposal subsystem installation[3] (a) No vents are required for MSD Treatment/Disposal subsystem. (b) Vents are required for MSD Treatment/Disposal subsystem.	N/A		a
245	Exhaust stack requirements for MSD waste Treatment/Disposal subsystem installation.[4] (a) Exhaust stack not required for MSD Treatment/Disposal subsystem. (b) Small exhaust stack required for MSD Treatment/Disposal subsystem. (c) Large exhaust stack required for MSD Treatment/Disposal subsystem.	N/A		c

(1) Piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote panels, etc.; ducting for ventilation, etc.
(2) Decentralization of components may require additional hookups and piping runs.
(3) Vents that are only internal to the compartment in which subsystem is located are not considered here.
(4) Notes:
- Electric incinerator requires small (2") exhaust.
- Fuel incinerator requires large (10") exhaust.

(5) Fuel oil day tank, compressed air, ventilation, electric power, electrical controls (control panel mounted with incinerator package).

(6) Palletized.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD JERED

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M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem (2)
25	Ease of installing MSD support equipment[1] Extent of additional support equipment required to accommodate MSD (a) No additional support equipment required for MSD subsystem. (b) Some additional support equipment required for MSD subsystem. (c) Much additional support equipment required for MSD subsystem.	a	a	b

(1) Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(2) Fire fighting equipment; ventilation.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD JERED — Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem — Large Boat	Attribute Data: Collect./Transp. Subsystem — Small Boat	Attribute Data: Treat./Disposal Subsystem
311	Effect of peak hydraulic loads in black[(1)] water stream on MSD performance[(2)] (a) No significant effect of black water peaks on MSD subsystem performance. (b) Effect of black water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water peaks.	(4) b	(4) b	(5) a
312	Effect of peak hydraulic loads in gray[(1)] water stream on MSD performance (2) (a) No significant effect of gray water peaks on MSD subsystem performance. (b) Effect of gray water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water peaks, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water peaks.	N/A System cannot handle gray water		N/A
321	Effect of low flow conditions/long idle times in black water stream on MSD performance(3) (a) No significant effect of black water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of black water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water low flow conditions/long idle times.	(6) a	(7) b	(8) a

(1) Includes instantaneous,hourly and daily loads.
(2) Peak load handling ability depends on C/T subsystem. The ability of an MSD which employs an influent surge tank to handle peaks usually depends almost entirely on the sizing of this tank.
(3) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(4) . Will handle large peaks unless VCT is close to being full.
. Lot of flushing results in vacuum pumps working longer, but this does not degrade performance.
(5) Sludge fed at a steady rate to incinerator.
(6) . Nothing stays in vacuum lines.
. If necessary, VCT has bleed line for aeration, or can empty tank and put in fresh water or disinfectant.
(7) . No bleed line for aeration.
. If tank contents go septic and pressure rises, could overload charcoal filter and produce odors in compartment.
. Can pump out tank and replace charcoal filter.
(8) . If sludge in incinerator is wet, may generate odor through stack when execute standard 30 sec air purge before firing up incinerator.
. Sludge line (between VCT and incinerator) cake up can be corrected or prevented by blowing out the line and cleaning with fresh water; corrective aeration may require disconnecting the line.

. MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD JERED

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
322	Effect of low flow conditions/long idle times in gray water stream on MSD performance(1)			
	(a) No significant effect of gray water low flow conditions/long idle times on MSD subsystem performance.			
	(b) Effect of gray water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome.	N/A System cannot handle gray water		N/A
	(c) Long-term effect of gray water low flow conditions/long idle times, difficult to overcome with long-term implications for MSD subsystem performance.			
	(d) No ability of MSD subsystem to handle gray water low flow conditions/long idle times.			
331	Ability of black water portion of MSD to handle additional personnel (on a long-term basis)(2)	(4, 5)	(4)	(6)
	(a) MSD black water subsystem will handle additional personnel with little or no degradation in performance.	a	a	a
	(b) MSD black water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance.			
	(c) MSD black water subsystem will not handle additional personnel			
332	Ability of gray water portion of MSD to handle additional personnel (on a long-term basis)(3)			
	(a) MSD gray water subsystem will handle additional personnel with little or no degradation in performance.	N/A System cannot handle gray water		N/A
	(b) MSD gray water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance.			
	(c) MSD gray water subsystem will not handle additional personnel.			

(1) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(2) Resulting in long-term increase in average black water stream hydraulic loading. The ability of an MSD which employs a black water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(3) Resulting in long-term increase in average gray water stream hydraulic loading. The ability of an MSD which employs a gray water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(4) If many flushes in short period of time, there may be a short (5-10 min.) delay in flushing action while vacuum pumps re-build to higher pressure.

(5) VCT can handle additional personnel (1/3 more than any system considered in study).

(6) In small boats, incinerator feed tank <u>sized</u> so as to make incinerator run at <u>maximum</u> rate.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD JERED

Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem — Large Boat	Attribute Data: Collect./Transp. Subsystem — Small Boat	Attribute Data: Treat./Disposal Subsystem
41	Ability of black water handling portion of MSD to operate for sustained time periods			
	(a) MSD black water subsystem can operate for indefinite period of time if no components fail. (1)	a	a	a
	(b) MSD black water subsystem can operate for only limited period of time, even if no components fail. (2)			
42	Ability of gray water handling portion of MSD to operate for sustained time period			
	(a) MSD gray water subsystem can operate for indefinite period of time if no components fail. (1)	N/A System cannot handle gray water		N/A
	(b) MSD gray water subsystem can operate for only limited period of time, even if no components fail. (2)			
51	Ability of MSD to handle ground garbage in black water stream	(4)	(4)	(5)
	(a) MSD black water subsystem will handle ground garbage in black water stream on a long-term basis.	a	a	
	(b) MSD black water subsystem will handle ground garbage in black water stream on at least a short-term basis.			b
	(c) MSD black water subsystem will not handle ground garbage in black water stream.			
52	Ability of MSD to handle foreign materials/objects (3) in black water stream	(6)	(6)	(7)
	(a) MSD subsystem will handle foreign materials/objects in black water stream on a long-term basis.			a
	(b) MSD subsystem will handle foreign materials/objects in black water stream on at least a short-term basis.			
	(c) MSD subsystem will not handle foreign materials/objects in black water stream.	b	b	

(1) Applies to a T/D subsystem with an incinerator.
(2) Applies to a T/D subsystem without an incinerator.
(3) Examples:
- Long, narrow objects (pens, pencils, toothpicks, etc.)
- Small hard objects (nut shells, pull tab from a flip top can, bottle caps, paper clips, coins, nuts/bolts/screws/nails, cuff links, etc.)
- Large soft objects (paper towels, newspaper page, stiff and shiny magazine page, strings from a floor mop, rag, tampons and sanitary napkins, etc.)

(4) An interface device is required to direct ground garbage slurry into vacuum lines. A urinal discharge valve can be used for this purpose.

(5) Particles in garbage (pieces of bone, melon pits, pieces of meat, etc) may clog feed line or spray nozzle in incinerator necessitating shutdown or cleanout.

(6) Toothpicks may interfere with operation of urinal discharge valve; magazine paper may interfere with operation of commode alone.

(7) Only if small (spray nozzle orifice (1/4").

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

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M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat (1)	Treat./Disposal Subsystem
53	Ability of MSD to handle detergents/surfactants in black water stream on a long-term basis.			
	(a) MSD subsystem will handle detergents/surfactants in black water stream on a long-term basis.	a		a
	(b) MSD subsystem will handle detergents/surfactants in black water stream on at least a short-term basis.		b	
	(c) MSD subsystem will not handle detergents/surfactants in black water stream.			
54	Ability of MSD to handle toxic materials in black water stream			
	(a) MSD subsystem will handle toxic materials in black water stream on a long-term basis.	a	a	a
	(b) MSD subsystem will handle toxic materials in black water stream on at least a short-term basis.			
	(c) MSD subsystem will handle toxic materials in black water stream.			
61	Ability of MSD secondary emissions to meet applicable standards for the discharge of air pollutants			(2)
	(a) No possibility of discharge of significant air pollution from MSD subsystem.	a	a	
	(b) MSD subsystem will meet standards for air pollutants under normal operating conditions.			b
	(c) MSD subsystem will meet standards for air pollutants under normal operating conditions and there is a strong possibility of non-conformance to standards under unusual operating conditions.			
62	Ability of MSD secondary emissions to meet applicable standards for disposal of oil-contaminated residues at sea			(3)
	(a) MSD subsystem has no potential for producing oil-contaminated residues at sea.	a	a	a
	(b) MSD subsystem has a potential for producing oil-contaminated residues at sea.			
71	Performance risk for black water handling portion of MSD			(4)
	(a) MSD black water subsystem has a history of fair or better test results.	a	a	
	(b) MSD black water subsystem has a history of poor test results.			b
	(c) No test results are available for the MSD black water subsystem.			
72	Performance risk for gray water water handling portion of MSD			
	(a) MSD gray water subsystem has a history of fair or better test results.	N/A System cannot handle gray water		N/A
	(b) MSD gray water subsystem has a history of poor test results.			
	(c) No test results are available for the MSD gray water subsystem.			

(1) Oil type vacuum pump life reduced if foaming washes out oil; oil and detergents may degrade charcoal filter performance decreasing recirculating pumping ability and odor removal.

(2) Under extraordinary or improper conditions, incinerator may exhaust pollutants.

(3) If incinerator is working poorly, ash may have some oil in it; fatty wastes possible, but not likely.

(4) Problems with incinerator (pot, flameout, under certain conditions).

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E - III - OPERABILITY

MSD JERED

Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
11	Degree of automation for MSD operation (1)		(4)	
	(a) MSD subsystem is almost fully automatic.			
	(b) MSD subsystem is semi-automatic: requires infrequent operator attention.	b		b
	(c) MSD subsystem is semi-automatic: requires a moderate degree of operator attention.		c	
	(d) MSD subsystem is semi-automatic: requires frequent operator attention.			
	(e) MSD subsystem is operated manually.			
12	Ease of disposal of MSD residue(s)(1)(2)	(5)	(6)	(7)
	(a) MSD subsystem has no residues, or disposal of residues from MSD subsystem is very convenient.		a	
	(b) Disposal of residues from MSD subsystem is moderately convenient.	b		b
	(c) Disposal of residues from MSD subsystem is inconvenient.			
14	Likelihood of violating effluent standards because of procedural errors in MSD operation. (3)	(8)	(8)	(9)
	(a) There is virtually no chance of violating effluent standards because of procedural errors in MSD operation.			
	(b) There is a low likelihood of violating effluent standards because of procedural errors in MSD operation.	b	b	b
	(c) There is a fair to moderate chance of violating effluent standards because of procedural errors in MSD operation.			
	(d) There is a high likelihood of violating effluent standards because of procedural errors in MSD operation.			
23	Skill level requirements for operator of MSD			
	MSD subsystem complexity ranking from 1 to 5	5	5	3
24	Training requirements for operator of MSD			
	MSD subsystem complexity ranking from 1 to 5	5	5	3

(1) Residue is any by-product of normal MSD operation, disposal of which is regular operating task. Examples are ash produced by an incinerator, seal water used by vacuum pumps, wastewater or sludge held in a tank, evaporator residue, etc.

(2) Length of time required for disposal is the main factor considered; other factors are ease of access of area of MSD containing the residue, amount of residue to be disposed of, and ease of storing residue on board or taking it off vessel, as appropriate.

(3) By dumping overboard effluent which doesn't meet standards, flush oil, evaporator residue, air pollutants from incinerator, etc.

(4) No automatic disposal; 4-way valve, manually operated.

(5) Seal water for liquid ring pumps.

(6) No residue

(7) Incinerator ash: Make sure incinerator is cool; remove screws that hold end plate; remove end plate; scoop or scrape out ashes - should be dry.

(8) Must misuse 2 sets of controls (buttons and/or valves).

(9) Improper operation of incinerator may result in discharge of air pollutants.

M/E III - OPERABILITY

MSD JERED

Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data: Collect./Transp. Subsystem		OPERABILITY Attribute Data: Treat./Disposal Subsystem
		Large Boat	Small Boat	
25	Effect of MSD operation on vessel work routines/schedules (a) MSD operation has minimal or no effect on work routines/schedules. (1) (b) Effect of MSD operation on work routines/schedules is more than minimal (i.e., is moderate or extensive).	a	a	a
32	Availability of specialized or unique consumables/expendables required for MSD operation (a) No specialized or unique consumables or expendables required for MSD subsystem operation. (b) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from ship's inventory. (c) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from Federal Stock System. (d) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from a commercial source.	a	a	(5) d
33	Operating requirements for special or unique MSD support equipment (a) No special or unique support equipment required by MSD subsystem. (b) Some special or unique support equipment required by MSD subsystem; equipment requires only minimal and infrequent attention(2) to keep operational. (3) (c) Some special or unique support equipment required by MSD subsystem; requires more than infrequent attention to keep operational. (4)	a	a	(6) b

(1) By C.G. direction, (a) applies to all MSDs considered in this study.
(2) No more frequently than weekly with a duration not greater than 10 minutes; or more frequently than semi-annually with a duration of 2 hours.
(3) E.g., firefighting equipment, special transformers, ozone detector, bilge alarm.
(4) E.g., compressor installed to support MSD operation.

(5) Incinerator related items (pot) obtain from manufacturer only.
(6) Fire fighting equipment for incinerator; ventilation.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD JERED

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem — Large Boat	Small Boat	Treat./Disposal Subsystem
11	Hazard of contact with/spillage of toxic/dangerous substances(1) due to MSD inherent design			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (form hands).

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD JERED

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat (2)	Treat./Disposal Subsystem (3)
12	Hazard of contact due with/spillage of toxic/dangerous substances[1] due to procedural error/equipment failures of MSD			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury o death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
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  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
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    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

(2) Requires multiple failures. In small boat, collection system could blow tank backwards, blowing gases back through commodes.

(3) . May come into contact with wet sludge when removing ash from incinerator.
. Leakage of fumes from incinerator possible.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD JERED Sheet 3 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem – Large Boat	SAFETY Attribute Data: Collect./Transp. Subsystem – Small Boat	SAFETY Attribute Data: Treat./Disposal Subsystem
21	Hazard of explosive potential for operator/maintainer due to inherent MSD design			
	L - Likelihood of hazard			
	(a) No chance	a	a	
	(b) Highly unlikely			b
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a	a	a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.			
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			
22	Hazard of explosive potential for operator/maintainer due to procedural errors/ equipment failures of MSD	Large Boat (1)	Small Boat (2)	(3)
	L - Likelihood of hazard			
	(a) No chance			
	(b) Highly unlikely	b		b
	(c) Fair to even chance			
	(d) Highly likely		c	
	S - Severity of hazard			
	(a) No resultant injury.	a		a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b	
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a		a
	(b) Hazardous situation is difficult to correct.		b	
	(c) Hazardous situation cannot be corrected.			

(1) If relief valve forms and compressed air regulator gets stuck.

(2) If flammable liquid is poured down commode, vacuum pump will [illegible] explosive vapors out into compartment of pump.

(3) If flammable liquid is fed into incinerator, will overheat.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD JERED Sheet 4 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
31	Hazard of fire ignition potential(1) due to inherent MSD design			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a
32	Hazard of fire ignition potential(1) due to procedural errors/equipment failure of MSD			(2)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited (c) Results in severe injury or death.	a	a	b
	C - Hazard correction (a) Hazardous situtation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	b

(1) Oil used for flushing is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

(2) If too much oil is fed into incinerator, the insulation comes away from combustion chamber.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD JERED

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data Collect./Transp. Subsystem Large Boat	Small Boat	Treat./Disposal Subsystem
4	Hazard of electrical shock potential(1) for operator/maintainer of MSD			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a
51	Physical hazards associated with MSD due to sharp edges(2)			(3)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Electric shock may result in severe burns and/or death; in addition, reaction to electric shock may casue affected individual to be thrown aside, possibly subjecting him to severe impact injuries and/or contact with sharge edges/hot surfaces.

(2) Combined effect of injury due to sharp edges/points and sewage contamination may introduce harmful pathogens into the bloodstream of an affected individual.

(3) Stock may have sheet metal wrap with sharp edges.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD JERED

Sheet 6 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
52	Physical hazards associated with MSD due to hot surfaces	(1)		(2)
	L - Likelihood of hazard			
	(a) No chance			
	(b) Highly unlikely	b	b	
	(c) Fair to even chance			c
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a	a	
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.			b
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			
53	Physical hazard for maintainer of MSD due to rotating machinery	(3)	(4)	(5)
	L - Likelihood of hazard			
	(a) No chance		a	
	(b) Highly unlikely			b
	(c) Fair to even chance	c		
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.		a	a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment	b		
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			

(1) Only with equipment failure, e.g., motor overheats.
(2) For maintainer.
(3) Vacuum pump shaft couplings are guarded, but could get hand under guard. Belt drives on effluent, transfer and grinder pumps.
(4) Vacuum pump is close coupled.
(5) Blower close-coupled.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD JERED — Sheet 1 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
11	Habitability problems(1) associated with bacterial contamination due to MSD inherent design (a) There is no bacterial contamination habitability problem due to MSD subsystem inherent design features. (b) There is a bacterial contamination habitability problem due to MSD subsystem inherent design features.	(3) a	a	a
12	Habitability problems(1) associated with bacterial contamination due to procedural errors/equipment failures of MSD(2) (a) A bacterial contamination problem due to procedural errors/equipment failures of MSD subsystem is highly unlikely. (b) Procedural errors/equipment failures of MSD subsystem are likely to cause a bacterial contamination problem	(4) a	(4) a	a
21	MSD fixture comfort (a) Commodes and urinals are comfortable and easy to use even under ship's motion. (b) Commodes and urinals are not comfortable and easy to use under ship's motion.	a	a	N/A
22	Flushing procedure requirements for MSD fixture (a) There are no "non-standard" requirements for flushing. (b) There are "non-standard" requirements for flushing.	b	b	N/A
23	Waste retention in MSD commode bowl (a) The amount of waste that remains in the bowl after flushing is less than that remaining after flushing a standard full water flushed fixture. (b) The amount of waste that remains in the bowl after flushing is the same as that remaining after flushing a standard full water flushed fixture. (c) The amount of waste that remains in the bowl after flushing is more than that remaining after flushing a standard full water flushed fixture.	b	b	N/A

(1) As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

(2) A vacuum waste collection subsystem is less likely to expose personnel to sewage in case of a line break than a pressurized waste collection subsystem; fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply.

(3) Even if blow tank is backwards, will blow air, not sewage.

(4) The JERED MSD, because it has a sewage vacuum collection system, is less likely to expose personnel to sewage in case of a line break.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD JERED

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem Large Boat	Collect./Transp. Subsystem Small Boat	Treat./Disposal Subsystem
24	Likelihood of user contact(1) with MSD fixture flushing medium (a) User is unlikely to come into contact with flushing medium. (b) User is more likely to come into contact with flushing medium than with standard water flushed fixture.	a(3)	a(3)	N/A
25	Appearance of MSD fixture flushing medium (a) The color and general appearance of the flushing medium is as acceptable as clear water. (b) The color and general appearance of the flushing medium are acceptable, but clear water is preferable. (c) The color and general appearance of the flushing medium are not acceptable.	a	a	N/A
26	Noise produced in flushing MSD fixtures (a) The noise produced in flushing fixtures is less than that of a standard commode/urinal. (b) The noise produced in flushing fixtures is the same as that of a standard commode/urinal. (c) The noise produced in flushing fixtures is greater than that of a standard commode/urinal.	c	c	N/A
31	Odors produced as a result of inherent MSD design (a) The MSD subsystem produces no odor as a result of inherent design. (b) The MSD subsystem produces a noticeable odor as a result of inherent design.	a	a	a
32	Odors produced as a result of procedural errors/equipment failures of MSD (a) The MSD subsystem produces no odor as a result of procedural errors/equipment failures. (b) The MSD subsystem produces a noticeable odor as a result of procedural errors/equipment failures.	(4) b	(5) b	(6) b
41	Heat generation for nearby personnel(2) due to inherent MSD design (a) As a result of inherent design features, the MSD subsystem does not generate enough heat to render its vicinity hotter than most shipboard areas containing machinery. (b) As a result of inherent design features, the MSD subsystem does generate enough heat to render its vicinity hotter than most shipboard areas containing machinery.	a	a	b

(1) Due to flushing medium composition, fixture design, motion of vessel (which may cause splatter, splashing, or spillage of flushing medium).

(2) For operator/maintainer/adjacent berthing and working areas.

(3) The JERED MSD, because it has a sewage vacuum collection system, is less likely to expose personnel to sewage in case of a line break.

(4) Ammonia odor from seal water tank.

(5) If charcoal filter is depleted.

(6) If sludge in incinerator is wet or fuel leaks.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V- HABITABILITY

MSD JERED

Sheet 3 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
42	Heat generation for nearby personnel[1] due to procedural errors/equipment failures of MSD. (a) The MSD subsystem does not generate enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery. (b) The MSD subsystem does generation enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery.	a	a	b
5	Noise level for personnel in vicinity of MSD[1] NI - Noise Index (a) The MSD subsystem is silent or nearly silent. (b) Noise level of MSD subsystem is approximately equal to background noise level of vessel. (c) The MSD subsystem is very loud, produces constant noise, drowns out vessel background noise in immediate area of the system; must shout to be heard.	b	b	b (3)
6	Vibration levels for nearby personnel[1] produced by MSD machinery VI - Vibration Index (a) MSD subsystem produces little or no perceptible vibration in addition to background level on vessel. (b) MSD subsystem produces perceptible vibration, but similar to vessel background. (c) MSD subsystem produces abnormal or disturbing intensity and/or frequency of vibration.	a	a	a
7	Effect of MSD on user housekeeping routines (restrictions on user imposed by subsystem[2]). (a) Subsystem characteristics do not impose restrictions on user. (b) Subsystem characteristics impose restrictions on user.	a	a	a

(1) For operator/maintainer/adjacent berth and working areas.

(2) E.g. . Must use water-soluble toilet paper which is not as comfortable as usual toilet paper.
. Must use special bowl cleaner which is less effective than usual cleaner
. Cannot dump detergents down galley sink; must store and off-load at shore.

(3) Incinerator blower produces fairly high pitched noise.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VI - RELIABILITY

MSD JERED   Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	RELIABILITY Characteristics	RELIABILITY Attribute Data: Collect./Transp. Subsystem		Treat./Disposal Subsystem
		Large Boat	Small Boat	
21	MSD complexity			
	Complexity index of MSD subsystem based on a complexity ranking from 1 to 5.	5	5	3
23	Extent of MSD equipment/component redundancy(1)	(6)	(7)	(8)
	(a) There is some significant redundancy in the MSD subsystem's major components.	a	a	
	(b) There is no significant redundancy in the MSD subsystem's major components.			b
24	Degree of equipment failure independence(2)	(9)	(10)	(11)
	(a) There is a high degree of equipment failure independence in MSD subsystem.			
	(b) There is a moderate degree of MSD equipment failure independence in MSD subsystem.			
	(c) There is a low degree of equipment failure independence in MSD subsystem.	c	c	c
25	Adequacy of MSD equipment ratings	(12)		(13)
	(a) Most MSD subsystem equipments are overrated.			
	(b) Some MSD subsystem equipment ratings are nominal, some are overrated.	b	b	b
	(c) Some MSD subsystem equipments are underrated, some are nominally rated.			
	(d) Most MSD subsystem equipments are underrated.			
26	Provisions for fault actuated cut-off mechanisms(3) for MSD protection	(14)	(15)	(16)
	(a) There are many fault actuated mechanisms in MSD subsystem, or they are not required.(4)			a
	(b) There are some fault actuated mechanisms in MSD subsystem.	b	b	
	(c) There are no or almost no fault actuated mechanisms in MSD subsystem.			
3	Reliability risk for MSD(5)			(17)
	(a) MSD subsystem has a history of fair or better test results.	a	a	
	(b) MSD subsystem has a history of poor test results.			b
	(c) No test results are available for MSD subsystem.			

(1) Any redundancy in electronic circuitry is not considered.
(2) I.e., failure of one item will not result in failure of major component or subsystem.
(3) Includes mechanisms to: (i) alert operator/maintainer to high stress or abnormal conditions that will result in failure, and/or (ii) to correct those conditions or turn off equipment.
(4) E.g., standard commodes and urinals in a gravity drain sewage collection subsystem do not require fault actuated cut-off mechanisms.
(5) E.g., innovative design, experience.

(6) . Dual vacuum pumps.
. Transfer dump pump and discharge are interchangeable.
. Compressed air for blowing out tank in case of vacuum pump failure.

Footnotes continued on following page.

(7) Vacuum pumps.

(8) Sludge nozzle has 12 holes.

(9) . Vacuum pump failure disables C/T system
. If seal water level becomes too low, vacuum stops pump.
. If seal water becomes too hot, vacuum is reduced.
. Level sensing probes get contaminated and do not measure level properly, causing grinder pump to pump tank empty.

(10) . Vacuum pumps failure makes flushing impossible.
. Four way valve failure results in loss of flushing capability or inability to empty VCT.
. Lubricator failure (lubricator not kept full) results in accelerated vacuum pump wearout.
. If filter clogs, performance is degraded.

(11) . Blower failure renders incinerator inoperative.
. If grinder pump fails, cannot use incinerator.

(12) . Vacuum pumps overrated for less than 200 men.
. Grinder pumps overrated.

(13) . Incinerator pot underrated.

(14) . If vacuum pumps run for more than 20 minutes continuously, alarm goes off (indicates probable leak in vacuum system).
. Commode sewage discharge valve fails closed if spring fails.
. Level sensor in seal water tank.
. If grinder pump runs continuously for more than 20 minutes, timer cuts it off or indicates by alarm.

(15) Two level switches - if one switch fails, there is a high level shut off assembly, similar to a float valve, that will prevent sewage from reaching vacuum pump.

(16) . Flame scanner; overtemperature sensor.
. Sludge cannot be fed into incinerator while incinerator is cold since compressed air pressure must be sufficiently high in order to open sludge feed line.
. Pressure switch for blower stops fuel oil from being fed to incinerator.

(17) Due to presence of incinerator (problems with incinerator pot).

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD JERED

Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data: Collect./Transp. Subsystem — Large Boat	Collect./Transp. Subsystem — Small Boat	Treat./Disposal Subsystem
131	Accessibility of replaceable MSD components (a) High degree of accessibility in MSD subsystem components. (b) Moderate degree of accessibility in MSD subsystem components. (c) Low degree of accessibility in MSD subsystem components.	(4) (5) c	(4) c	(6) b
132	Extent of MSD modularization for ease of repair/replacement (a) High degree of MSD subsystem modularization. (b) Moderate degree of MSD subsystem modularization. (c) Low degree of MSD subsystem modularization.	c	(7) c	(8) c
133	Degree of MSD repairability on board vessel.(1) (a) All MSD subsystem items are repairable on vessel. (b) Some MSD subsystem items are repairable on vessel; some must be replaced. (c) All MSD subsystem items must be replaced.	(9) b	a	(10) b
134	Availability of manufacturer field support and training programs for MSD (a) Manufacturer field support and a training program is available. (b) Manufacturer field support(2) is available but no training program is available. (c) Manufacturer training program is available but field support is not available. (d) Neither field support nor training program are available from manufacturer.	a	a	a
142	Special/proprietary(3) item requirements for MSD equipment repair (a) No special items required for any MSD subsystem repairs. (b) Some special items required for some MSD subsystem repairs. (c) All items required for MSD subsystem repairs are special items.	(11)(12) b	(11)(13) b	(14) b

(1) Versus necessity for replacement of failed equipment.
(2) May include some limited training support during initial MSD installation.
(3) E.G., incinerator pots, filters versus standard supply parts.

(4) Must remove commode to access flush mechanism; commodes held in place by four mounting bolts.
(5) . To access level sensors, must lose vacuum, remove flange bolts from tank.
. Grinder and other pumps are very heavy - need crane to lift.
(6) Blower is heavy though well exposed - possible to disassemble in place by removing blower housing.
(7) Filters are cartridge type.
(8) Spark plug screws in and out, but not quickly.
(9) . Solid state modules must be replaced.
. Water dispensing valve is throw away item.
. Could repair vacuum pumps on vessel - alignment is difficult on vessel.
(10) Sensors and incinerator liner must be replaced.
(11) Commodes, urinals and discharge valves are special.
(12) Level sensor (and associated links) for large VCT.
(13) High level shut off assembly may be special.
(14) . Sludge nozzle may be special.
. Combustion liner is a ceramic cylinder of special dimensions - possibly a catalogue item.
. Incinerator pot special item.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD JERED Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data		
		Collect./Transp. Subsystem		Treat./Disposal Subsystem
		Large Boat	Small Boat	
23	Effect of MSD preventive maintenance on watchstander routines (a) No effect on watchstander routines.[1] (b) There is some effect on watchstander routines.	a	a	a a
33	Special docking requirements for MSD overhauls (a) There are no special docking requirements for the MSD.[1] (b) There are special docking requirements for the MSD.	a	a	a
4	Logistic requirements for MSD (a) No special parts are required for the MSD subsystem. (b) Few different categories of special parts are required for the MSD subsystem and there are few parts in each category. (c) Few different categories of special parts are required for the MSD subsystem but many parts of each type are required, or many different categories of special parts are required but there are few parts in each category. (d) Many different categories of parts are required for the MSD subsystem and there is a large number of parts in each category.	b	b	b

(1) By C.G. direction, this applies to all MSDs considered in this study.

JERED

EQUIPMENT AND INITIAL SPARES ACQUISITION COSTS

Equipment		Equipment Cost	Cost of Associated Inital Spares Package
Commode		$ 300	$ 300[a]
Urinal Disch. Valve		300	150[a]
VCT (with associated equipment and controls)	30 gal. (Small Boat)	5,000	400[b]
	60 gal. (Small Boat)	5,000	400[b]
	120 gal. (Small Boat)	6,000	500[b]
	200 gal. (Large Boat)	20,000	1,200[b]
	250 gal. (Large Boat)	20,000	1,200[b]
Incinerator	(including controls)	33,000	8,250[b], [c]

Note:

1. Please supply cost estimates for each equipment based on a production run of up to 100 units.
2. All cost estimates are to be based on 1976 costs.
3. Identify recommended contents of Initial Spares Package associated with each equipment.

(a) Manufacturer recommends one initial spares package for every 5 associated equipments on board the vessel.

(b) Manufacturer recommends one initial spares package for every associated equipment on board the vessel.

(c) Includes the cost of one incinerator liner (Inconel 601 at $6,500) which was not included in cost provided by manufacturer. A new incinerator liner (Inconel 671 at $7,800) is currently being evaluated by the Navy.

[illegible] OPERATING CHARACTERISTICS AND COST ESTIMATES
[illegible]

MSD JERED

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs-Min)	Number Operators/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED — Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing Water (kwh/day)	Compressed Air (SCF/day @ P)**	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 38¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ [illegible]/1000 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	Annual Operating Cost ($)
C.T SUBSYSTEM																					
VACUUM COLLECTION SUBSYSTEM																					
Flush commode (by user)									0.75 m/c	0.11/c				$5.48/c / 0.19/c	0.50¢/c						5.48/c / 0.19/c
Flush urinal (by user)									0.63 m/c	0.10/c											
Inspect exterior of flushing fixture(s) (commode/urinal)	24 [illegible]	-1/ [illegible]	1-mk2 [illegible]	6.27	6.08/u	38.15/u								$4.55/c / 0.16/c	0.41¢/c						4.56/c / 0.16/c / 38.75/u
Check piping for air leaks; repair if necessary	168	-15	1-mk2	6.27	13.00																81.51
TOTALS					6.08/u +13.60	38.15/u +81.51			1.38/c	0.21/c				$10.04/c / 0.35/c	0.91/c						
Large Boat VCT (200, 250 gal)																					
Mode changeover cycles***																					
. primary - overboard	-	-20	1-mk2	6.27	0.33/cy	2.09/cy															2.09/cy
. pierside - primary	-	{ -20 / -10	1-mk2 / 2-mk2	6.27 / 6.27	0.33/cy / 0.33/cy	2.09/cy / 2.09/cy	(required for hose holding)														2.09/cy / 2.09/cy
VCT operation (automatic)							0.122/c					$1.99/c									1.99/c
Pumped discharge - air pressurization discharge	8760	-30	1-mk2	6.27	0.5	3.14															3.14
Inspect exterior of tank assembly	24 [n]	-6 [n]	1-mk2 [n]	6.27	36.50	228.86															228.86
Check seal water level; add if necessary	24 [n]	-6 [n]	1-mk2 [n]	6.27	36.50	228.86															228.86

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

** Compressed Air Cost in ¢/Year = $(6.12268\,(14.7+p)^{0.1429} - 8.9899)$ (SCF/day) where p is in psig.

*** It is assumed that similar effort is required for mode changeovers when a holding tank or evaporator is substituted for an incinerator.

/c = per capita (crew member)

/cy = per changeover cycle

SCF = Standard cubic feet at 14.7 psi and 70°F

D = maximum liquid depth in feet

u = unit

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs-Min)	Number Operators/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED – Resource Usage Rate: Electric Power (kwh-day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing water (kwh/day)	Compressed Air (SCF/day @ P) **	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 38¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.83¢/1000 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	TOTAL: Annual Operating Cost ($)
Change seal water	168[a]	-6[a]	1-mk2[a]	6.27	5.20	32.60			7(ave)					$51.10 $ 1.78							51.10/c 1.78/c
Check VCT for air leaks; measure vacuum recovery time	720[a]	-5[a]	1-mk2[a]	6.27	1.20	7.52															7.52
TOTALS				6.80 +13.60	39.15a +81.51		0.182/c		7			$1.99/c		$51.10 $ 1.78							
Small Boat VCT (all sizes)																					
Mode changeover cycles***																					
. primary - overboard	-	-10	1-mk2	6.27	0.17/cy	1.05/cy															1.05/cy
. pierside - primary	-	{-10 -5	1-mk2 2-mk2	6.27	0.17/cy 0.17/cy	1.05/cy 1.05/cy	(required for hose handling)														1.05/cy 1.05/cy
VCT operation (automatic)							0.070/c					37¢/c									0.77/c
Waste transfer from VCT	72	-15	1-mk2	6.27	30.25	189.67															189.67
T/D SUBSYSTEM																					
INCINERATOR																					
Incinerator operation (automatic)							0.355/c	0.844/c			101/c @ 30	$3.89/c	$120.11/c			$1.56/c					125.56/c
Remove ashes	168[a]	-12[a]	1-mk2[a]	6.27	10.40	65.21															65.21
Inspect sludge nozzle, burner flame and external surfaces	24[a]	-12[a]	1-mk2[a]	6.27	73.00	457.71															457.71
Drain water from trap in compressed air line	24	-5	1-mk2	6.27	30.42	190.71															190.71
Clean burner head components	720[a]	-30[a]	1-mk3[a]	6.84	6.0	41.04															41.04
TOTALS					119.82	954.67	0.355/c	0.844/c			101/c	3.89/c	$120.11/c			$1.56/c					

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

** Compressed Air Cost in ¢/Year = (¢.12268 (14.7+p)$^{0.1429}$ -8.9898) (SCF/day) where p is in psig.

*** It is assumed that similar effort is required for mode changeovers when an evaporator is substituted for a holding tank.

/c = per capita (crew member)

/cy = per changeover cycle

SCF = Standard cubic feet at 14.7 psi and 70°F

D = maximum liquid depth in feet

u = unit

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
C/T SUBSYSTEM											
VACUUM COLLECTION SUBSYSTEM											
Commode											
Inspect W.C. flushing mechanism	4380^{n}	-30^{n}**	1-mk3	6.84	1.01/**	6.84/**					68.40
Clean in-line strainers in urinal drain piping	4380^{n}	$1-^{n}$ *	$1-mk2^{n}$	6.27	2.00*	12.54*					12.54*
Clean urinal discharge valve	360^{a}	-10	1-mk2	6.27	4.00*	25.08*					25.08
Large Boat VCT (200, 250 gal)											
Clean exterior of VCT, seal water tank and ancillary pumps, adjoining piping, etc.	2190	2-	1-mk2	6.27	8.00	50.16					50.16
Rinse level sensor probes (5) in VCT	720^{n}	-35^{n}	$1-mk2^{n}$	6.27	7.20	45.14					45.14
Lubricate pumps and motors											
- vacuum pumps (2)	2190^{a}	-12^{n}	$1-mk2^{n}$	6.27	0.80	5.02					5.02
- incinerator (effluent)	2190^{n} 8760^{a}	-9 -36	$1-mk2^{n}$ $1-mk2^{n}$	6.27 6.27	0.60 0.60	3.76 3.76					7.52
- transfer/dump (overboard discharge) pump	2190^{n} 8760^{a}	-9 -36	$1-mk2^{n}$ $1-mk2^{n}$	6.27 6.27	0.60 0.60	3.76 3.76					7.52
- grinder pump (Maz-O-Rator)	8760^{n}	-12	$1-mk2^{n}$	6.27	0.20	1.25					1.25
Adjust pump packing gland (5 pumps)	720^{a}	-36	$1-mk2^{a}$	6.27	7.20	45.14					45.14
Clean fan, fan shield and body fins of pump motors (5)	8760^{a}	1-30	1-mk2	6.27	1.50	9.41					9.41

* Per urinal discharge valve.
** Per unit.

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
Washdown tank interior	4380[a]	-48[a]	1-mk2[a]	3.27	1.60	10.03					10.03
Test operate pressure relief valve	4380[a]	-18[a]	1-mk2[a]	3.27	0.60	3.76					3.76
Inspect/tighten foundation bolts and clean and calibrate vac/press gages	8760[a]	-6 1-30	1-mk2[a] 1-mk3[a]	6.27 6.84	0.10 1.50	0.63 10.26					10.89
Polish level sensing probe tips	8760[a]	3-[a]	1-mk3[a]	6.84	3.00	20.52					20.52
Clean vacuum pump water inlet line and Y-type strainer	720[a]	-48	1-mk2[a]	3.27	9.60	60.19					60.19
Washdown seal water tank interior	8760[a]	-48[a]	1-mk2[a]	6.27	0.80	5.02					5.02
Observe freedom of movement of incinerator feed, transfer and grinder pumps	168[a]	-30[a]	1-mk2[a]	6.27	26.00	163.02					163.02
Check calibration of incinerator feed pump	168[a]	-18[a]	1-mk2[a]	6.27	15.60	97.81					97.81
Reverse rotation of grinder pump	8760[a]	-12[a]	1-em3[a]	5.96	0.20	1.19					1.19
Replace packing in pumps (5)	8760[a]	2-	1-mk2	6.27	2.00	12.54	Packing	5	6.03(ave)[b]	30.15	42.69
Inspect indicating lamps	720[a]	-10	1-em2	5.45	2.00	10.90	Indicating lamps	4	0.40[m]	1.60	12.50
Measure motor insulation resistance (3)	2190[a]	-12	1-em3	5.96	1.20	7.15					7.15
Inspect AC controller	2190[a]	-10	1-em2	5.45	0.67	3.63					3.63

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
Test operate pumps (4)	8760[a]	-20	1-mk2	6.27	0.33	2.09					2.09
Clean controller	8760[a]	-12	1-em2	5.45	0.20	1.09					1.09
Calibrate gages (3)	8760[a]	-30	1-mk2	6.27	0.50	3.14					3.14
Adjust V-belt tension for incinerator and transfer/dump pumps	2190[a]	-12	1-mk2[a]	6.27	0.80	5.02					5.02
Clean vacuum pump's check valves and gage line	4380[a]	1-[a]	1-mk2[a]	6.27	2.00	12.54					12.54
Inspect foundation bolts	8760[a]	-20	1-mk2	6.27	0.33	2.09					2.09
TOTALS					96.33	603.76					635.53

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

Preventive Maintenance Requirement	LABOR: Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	TOTAL: Annual Preventive Maintenance Cost ($)
Small Boat VCT's (30, 60, 120 gal)											
Inspect exterior of VCT and ancillary components[a]	24	-5	1-mk2	6.27	30.42	190.71					190.71
Clean liquid level sensors	720	-15	1-mk2	6.27	3.00	18.81					18.81
Lubricate vacuum pump motor[a]	2190	-10	1-mk2	6.27	0.67	4.18					4.18
Replace air filter for vacuum pump	2190	-10	1-mk2	6.27	0.67	4.18	Air filter	4	5.00[m]	20.00	24.18
Add oil to vacuum pump lubricator	163	-5	1-mk2	6.27	4.33	27.17					27.17
Check pressure switch functionality[a]	168	-10	1-mk2	6.27	8.67	54.34					54.34
Flush system with cleaner[a]	240	-20	1-mk2	6.27	12.00	75.24	Cleaner (Clorox)	36.50	0.50[m]	18.25	93.49
Clean exterior of VCT and ancillary components	2190	1-	1-mk2	6.27	4.0	25.08					25.08
TOTALS					63.76	399.71				38.25	437.96

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

	LABOR						PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
T/D SUBSYSTEM											
INCINERATOR											
Clean sludge nozzle	168[a]	-21	1-mk2	6.27	18.26	114.11					114.11
Replace fuel filter element	2190[a]	-18[n] -6[n]	1-mk2[b] 1-em3[n]	6.27 5.96	1.20 0.40	7.52 2.38	oil filter element	4	2.25[b]	9.00	18.90
Clean/inspect fuel oil in-line strainer	4380[n]	-18[n]	1-mk2[n]	6.27	0.63	3.76					3.76
Clean and inspect . canner assembly	3760[a]	-15	1-mk2	6.27	0.25	1.57					1.57
Lubricate fuel oil pump motor	2190	-5	1-mk2	6.27	0.33	2.09					2.09
Clean and inspect incinerator interior	4380[a]	1-	1-mk3	6.84	2.00	13.68	door gasket	2	4.00[m]	8.00	21.68
Clean and inspect AC motors	8760[a]	-30	1-mk2	6.27	0.50	3.14					3.14
Clean and inspect fuel nozzle and spark plug	8760[a]	-24	1-mk2	6.27	0.40	2.51	gaskets (2)	2	6.00[m]	12.00	14.51
Calibrate gages (2)	8760[a]	-20	1-mk2	6.27	0.33	2.09					2.09
Clean solenoid valve and replace worn components	4380[a]	-24	1-mk2	6.27	0.80	5.02	valve components	1 set	3.00[m]	3.00	8.02
Measure motor insulation resistance (2)	2190[a]	-32	1-em3	5.96	0.80	4.77					4.77
Inspect AC controller	2190[a]	-10	1-em2	5.45	0.67	3.63					3.63
TOTALS					26.48	366.27				32.00	198.27

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
C/T SUBSYSTEM											
VACUUM COLLECTION SUBSYSTEM											
Commode											
Repair commode flush mechanism											
. adjustments	11424[p]	-30[p]	1-mk3	6.84	0.38*	2.82*					
. lubricate activation valve and gravity timer	4380	-30*	1-mk2	6.27	1.00*	6.27*					
Unclog commode	3620[h]	-20*	1-mk2	6.27	0.81*	5.09*					
Replace flush mechanism components in commode											
- activation valve	2yr	-40*	1-mk3	6.84	0.33*	2.28*	Activation valve	0.5*	146.00[b]	73.00*	75.28*
- gravity timer	8760	-40*	1-mk3	6.84	0.67*	4.56*	gravity timer	1.0*	54.10[b]	54.10*	58.66*
- vacuum dispensing valve	2yr	-30*	1-mk3	6.84	0.25*	1.71*	vacuum disp. valve	0.5*	27.00[b]	13.50*	15.21*
- sewage discharge valve	19,910[h]	-40*	1-mk3	6.84	0.29*	2.01*	Sewage dish. valve	0.44*	41.00[b]	18.04*	20.05*
- water dispensing valve	2yr	-30*	1-mk3	6.84	0.25*	1.71*	Water disp. valve	0.5*	28.00[b]	14.00*	15.71*
- in-line check valves	2yr	-30*	1-mk3	6.84	0.25*	1.71*	Check valves	0.5*	10.00[b]	5.00*	6.71*
- tubing and clamps	2yr	-30*	1-mk3	6.84	0.25*	1.71*	Tubing and clamps	0.5*	2.00[m]	1.00	2.71*
TOTALS					4.48*	29.67*		3.94*		178.64*	178.62*
Urinal											
Replace Urine Discharge Valve Assembly	7964[h]	-10*	1-mk2	6.27	0.18*	1.15*	UDV assembly	1.1	64.25[b]	70.67*	71.82*
Unclog Urine Discharge Valve	1327[h]	-10*	1-mk2	6.27	1.10*	6.90*					6.90*
Replace Urinal Flushometer Int...s	2yr	-6[m]*	1-mk2[m]	6.27	0.05*	0.31*	Flushometer internals	0.5	7.00[m]	3.50*	3.81*
TOTALS	8				1.33*	8.36*		1.5*		74.17*	83.53*

* Per unit, i.e., commode, UDV, flushometer.

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

	LABOR						PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Large Boat VCT (200, 250 gal)											
Clean level sensor probe(s)	498[b]	-15[a]	1-mk2	6.27	4.40	27.57					27.57
Adjust vacuum pump packing gland	168[c]	-12[a]	1-mk3[a]	6.84	10.40	71.14					71.14
Adjust grinder pump packing	362[b]	-10[b]	1-mk3	6.84	4.03	27.59					27.59
Replace pump packing:											
vacuum pump	3982[b]	-30[a]	1-mk3[a]	6.84	1.10	7.52	Pump packing	2.2	4.85[b]	10.67	18.19
incinerator or transfer/dump pump	4380	-30	1-mk3[a]	6.84	1.0	6.84	Pump packing	2.0	4.85[b]	9.70	16.54
grinder pump	3982[b]	-48[a]	1-mk3[a]	6.84	1.76	12.04	Pump packing	2.2	10.75[b]	23.65	35.69
Adjust pump motor coupling alignment for vacuum pump (2)	17520[c]	2-[a]	1-mk3[a]	6.84	1.00	6.84					6.84
Adjust V-belt tension											
- incinerator pump	240[c]	-30[a]	1-mk3[a]	6.84	18.25	124.83					124.83
- transfer/dump pump	3982[b]	-30[a]	1-mk3[a]	6.84	1.10	7.52					[illegible]
Replace V-belts	4380[c]	-30[c]	1-mk2	6.27	1.00	6.27	V-belts	2	1.75[b]	3.50	9.77
Replace cutter ring and impeller tip in grinder pump	6570	1-30 1-30	1-mk5 1-mk3	8.13 6.84	2.00 2.00	16.26 13.68	Cutter ring & tips	1.33	32.00[b]	42.67	72.61
Replace ball valve seats and seals	4380	-30	1-mk2	6.84	1.00	6.84	Seats and seals	2	11.68[b] (ave)	23.36	30.20

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

	LABOR						PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Replace pump stator (progressing cavity type)											
- incinerator pump	8760	-45	1-MK5	8.13	0.75	6.10	Pump stator	1	307.50[b]	307.50	318.73
-transfer/dump pump	17520	-45 -45 -45	1 MK3 1 MK5 1 MK3	6.84 8.13 6.84	0.75 0.38 0.38	5.13 3.05 2.57	Pump stator	0.5	307.50[b]	153.75	159.37
Replace motor bearing (5 motors)	8760	-46 -20	1-EM5 1-EM2	7.22 5.45	0.67 0.33	4.81 1.82	Motor bearing	1	7.00[m]	7.00	13.63
Replace vacuum pumps vent filter medium	8760	-30[a]	1-MK2[a]	6.27	0.50	3.14	Filter	1	10.00[m]	10.00	13.14
Replace motor starter (contactor)	8760	-10	1-EM3	5.96	0.17	0.99	Motor starter	1	200.00[b]	200.00	200.99
Replace mechanical relay	8760	-6	1-EM2	5.45	0.10	0.55	Relay	1	44.10[b]	44.10	44.65
Replace timer	17520	-6	1-EM2	5.45	0.05	0.27	Timer	0.5	157.50[b]	78.75	79.02
Replace overload heater	17520	-10	1-EM3	5.96	0.08	0.50	Overload heater	0.5	11.25[b]	5.63	6.13
Replace transistor relay	17520	-10	1-EM5	7.22	0.08	0.60	Transistor relay	0.5	150.00[b]	75.00	75.60
Replace float switch	17520	-15	1-EM4	6.50	0.13	0.81	Float Switch	0.5	40.00[m]	20.00	20.81
Clean grinder pump inlet line	2920	-13[a]	1-mk2[a]	6.27	1.50	9.41					9.41
Clean ports (sight plugs)	366[h]	-10	1-mk2	6.27	4.77	29.92					29.92
TOTALS	183.98				59.68	404.61		19.23		1015.28	1439.12

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Small Boat VCT (all sizes)											
Replace liquid level sensor	6570	-15	1-EM2	5.45	0.33	1.82	Level sensor	1.33	30.00[m]	40.00	41.82
Replace vanes in vacuum pump	8760	-30	1-MK3	6.84	0.50	3.42	Pump vanes	1	15.00[m]	15.00	18.42
Replace O-rings in vacuum/pressure control valve	8760	-15	1-MK2	6.27	0.25	1.57	O-Rings	1	2.00[m]	2.00	3.57
Clean sight gage in VCT	720	-10	1-MK2	6.27	2.00	12.54					12.54
Repair vacuum pump motor	17520	-45	1-EM3	5.96	0.38	2.24					2.24
Replace charcoal filter element	2190	-10	1-MK2	6.27	0.67	4.18	Charcoal element	4.0	15.00[m]	60.00	64.18
Replace vacuum pressure switch	17520	-30	1-EM3	5.96	0.17	0.99	Vacuum switch	0.5	44.85[b]	22.43	23.42
Replace seats and stem seal in ball valves	8760	-20	1-MK3	6.84	0.33	2.28	Seats and seals	1	11.68[b] (ave)	11.68	13.96
TOTALS	5				4.63	29.04		8.88		151.11	180.15

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
T/D SUBSYSTEM											
INCINERATOR											
Clean sludge nozzle	1991[h]	-13[n] -6[n]	1-mk2[n] 1-em3[n]	6.27 5.96	1.32 0.44	8.28 2.62					10.90
Replace sludge nozzle	4380	-16[n]	1-MK3	6.84	0.60	4.10					4.10
Replace liner (partial) **	4444m-d*	8-[e] 3-[e]	1-MK5 1-MK2	8.13 6.27	0.25/c 0.25/c	2.00/c 1.57/c	Liner and refractory	0.082/c[g]	6500[dgp]	528.65/c	[illegible]/c
Replace fuel oil filter element	3382[h]	-13[n] -6[n]	1-mk2[n] 1-em3[n]	6.27 5.96	0.66 0.22	4.14 1.31	Filter element	2.2	2.25[b]	4.95	10.40
Replace dirt alarm fuel filter element	4380	-15[n] -6[n]	1-mk2[n] 1-em3[n]	6.27 5.96	0.60 0.20	2.76 1.19	Element	2	2.25[m]	4.50	8.45
Replace fuel pump	17520	-20	1-MK3	6.84	0.17	1.14	Fuel pump	0.5	50.00[b]	25.00	26.14
Replace bearings in blower motor	17520	-40 -20	1-EM5 1-EM2	7.22 5.45	0.33 0.17	2.41 0.91	Motor bearings	0.5	7.00[n]	3.50	6.82
Replace combustion air pressure switch	26280	-10	1-EM2	5.45	0.05	0.30	Pressure switch	0.33	63.00[b]	21.00	21.30
Clean fire eye scanner cell	604[h]	-15	1-EM2	5.45	3.30	17.98					17.98
Replace fire eye scanner cell	2688[p]	-20	1-EM3	5.96	1.09	6.47	Scanner cell	3.26	18.60[b]	60.62	67.09
Replace thermocouple	4380	-10	1-EM2	5.45	0.33	1.82	Thermocouple	2	40.00[b]	80.00	81.82
Replace ignition spark plug	1440[e]	-30[e]	1-EM2	5.45	3.00	16.35	Spark plug	6	36.00[b]	216.00	232.35
Adjust temperature controller	2190	1-	1-EM6	9.73	4.00	38.92					38.92

* Incinerator Liner: $\frac{500 \text{ burn-hrs}^{(g)}}{\text{liner}} \times \frac{30 \text{ gal}}{\text{burn hour}} \times \frac{\text{man-day}}{[1.875(\text{sanitary}) + 1.5 (\text{garb. grinder})] \text{ gal}}$ = 4444 man-days per liner

** Liner used in this study is the Inconel 601 currently in field use. A new incinerator liner (Inconel 671 at a mfg stated cost of $7800) is currently under evaluation by the Navy. Manufacturer expects a life of 6,000-10,000 burn hours.

/c = per capita (crew member)

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES

(Based on 100% Utilization Factor)

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Replace timer in fire controller	17520	-15	1-EM3	5.96	0.13	0.75	Timer	0.5	80.00[m]	40.00	40.75
Replace motor starter (contactor) (2)	17520	-15	1-EM3	5.96	0.13	0.75	Motor starter	0.5	200.00[b]	100.00	100.75
Replace relay (3)	17520	-6	1-EM2	5.45	0.05	0.27	Relay	0.5	150.00[b]	75.00	75.27
Replace timer (2Agastats)	17520	-10	1-EM3	5.96	0.08	0.50	Agastat timer	0.5	157.50[b]	78.75	79.25
Replace overload relay element	17520	-10	1-EM2	5.45	0.08	0.45	Overload Relay Element	0.5	11.25[b]	5.63	6.08
Replace solenoid valve (3)	8760	-6	1-EM2	5.45	0.10	0.55	Solenoid valve	1	95.25[b]	95.25	95.80
Clean sludge line	355[p]	-15	1-mk2	6.27	6.17	38.68					38.68
TOTALS	62+ 4444m-d				23.28 +0.5/c	153.65 +.57/c		20.29+ 0.062/c		810.20+ 533.65/c	963.85+ 537.22/c

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
CT SUBSYSTEM											
VACUUM COLLECTION SUBSYSTEM											
Commode											
Replace commode internal components	4[a]	1-10/u	1-MK3	6.84	1.17/u	7.98/u	Commode internals	1 set/u	306.10[b]/u	306.10/u	314.08/u
Urinal											
Replace urine discharge valve assembly	4[a]	-5[b]/u	1-MK2	6.27	0.08/u	0.52/u	UDV assembly	1/u	64.25[b]	64.25/u	64.77/u
Large Boat VCT (200, 250 gal)											
Replace ball valve seats and seals	4[a]	3-	1-MK2	6.27	3.0	18.81	Seats and seals	10[m]	11.68[b] (ave)	116.80	135.61
Refurbish VCT interior (e.g., sandblast, repaint)	4[a]	32[e] 32[e]	1-MK6 1-MK3	11.16 6.84	32.0 32.0	357.12 218.88					576.00
Refurbish seal water tank interior	4[a]	8[e]	1-MK3	6.84	8.0	54.72					54.72
Replace level sensor probe rods (10)	4[a]	2-	1-MK3	6.84	2.0	13.68	Sensor probes	10	14.06[b] (ave)	140.60	154.28
Replace vacuum hoses	4[a]	1-	1-MK2	6.27	1.0	6.27	Hose	4	4.05[b] (ave)	16.20	22.47
Replace pressure hoses	4[a]	-24	1-MK2	6.27	0.40	2.51	Hose	2	4.05[b] (ave)	8.10	10.61
Replace hose clamps	4[a]	-30	1-MK2	6.27	0.50	3.14	Clamps	12	1.00[b] (ave)	12.00	15.14
Replace vacuum relief valve	4[a]	-5	1-MK2	6.27	0.08	0.52	Vacuum relief valve				
Adjust pressure relief valve	4[1]	-15	1-MK3	6.84	0.25	1.71	Relief valve	1	20.00[m]	20.00	21.71
Replace vacuum switch	4[a]	-15	1-EM2	5.45	0.25	1.36	Vacuum switch	1	44.85[b]	44.85	46.21
Replace V-belts	4[a]	-6	1-MK2	6.27	0.16	0.63	V-belts	2	1.75[b]	3.50	4.13

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

u = unit.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Replace vacuum pump (2) internals	4[a]	16-[e] 16-[e]	1-MK5 1-MK3	8.13 6.84	16.0 16.0	130.08 109.44					
- bearings - shaft sleeve - impeller blades and end plates - gaskets, seals, packing							bearing shaft sleeve impellers and plates gaskets	2	200.00[m]	400.00	639.52
Replace internal parts of incinerator and transfer/dump pumps	4[a]	16-[e] 16-[e]	1-MK5 1-MK3	8.13 6.84	16.0 16.0	130.08 109.44					1281.52
- bearings							bearings	4	7.00[m]	28.00	
- rotor							rotor	2	196.50[m]	393.00	
- stator							stator	2	307.50[b]	615.00	
- gaskets, seals, packing							gaskets	2 sets	3.00[m]	6.00	
Replace internal parts of grinder pump	4[a]	8-[e] 8-[e]	1-MK6 1-MK3	11.16 6.84	8.0 8.0	89.28 54.72					243.00
- cutter ring							cutter ring	1	32.00[b]	32.00	
- impeller							impeller	1	40.00[m]	40.00	
- shaft sleeve							shaft sleeve	1	8.00[m]	8.00	
- bearings							bearings	2	7.00[m]	14.00	
- grease seals, gaskets, packing							seals, gaskets	1 set	5.00[m]	5.00	
Replace motor bearings	4[a]	3-	1-EM4	6.50	3.0	19.50	Motor bearings	10	8.00[m]	80.00	99.50
TOTALS	15				162.64	1321.89		72./unit		2401.40	3723.29

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD JERED

Overhaul Requirement	LABOR: Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs-Min)	No. Maintainers/Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	PARTS CONSUMED: Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	TOTAL: Major Overhaul Cost ($)
Small Boat VCT (30, 60, 120 gal)											
Refurbish VCT interior and sight gage		2-	1-MK2	6.27	2.0	12.54					12.54
Replace liquid level sensor		-15	1-EM2	5.45	0.25	1.36	Level sensor	1	30.00 [m]	30.00	31.56
Calibrate compound pressure gage		-30	1-MK4	7.42	0.50	3.71					3.71
Replace internal parts of vacuum pump (2)		1-	1-MK3	6.84	1.00	6.84	Vac. pump internals	2	25.00 [m]	50.00	56.84
Replace vacuum pump motor bearings (2)		1-	1-EM3	5.96	1.00	5.96	Motor bearings	4	5.00 [m]	20.00	25.96
Calibrate vacuum pressure switch		-20	1-MK4	7.42	0.33	2.47					2.47
Replace seats and seals in ball valve		1-	1-MK3	6.84	1.0	6.84	Seats and seals	5	11.68 [b] (ave)	58.40	65.24
TOTALS	7				6.08	39.72		12		158.40	196.12
T/D SUBSYSTEM											
Incinerator											
Replace chamber liner and refractory	4 [a]	3- [e] 3- [e]	1-MK5 1-MK2	8.13 6.27	3.0 3.0	24.39 18.81	Liner	1	6500.00	6500.00	6543.00
Replace fire eye scanner cell	4 [a]	-20	1-EM3	5.96	0.33	1.99	Scanner cell	1	18.60 [b]	18.60	20.59
Replace thermocouple	4 [a]	-10	1-EM2	5.45	0.17	0.91	Thermocouple	1	40.00 [b]	40.00	40.91
Replace fuel oil pump	4 [a]	-20	1-MK3	6.84	0.33	2.28	Fuel oil pump	1	50.00 [b]	50.00	52.28
Replace sludge nozzle	4 [a]	-18 [a]	1-MK3	6.84	0.30	2.05	Sludge nozzle	1	100.00 [b]	100.00	102.05
Replace spark plug fuel nozzle and vaporizing tube	4 [a]	-30	1-MK2	6.27	0.5	3.14	Burner head parts	1	64.00 [b]	64.00	67.14

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD JERED

LABOR							PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Replace blower motor bearings	4[a]	-40 -20	1-EM5 1-EM2	7.22 5.45	0.67 0.33	4.81 1.82	Motor bearings	2	8.00[m]	16.00	22.63
Calibrate gages, air pressure switch and temp controller	4[a]	1-	1-MK3	6.84	1.0	6.84					6.84
Replace fuel oil filter element	4[a]	-18[a] -6[a]	1-MK2[n] 1-EM3[n]	6.27 5.96	0.30 0.1	1.88 0.60	Filter element	1	2.25[b]	2.25	4.73
Replace dirt alarm filter element	4[a]	-18[a] -6[a]	1-MK2[n] 1-EM3[n]	6.27 5.96	0.30 0.10	1.88 0.60	Filter element	1	2.25[m]	2.25	4.73
Clean sludge transfer line to incinerator	4[a]	-20	1-MK2	6.27	0.33	2.09					2.09
TOTALS	11				10.76	74.09		10		6793.10	6867.19

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

GATX EVAPORATIVE TOILET SYSTEM (ETS)

PRINCIPLES OF OPERATION

The GATX Evaporative Toilet System (ETS) is a "no discharge" system that is characterized by four basic features. It utilizes:

- Reduced volume flush commodes and urinals (also called controlled volume flush (CVF) water closets and urinals).
- Transport of wastes by macerator/transfer (M/T) pumps.
- Evaporation of the water content of the concentrated sewage.
- Holding of residual sludge in evaporator for subsequent disposal, either to pier connection or overboard.

Because the flush fluid requirement is small (about 1.5 gallons per capita per day (gpcd) rather than 8.5 gpcd), this system is practical with fresh water as well as sea water flushing. The penalties involved with the use of fresh water flushing are offset in part by the reduced corrosion and lower residual volumes in the evaporator. Thus, the evaporator can be smaller or be used for longer periods of time without unloading.

The MSD is fully automatic except for periodic servicing of the evaporator, involving pumping out the sludge, and rinsing and refilling the evaporator with the initial charge of fresh water.

The collection subsystem is required to be operational at all times to provide toilet facilities for the crew. Since the sewage transport pumps are decentralized, only one M/T pump and the urinals and commodes that drain to it need be kept operational, if minimal facilities are required. While at pierside or beyond restricted waters, the M/T pump discharge can be diverted to the pier connection or overboard in a simple MSD system. Where multiple evaporators necessitate an intermediate feed tank, diversion of raw sewage off the vessel is effected by a transfer pump, taking the wastes from the feed tank. A functional block diagram of the GATX Evaporative Toilet System appears in Figure 8.

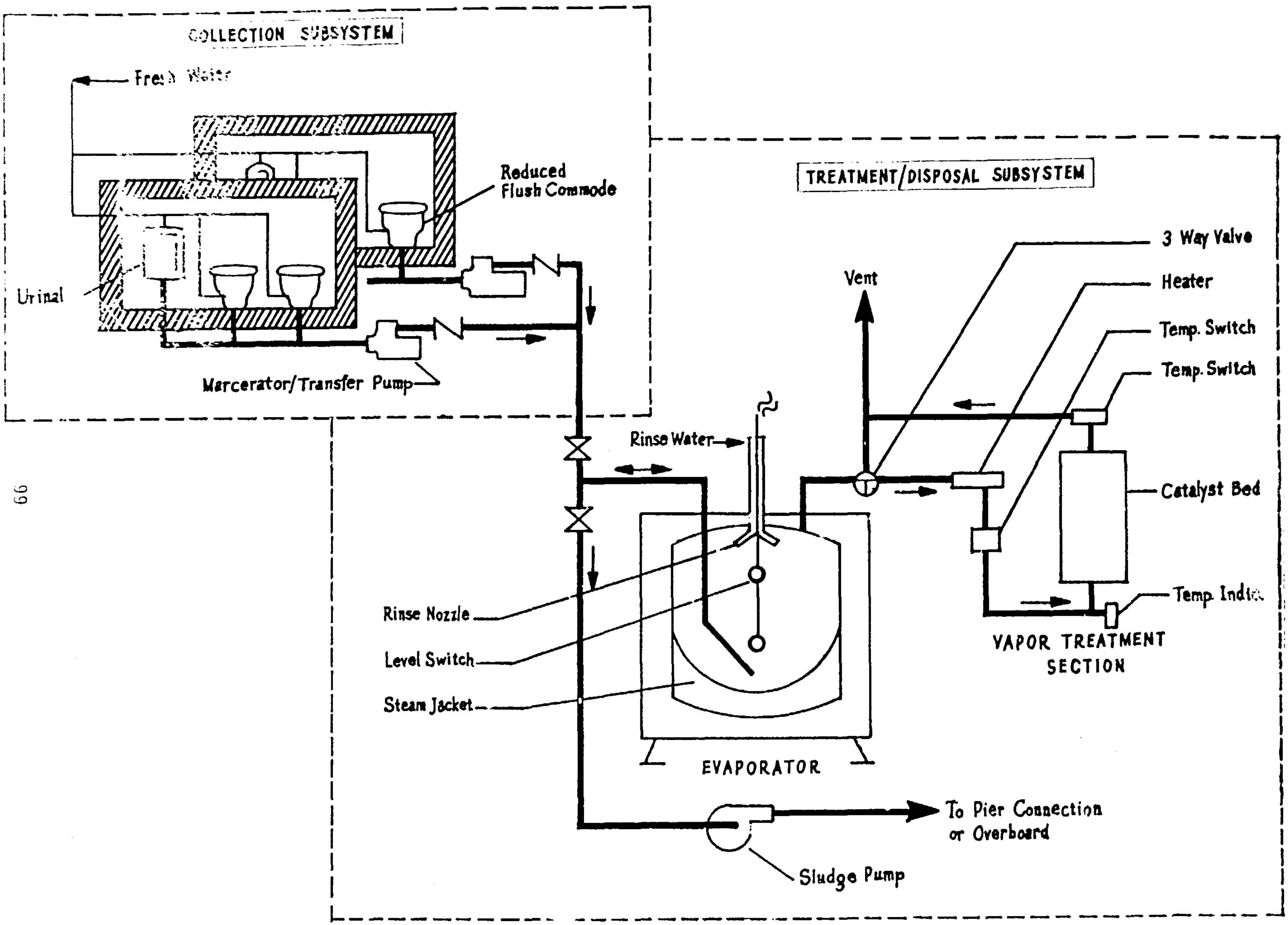

Figure 8

GATX EVAPORATIVE TOILET SYSTEM

SYSTEM DESCRIPTION

For ease of description and visualization of hybrid WMS, the GATX MSD is presented as two subsystems: collection and treatment/disposal.

Collection Subsystem

The collection subsystem is comprised of:

- Special commodes
- Standard urinals with modified flushometers
- Macerator/transfer pump(s)
- Controls

A. Commodes

The commode is a vitrious china unit that uses a swing-away discharge valve, instead of a trap, to seal off sewer odors or gases. This permits an effective flushing action with a minimal water volume on the order of one quart. Before defecation, the user actuates the flushometer by hand to dispense one pint. This water minimizes soiling of the bowl and release of odor during usage. After usage, a pedal, mounted on the commode, is actuated. This operation opens the swing-away flapper valve, releasing the contents of the bowl. An actuating cable, attached from the pedal linkages to the flushometer handle, causes the flushometer to release another pint to wash down the bowl while the flapper valve is open. After the valve closes, the small amount of water draining from the supply passageways effects a water seal between the valve and the discharge port. The discharged wastes flow by gravity into a short three or four inch diameter sewer which is connected to the inlet of a macerating/transfer (M/T) pump.

Built into the pedal flush mechanism is a switch which actuates the M/T pump through a time-delay relay and contactor. The pump operates for ten seconds after each actuation. As many as four commodes may be hooked up to one pump; each flush mechanism can actuate the pump.

B. Urinals

The urinals are standard units with special flushometers. Wastes from the urinals discharge into the M/T pump inlet pipe. Several arrangements of the flushometer have been used, designed, and proposed. The original flushometer design used on the Navy's MONOB was a timed solenoid valve, push-button operated. An electric counter actuated the M/T pump after five urinal flushes. The current design, which is assumed for this study, calls for a special, manually operated flushometer with an electrical switch. The switch can optionally actuate the M/T pump after each flush, or after several flushes. If the sewage piping is installed in a continually descending arrangement, the urinal(s) can drain through a pump that is not operating, providing no other M/T pump is running. One operating pump pressurizes the discharge line and closes the check valves on all other M/T pumps, thereby preventing gravity drainage from a urinal.

C. Macerator/Transfer (M/T) Pump

The M/T pump is a close-coupled grinder pump and motor that was originally designed for submerged sewage service. The inlet adapter can be chosen to accept 3-or 4-inch suction piping. Discharge is through a 1-1/4 inch screwed pipe connection. A rotating, hardened impeller tip cuts up solids against a stationary cutter ring through which the solids and liquids flow. The impeller provides centrifugal pumping characteristics of a nominal 20 gpm at 35 psig or 34 gpm at 25 psig.

The M/T pump is hung from the overhead for the deck below the commodes and should be located no more than eight feet (horizontally) from the farthest commode. Sewage flows by gravity to the pump, whereas the pumped sewage flows by pressure in a small (1-1/4 in.) filled pipe. Therefore routing of this line is unrestrained, i.e. it need not be sloped and can flow vertically upwards if necessary, limited only by pump pressure. The M/T pump operates for approximately 10 seconds following the signal from a commode or urinal. An interlock relay prevents M/T pump operation if the high level sensor in the evaporator is actuated, thereby avoiding overfilling the evaporator. The interlock relay will shut down control circuits for all M/T pumps in a multiple pump installation.

In a simple MSD, the M/T pump(s) discharges(s) directly into an evaporator in the treatment/disposal subsystem. In larger systems with more than one evaporator, or in a hybrid system with an incinerator, the M/T pump(s) discharge(s) into an intermediate feed tank for distribution and/or metering of the sewage.

Treatment/Disposal Subsystem

The treatment/disposal subsystem is comprised of an

- Evaporator
- Vapor treatment section
- Sludge pump
- Controls

A. Evaporator

The evaporator is a modified commercial steam-jacketedkettle, made of stainless steel, and electrically heated. It is used to receive and hold sewage collected by the commodes and urinals, and delivered to the tank by M/T pump(s). It treats the sewage by evaporating the water content at elevated temperature, and retains the residual sludge until an appropriate time for unloading.

The standard unit for the GATX MSD is a modification of the largest size kettle (80 gallons) made by the supplier. The tank interior is teflon lined and the exterior (and jacket) is insulated with fiber glass. A metal shroud covers the insulation. The evaporator tank has a gasketed top cover that provides a positive watertight seal to prevent fluid seepage and leakage of tank odors. A 10-inch diameter gasketed port with a Pyrex window is also provided in the cover, to permit access to the interior of the tank for cleaning and inspection purposes. Fittings are provided in the cover for waste input, rinse water, vapor venting, pressure relief, and electrical connections.

The 1-1/4 inch waste input line terminates near the bottom of the tank's hemispherical underside. Incoming sewage prevents settled sludge from becoming hard and difficult to remove. The influent pipe is also used for emptying the evaporator. Rinse water (sea water) is dispensed by 14 spray nozzles to wash down the inside of the tank at the end of the sludge removal cycle. As water is evaporated from the sewage, it exits, through the vapor connection in the cover, to the Vapor Treatment Section.

Extending through the rinse water connection, along the vertical centerline of the tank, is a two stage liquid level switch. The lower float magnetically actuates a reed switch to operate the heaters when the level is high and shut them off when evaporation has lowered the level sufficiently. The upper float actuates a FULL light to indicate that the level is high, a SERVICE indicator light when the sewage is fairly concentrated, at which time it stops any M/T pump from operating. The term "service" is used for the procedure of draining, rinsing and partially refilling the evaporator with fresh water.

The controls on the steam jacket are a pressure gage, steam relief valve, water fill valve, level sight glass, low level switch, high temperature switch (set at 240°F) and a high pressure switch (set at 27 psig). As the sewage in the evaporator becomes concentrated, heat transfer from steam to sewage decreases, thereby causing the jacket pressure and temperature to rise. Actuation of either switch will shut off the heaters and notify the operator of the need for servicing when the tank is full. The jacket pressure relief valve will prevent jacket rupture in the event of a control failure.

Smaller size evaporators are available from the kettle manufacturer in sizes of 20, 40, and 60 gallons. These units can be modified in similar manner to the 80 gallon units for use in vessels with smaller requirements. For larger vessels, multiple evaporators would be required, necessitating one of three distribution schemes, namely:

1. Each evaporator supplied by its own collection subsystem.
2. Equal disbursement to each evaporator from a central feed tank, using one or more transfer pumps.
3. Sequential filling, i.e. all sewage goes to one evaporator until it is full, whereupon automatic switchover to the next evaporator takes place.

B. Vapor Treatment Section

The vapor and gases leaving the evaporator are passed through a hot catalyst bed along with compressed air where the odoriferous compounds are oxidized to mainly carbon dioxide and water vapor. The vapor treatment section (VTS) consists mainly of 1-1/2 inch piping incorporating instruments, controls and a 6 in. diameter by 18 in. long pipe containing catalyst, in a predesigned configuration. A compressed air control station feeds ship's service air to the VTS. A three-way valve at the inlet to this section can be set to bypass the entire section in an emergency.

A 1600-watt heating element maintains high temperature in the vapor/air mixture flowing in the insulated piping and catalyst bed to prevent condensation of water. A thermal switch downstream of the heater shuts it off if the temperature reaches 500°F. Another thermal switch downstream of the catalyst bed does not permit the evaporator heaters to go on until the gases (initially air) leaving the catalyst bed reach 250°F. The compressed air controls regulate the pressure and thereby the flow through an orifice. A pressure switch upstream of the orifice allows operation of the evaporator heaters only when the air pressure reaches 13 psig. These two switches assure deodorization of the vapors leaving the evaporator by requiring both oxidation air and high temperature at the catalyst.

Since the VTS is a fabricated assembly, it can be scaled up or down readily by maintaining:

- The ratio of air flow to vapor flow.
- The same temperature.
- Equal flow rate and gas retention time through the catalyst bed.

Although one large VTS could handle the output of several evaporators, numerous complexities are involved that may make it more practical to have one VTS per evaporator.

C. Sludge Pump

In the MONOB design, the sludge pump is placed underneath the evaporator where it withdraws concentrated sewage (followed by manually injected rinse water) from the evaporator and discharges them from the vessel. This close-coupled centrifugal pump could be located elsewhere in the vicinity of the evaporator. The motor is actuated by a manual starter.

GATX

COMPONENT PHYSICAL CHARACTERISTICS

Component	Weight		Volume	Dimensions		
	Dry	Filled	cu ft	Height	Length	Width
Commode	80	81	3.5	19	21	15
M/T Pump	125	127	1.0	10	25	7
Evaporator						
20 gal	300*	433*	13.2	43	-	26 dia
40 gal	470*	743*	20.0	43	-	32 dia
60 gal	620*	1025*	27.1	46	-	36 dia
80 gal	750	1375*	32.8	50	-	38 dia
Sludge Pump	35	35	0.3	7 dia	15	-
Catalytic Oxidizer (uninsulated)	90*	-	0.3	18	-	6 dia
Controls	75	-	3.1	21	12	21

* Estimated. Dry tank weight taken as 2/3 power of ratio to 80-gal tank. Water weight proportionately based on 65 gals in 80-gal tank plus 10 gals in steam jacket.

GATX

COMPONENT PIPE CONNECTIONS

Macerator/Transfer Pump	Inlet:	3-inch NPT
	Outlet:	1 1/4-inch NPT
Evaporator		
Waste Inlet (and sludge suction)	1 1/4-inch NPT	
Vapor Outlet	1 1/2-inch NPT	
Sludge Pump (in and out)	1 1/4-inch NPT	
Vapor Treatment System (80-gal evap.)		
Vapor (in and out)	1 1/4-inch NPT	
Compressed Air	1/4-inch NPT	

GATX

COMPONENT VESSEL RESOURCE REQUIREMENTS

Component	HP	Watts	Volts	Phase	Hertz	Amp.	Compressed Air SCFM	Flush Water
M/T Pump	1 1/2		440	3	60			
Evaporator (Std)								30 psig
20 gal		1,373	440	3	60			
40 gal		2,745	440	3	60			
60 gal		4,118	440	3	60			
80 gal		5,490	440	3	60			
Sludge Pump	1 1/2		440	3	60			
Vapor Treatment System								
20 gal std. evap.		325	440	1	60		2.5	
40 gal std. evap.		650	440	1	60		5	
60 gal std. evap.		975	440	1	60		7.5	
80 gal std. evap.		1,300	440	1	60		10	
Controls		200 est.	440	1	60			

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GATX

Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	INSTALLATION Attribute Data: Treat./Disposal Subsystem
12	MSD materials disallowed or not recommended.(1) (a) No disallowed or not recommended materials present(2) in MSD subsystem. (b) Some disallowed or not recommended materials present in MSD subsystem, but resultant problems can be solved or compensated for. (c) Presence of disallowed or not recommended materials in MSD subsystem presents problems with no feasible solutions.	a	a
13	Extent of additional support systems or equipment required to accommodate MSD(3) Identification of support system requirements for MSD subsystem.		
21	Extent of fixture modifications required for MSD installation. (a) MSD uses standard commodes and urinals. (b) MSD uses non-standard commodes and special equipment is associated with the urinals. (c) MSD uses non-standard commodes, special equipment is associated with the urinals and each fixture has additional hook-up requirements.	(7) c	N/A
22	Extent of flush medium supply modifications required for MSD installation. (a) MSD uses sea water for flushing fixtures. (b) MSD uses fresh water for flushing fixtures. (c) MSD uses a non-aqueous for flushing fixtures.	b	N/A
231	Hookup requirements(4) for MSD Collection/Transport subsystem installation. (a) MSD uses standard Collection/Transport subsystem. (b) MSD uses recirculating Collection/Transport subsystem.(5) (c) MSD uses non-standard and centralized Collection/Transport subsystem. (d) MSD uses non-standard and non-centralized Collection/Transport subsystem.(6)	(8) d	N/A

(1) As specified in subchapters J&F of Merchant Marine Code and C.G. MSD regulations.
(2) For purposes of this study, C.G. directs choice (a) for all MSDs.
(3) Examples:
- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(4) Drain piping; electric cables for connecting commodes, M/T pump and control panel, compressed air, etc.
(5) In existing gravity drain system.
(6) Includes conversion from reduced flush vacuum collection to a standard gravity drain system with or without recirculation.

(7) M/T pumps associated with commodes; replacement of flushometer valves with special electrically controlled units.
(8) Electric power, electrical controls (control panel, M/T pumps, urinal flushometers), fresh water.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GATX

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
232	Routing flexibility for drain piping modifications(1) associated with MSD Collection/Transport subsystem installation(2) (a) Routing of MSD Collection/Transport piping is highly flexible. (b) Routing of MSD Collection/Transport piping is moderately flexible with some restrictions. (c) Routing of MSD Collection/Transport piping is highly inflexible.	(3) b	N/A
233	Space requirements for MSD Collection/Transport subsystem installation (a) Space required for MSD Collection/Transport subsystem is little or no greater than that required for standard Collection/Transport subsystem. (b) Space required for MSD Collection/Transport subsystem is moderately increased over that required for standard Collection/Transport subsystem. (c) Space required for MSD Collection/Transport subsystem is much greater than that required for standard Collection/Transport subsystem.	(4) b	N/A
234	Modularity of MSD Collection/Transport subsystem (as it affects installation). (a) Collection/Transport subsystem is highly modular. (b) There is an option for some decentralization of the MSD Collection/Transport subsystem. (c) The MSD Collection/Transport subsystem is highly centralized.	b	N/A
235	Vent requirements for MSD Collection/Transport subsystem installation. (a) MSD Collection/Transport subsystem requires no vents. (b) MSD Collection/Transport subsystem requires few vents. (c) MSD Collection/Transport subsystem requires many vents.	(5) c	N/A

(1) Of the three relevant categories of routing lines (piping, ventilation, electrical), piping is the most important for assessing ease of MSD installation.

(2) Notes:

- With gravity drainage, lines must always slope downward and require venting.
- Smaller size lines are inherently more flexible.
- With pump or vacuum Collection/Transport subsystem, sharp bends, risers and long runs can be accommodated in piping.

(3) M/T pumps must be close to commodes since waste is gravity drained to M/T pumps.

(4) M/T pumps are close to overhead of decks below head spaces.

(5) Vents required on gravity drain portion of piping to M/T pumps. As for standard drain lines (i.e., all traps must be vented). Answer applies to new installation only; if standard drain line already installed in vessel, then (a) applies.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GATX

Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	Attribute Data Collect./Transp. Subsystem	Attribute Data Treat./Disposal Subsystem
242	Hookup requirements[1] for MSD waste Treatment/Disposal subsystem installation (a) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are minimal. (b) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are moderate. (c) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are extensive.	N/A	(5) b
243	Degree of modularity of MSD waste Treatment/Disposal subsystems (as it affects installation)[2] (a) MSD Treatment/Disposal subsystem is highly modular. (b) There is an option for some decentralization of the MSD Treatment/Disposal subsystem. (c) MSD Treatment/Disposal subsystem is highly centralized.	N/A	(6) c
244	Vent requirements for MSD waste Treatment/Disposal subsystem installation[3] (a) No vents are required for MSD Treatment/Disposal subsystem. (b) Vents are required for MSD Treatment/Disposal subsystem.	N/A	(7) b
245	Exhaust stack requirements for MSD waste Treatment/Disposal subsystem installation.[4] (a) Exhaust stack not required for MSD Treatment/Disposal subsystem. (b) Small exhaust stack required for MSD Treatment/Disposal subsystem. (c) Large exhaust stack required for MSD Treatment/Disposal subsystem.	N/A	a

(1) Piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote panels, etc.; ducting for ventilation, etc.
(2) Decentralization of components may require additional hookups and piping runs.
(3) Vents that are only internal to the compartment in which subsystem is located are not considered here.
(4) Notes:
- Electric incinerator requires small (2") exhaust.
- Fuel incinerator requires large (10") exhaust.

(5) Fair number of cables required (electric power, electrical controls); line for flushing evaporator tank.

(6) Vapor treatment unit may be separated from evaporator.

(7) One vent is required for evaporator.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GATX

Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
25	Ease of installing MSD support equipment[(1)] Extent of additional support equipment required to accommodate MSD (a) No additional support equipment required for MSD subsystem. (b) Some additional support equipment required for MSD subsystem. (c) Much additional support equipment required for MSD subsystem.	a	a

(1) Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GATX

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem
311	Effect of peak hydraulic loads in black[1] water stream on MSD performance[2]	(4)	(5)
	(a) No significant effect of black water peaks on MSD subsystem performance.	a	
	(b) Effect of black water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome.		b
	(c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for MSD subsystem performance.		
	(d) No ability of MSD subsystem to handle black water peaks.		
312	Effect of peak hydraulic loads in gray[1] water stream on MSD performance (2)		
	(a) No significant effect of gray water peaks on MSD subsystem performance.		
	(b) Effect of gray water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome.	N/A System cannot handle gray water	N/A
	(c) Long-term effect of gray water peaks, difficult to overcome with long-term implications for MSD subsystem performance.		
	(d) No ability of MSD subsystem to handle gray water peaks.		
321	Effect of low flow conditions/long idle times in black water stream on MSD performance(3)	(6)	
	(a) No significant effect of black water low flow conditions/long idle times on MSD subsystem performance.	a	a
	(b) Effect of black water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome.		
	(c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for MSD subsystem performance.		
	(d) No ability of MSD subsystem to handle black water low flow conditions/ long idle times.		

(1) Includes instantaneous, hourly and daily loads.

(2) Peak load handling ability depends on C/T subsystem. The ability of an MSD which employs an influent surge tank to handle peaks usually depends almost entirely on the sizing of this tank.

(3) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(4) In the unlikely event that two or more M/T pumps that feed into the same 1-1/4" drain run simultaneously, it would not pull all liquid from 3" drain since 1-1/4" line capacity will limit pumping rate of M/T pumps.

(5) If evaporator is full or almost full when peak occurs, the tank must evaporate some of its contents before being able to accept the peak load.

(6) Solids will settle but M/T pumps should sweep out lines.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GATX — Sheet 2 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem
322	Effect of low flow conditions/long idle times in gray water stream on MSD performance[1] (a) No significant effect of gray water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of gray water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water low flow conditions/long idle times, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water low flow conditions/long idle times.	N/A System cannot handle gray water	N/A
331	Ability of black water portion of MSD to handle additional personnel (on a long-term basis)[2] (a) MSD black water subsystem will handle additional personnel with little or no degradation in performance. (b) MSD black water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance. (c) MSD black water subsystem will not handle additional personnel	a	(4) b
332	Ability of gray water portion of MSD to handle additional personnel (on a long-term basis)[3] (a) MSD gray water subsystem will handle additional personnel with little or no degradation in performance. (b) MSD gray water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance. (c) MSD gray water subsystem will not handle additional personnel.	N/A System cannot handle gray water	N/A

(1) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(2) Resulting in long-term increase in average black water stream hydraulic loading. The ability of an MSD which employs a black water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(3) Resulting in long-term increase in average gray water stream hydraulic loading. The ability of an MSD which employs a gray water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(4) Will have to service evaporator more frequently.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GATX

Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
41	Ability of black water handling portion of MSD to operate for sustained time periods (a) MSD black water subsystem can operate for indefinite period of time if no components fail.(1) (b) MSD black water subsystem can operate for only limited period of time, even if no components fail.(2)	a	b
42	Ability of gray water handling portion of MSD to operate for sustained time period (a) MSD gray water subsystem can operate for indefinite period of time if no components fail.(1) (b) MSD gray water subsystem can operate for only limited period of time, even if no components fail.(2)	N/A System cannot handle gray water	N/A
51	Ability of MSD to handle ground garbage in black water stream (a) MSD black water subsystem will handle ground garbage in black water stream on a long-term basis. (b) MSD black water subsystem will handle ground garb. ge in black water stream on at least a short-term basis. (c) MSD black water subsystem will not handle ground garbage in black water stream.	(4) c	(5) b
52	Ability of MSD to handle foreign materials/objects(3) in black water stream (a) MSD subsystem will handle foreign materials/objects in black water stream on a long-term basis. (b) MSD subsystem will handle foreign materials/objects in black water stream on at least a short-term basis. (c) MSD subsystem will not handle foreign materials/objects in black water stream.	(6) b	(7) c

(1) Applies to a T/D subsystem with an incinerator.
(2) Applies to a T/D subsystem without an incinerator.
(3) Examples:
- Long, narrow objects (pens, pencils, toothpicks, etc.)
- Small hard objects (nut shells, pull tab from a flip top can, bottle caps, paper clips, coins, nuts/bolts/ screws/nails, cuff links, etc.)
- Large soft objects (paper towels, newspaper page, stiff and shiny magazine page, strings from a floor mop, rag, tampons and sanitary napkins, etc.)

(4) C/T subsystem does not handle ground garbage slurry; it is fed by separate line directly into evaporator.
(5) Detergents in ground garbage slurry may cause foaming. Will have to empty evaporator more often.
(6) M/T pumps will handle if material is not too hard.
(7) Might interfere with operation of sludge pump.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GATX | Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem
53	Ability of MSD to handle detergents/surfactants in black water stream on a long-term basis. (a) MSD subsystem will handle detergents/surfactants in black water stream on a long-term basis. (b) MSD subsystem will handle detergents/surfactants in black water stream on at least a short-term basis. (c) MSD subsystem will not handle detergents/surfactants in black water stream.	a	(1) b
54	Ability of MSD to handle toxic materials in black water stream (a) MSD subsystem will handle toxic materials in black water stream on a long-term basis. (b) MSD subsystem will handle toxic materials in black water stream on at least a short-term basis. (c) MSD subsystem will handle toxic materials in black water stream.	a	(2) a
61	Ability of MSD secondary emissions to meet applicable standards for the discharge of air pollutants (a) No possibility of discharge of significant air pollution from MSD subsystem. (b) MSD subsystem will meet standards for air pollutants under normal operating conditions. (c) MSD subsystem will meet standards for air pollutants under normal operating conditions and there is a strong possibility of non-conformance to standards under unusual operating conditions.	a	a
62	Ability of MSD secondary emissions to meet applicable standards for disposal of oil-contaminated residues at sea (a) MSD subsystem has no potential for producing oil-contaminated residues at sea. (b) MSD subsystem has a potential for producing oil-contaminated residues at sea.	a	a
71	Performance risk for black water handling portion of MSD (a) MSD black water subsystem has a history of fair or better test results. (b) MSD black water subsystem has a history of poor test results. (c) No test results are available for the MSD black water subsystem.	a	a
72	Performance risk for gray water water handling portion of MSD (a) MSD gray water subsystem has a history of fair or better test results. (b) MSD gray water subsystem has a history of poor test results. (c) No test results are available for the MSD gray water subsystem.	N/A System cannot handle gray water	N/A

(1) Could affect evaporation process: If foam build up, the foam may get into the vapor treatment section, damaging the catalyst or decreasing the sections temperature so that odors are produced.

(2) Some toxic materials may get through vapor treatment section and be vented (no standards against it).

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD GATX Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data Collect./Transp. Subsystem	 Treat./Disposal Subsystem
11	Degree of automation for MSD operation (1) (a) MSD subsystem is almost fully automatic. (b) MSD subsystem is semi-automatic: requires infrequent operator attention. (c) MSD subsystem is semi-automatic: requires a moderate degree of operator attention. (d) MSD subsystem is semi-automatic: requires frequent operator attention. (e) MSD subsystem is operated manually.	a	(4) b
12	Ease of disposal of MSD residue(s)(1)(2) (a) MSD subsystem has no residues, or disposal of residues from MSD subsystem is very convenient. (b) Disposal of residues from MSD subsystem is moderately convenient. (c) Disposal of residues from MSD subsystem is inconvenient.	a	(5) b
14	Likelihood of violating effuent standards because of procedural errors in MSD operation. (3) (a) There is virtually no chance of violating effluent standards because of procedural errors in MSD operation. (b) There is a low likelihood of violating effluent standards because of procedural errors in MSD operation. (c) There is a fair to moderate chance of violating effluent standards because of procedural errors in MSD operation. (d) There is a high likelihood of violating effluent standards because of procedural errors in MSD operation.	a	(6) b
23	Skill level requirements for operator of MSD MSD subsystem complexity ranking from 1 to 5	4	2
24	Training requirements for operator of MSD MSD subsystem complexity ranking from 1 to 5	4	2

(1) Residue is any by-product of normal MSD operation, disposal of which is regular operating task. Examples are ash produced by an incinerator, seal water used by vacuum pumps, wastewater or sludge held in a tank, evaporator residue, etc.

(2) Length of time required for disposal is the main factor considered; other factors are ease of access of area of MSD containing the residue, amount of residue to be disposed of, and ease of storing residue on board or taking if off vessel, as appropriate.

(3) By dumping overboard effluent which doesn't meet standards, flush oil, evaporator residue, air pollutants from incinerator, etc.

(4) Evaporator requires infrequent servicing.

(5) Procedure is as follows: Stop M/T pumps and wait 15-30 minutes; leave heater on for 15 minutes to sterilize any remaining sewage coming in; let evaporator cool down; prime sludge pump; empty evaporator; turn on rinse water; clean and refill.

(6) May pump sewage overboard.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD GATX — Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data Collect./Transp. Subsystem	 Treat./Disposal Subsystem
25	Effect of MSD operation on vessel work routines/schedules (a) MSD operation has minimal or no effect on work routines/schedules. (1) (b) Effect of MSD operation on work routines/schedules is more than minimal (i.e., is moderate or extensive).	a	a
32	Availability of specialized or unique consumables/expendables required for MSD operation (a) No specialized or unique consumables or expendables required for MSD subsystem operation. (b) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from ship's inventory. (c) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from Federal Stock System. (d) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from a commercial source.	a	(5) a
33	Operating requirements for special or unique MSD support equipment (a) No special or unique support equipment required by MSD subsystem. (b) Some special or unique support equipment required by MSD subsystem; equipment requires only minimal and infrequent attention(2) to keep operational.(3) (c) Some special or unique support equipment required by MSD subsystem; requires more than infrequent attention to keep operational.(4)	a	a

(1) By C.G. direction, (a) applies to all MSDs considered in this study.
(2) No more frequently than weekly with a duration not greater than 10 minutes; or more frequently than semi-annually with a duration of 2 hours.
(3) E.g., firefighting equipment, special transformers, ozone detector, bilge alarm.
(4) E.g., compressor installed to support MSD operation.

(5) Catalyst bed not special.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GATX — Sheet 1 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem
11	Hazard of contact with/spillage of toxic/dangerous substances[1] due to MSD inherent design	(2)	(3)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	d	d
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (form hands).

(2) Since M/T pumps are mounted overhead, contact with sewage is highly likely, even if maintainer wears protective clothing.

(3) For operator: almost no chance; splatter of sewage in rinsing evaporator is possible, but avoidable. For maintainer: may have to get into part of evaporator to service and even with protective clothing, some contact with sewage is highly likely.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GATX

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
		(2)	(3)
12	Hazard of contact due with/spillage of toxic/dangerous substances[1] due to procedural error/equipment failures of MSD		
	L - Likelihood of hazard		
	(a) No chance		
	(b) Highly unlikely	b	
	(c) Fair to even chance		c
	(d) Highly likely		
	S - Severity of hazard		
	(a) No resultant injury.	a	a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		
	(c) Results in severe injury or death.		
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected.	a	a
	(b) Hazardous situation is difficult to correct.		
	(c) Hazardous situation cannot be corrected.		

(1) Examples:

- . Leakage of fumes from incinerator into adjacent berthing and working spaces.
- . Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- . Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- . Sewage contamination.
  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

(2) . Check valve could fail to open and another M/T pump running pushes sewage through check valve into fixture.
. Drain line gasket failure results in leakage---sewage drips on someone.

(3) . No danger from vapor treatment section.
. Evaporator priming valve might be left open (a procedural error).
. If M/T pump does not shut off due to control valve relay coil burnout, evaporator may overfill and pressure relief valve may spray sewage all over compartment.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GATX

Sheet 3 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem
21	Hazard of explosive potential for operator/maintainer due to inherent MSD design	(1)	(2)
	L - Likelihood of hazard		
	(a) No chance	a	
	(b) Highly unlikely		b
	(c) Fair to even chance		
	(d) Highly likely		
	S - Severity of hazard		
	(a) No resultant injury.	a	
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b
	(c) Results in severe injury or death.		
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected.	a	a
	(b) Hazardous situation is difficult to correct.		
	(c) Hazardous situation cannot be corrected.		
22	Hazard of explosive potential for operator/maintainer due to procedural errors/ equipment failures of MSD		(3)
	L - Likelihood of hazard		
	(a) No chance	a	
	(b) Highly unlikely		
	(c) Fair to even chance		c
	(d) Highly likely		
	S - Severity of hazard		
	(a) No resultant injury.	a	
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b
	(c) Results in severe injury or death.		
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected.	a	a
	(b) Hazardous situation is difficult to correct.		
	(c) Hazardous situation cannot be corrected.		

(1) Except if discharge line is not drained, sewage goes septic and generates methane.
(2) Evaporator has pressurized steam jacket, with safety relief valve.
(3) If flammable liquid (e.g. lighter fluid) is dumped into evaporator (or commodes); if many liquids were dumped into evaporator, may have to turn off heater to prevent further burning.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GATX

Sheet 4 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
31	Hazard of fire ignition potential(1) due to inherent MSD design		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a
32	Hazard of fire ignition potential(1) due to procedural errors/equipment failure of MSD		(2)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situtation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a

(1) Oil used for flushing is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

(2) If insulation comes off evaporator or vapor treatment section.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GATX

Sheet 5 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data Collect./Transp. Subsystem	SAFETY Attribute Data Treat./Disposal Subsystem
4	Hazard of electrical shock potential(1) for operator/maintainer of MSD	(3)	
	L - Likelihood of hazard		
	(a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b
	S - Severity of hazard		
	(a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	c
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a
51	Physical hazards associated with MSD due to sharp edges(2)	(4)	(5)
	L - Likelihood of hazard		
	(a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	c
	S - Severity of hazard		
	(a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	b
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a

(1) Electric shock may result in severe burns and/or death; in addition, reaction to electric shock may cause affected individual to be thrown aside, possibly subjecting him to severe impact injuries and/or contact with sharge edges/hot surfaces.

(2) Combined effect of injury due to sharp edges/points and sewage contamination may introduce harmful pathogens into the bloodstream of an affected individual.

(3) In servicing flushometer, commode microswitch flush switch, M/T pump, it is possible for maintainer to get an electric shock.

(4) If maintainer had to dislodge hard material which had sharp edges by the M/T pump.

(5) . Hard objects may be sharpened by passing through M/T pump and may jam sludge pump; in servicing either pump, may get cut on sharpened object.
. Inside electrical control box, there are many burrs from stamped metal parts.
. Stainless steel evaporator housing may have sharp edges on which maintainer could be cut.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GATX Sheet 6 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem
52	Physical hazards associated with MSD due to hot surfaces	(1)	(2)
	L - Likelihood of hazard		
	(a) No chance		
	(b) Highly unlikely	b	
	(c) Fair to even chance		c
	(d) Highly likely		
	S - Severity of hazard		
	(a) No resultant injury.	a	
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b
	(c) Results in severe injury or death.		
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected.	a	a
	(b) Hazardous situation is difficult to correct.		
	(c) Hazardous situation cannot be corrected.		
53	Physical hazard for maintainer of MSD due to rotating machinery	(3)	(4)
	L - Likelihood of hazard		
	(a) No chance		
	(b) Highly unlikely	b	b
	(c) Fair to even chance		
	(d) Highly likely		
	S - Severity of hazard		
	(a) No resultant injury.	a	a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment		
	(c) Results in severe injury or death.		
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected.	a	a
	(b) Hazardous situation is difficult to correct.		
	(c) Hazardous situation cannot be corrected.		

(1) Maintainer might touch hot pump motor.

(2) . Vapor treatment section surfaces are well insulated; if over temperature switch fails, section can overheat.
. Evaporator is insulated; maintainer removing evaporator cover while still hot may get a burn.

(3) From M/T pump, if maintainer very careless.

(4) From sludge pump, if maintainer careless.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD GATX   Sheet 1 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	HABITABILITY Attribute Data: Treat./Disposal Subsystem
11	Habitability problems(1) associated with bacterial contamination due to MSD inherent design (a) There is no bacterial contamination habitability problem due to MSD subsystem inherent design features. (b) There is a bacterial contamination habitability problem due to MSD subsystem inherent design features.	a	a
12	Habitability problems(1) associated with bacterial contamination due to procedural errors/equipment failures of MSD(2) (a) A bacterial contamination problem due to procedural errors/equipment failures of MSD subsystem is highly unlikely. (b) Procedural errors/equipment failures of MSD subsystem are likely to cause a bacterial contamination problem	(3) b	a
21	MSD fixture comfort (a) Commodes and urinals are comfortable and easy to use even under ship's motion. (b) Commodes and urinals are not comfortable and easy to use under ship's motion.	a	N/A
22	Flushing procedure requirements for MSD fixture (a) There are no "non-standard" requirements for flushing. (b) There are "non-standard" requirements for flushing.	b	N/A
23	Waste retention in MSD commode bowl (a) The amount of waste that remains in the bowl after flushing is less than that remaining after flushing a standard full water flushed fixture. (b) The amount of waste that remains in the bowl after flushing is the same as that remaining after flushing a standard full water flushed fixture. (c) The amount of waste that remains in the bowl after flushing is more than that remaining after flushing a standard full water flushed fixture.	c	N/A

(1) As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

(2) A vacuum waste collection subsystem is less likely to expose personnel to sewage in case of a line break than a pressurized waste collection subsystem; fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply.

(3) The GATX MSD, because it has a pressurized sewage collection system, is more likely to expose personnel to sewage in case of a line break.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD GATX Sheet 2 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	HABITABILITY Attribute Data: Treat./Disposal Subsystem
24	Likelihood of user contact[(1)] with MSD fixture flushing medium (a) User is unlikely to come into contact with flushing medium. (b) User is more likely to come into contact with flushing medium than with standard water flushed fixture.	(3) b	N/A
25	Appearance of MSD fixture flushing medium (a) The color and general appearance of the flushing medium is as acceptable as clear water. (b) The color and general appearance of the flushing medium are acceptable, but clear water is preferable. (c) The color and general appearance of the flushing medium are not acceptable.	a	N/A
26	Noise produced in flushing MSD fixtures (a) The noise produced in flushing fixtures is less than that of a standard commode/urinal. (b) The noise produced in flushing fixtures is the same as that of a standard commode/urinal. (c) The noise produced in flushing fixtures is greater than that of a standard commode/urinal.	b	N/A
31	Odors produced as a result of inherent MSD design (a) The MSD subsystem produces no odor as a result of inherent design. (b) The MSD subsystem produces a noticeable odor as a result of inherent design.	a	(4) a
32	Odors produced as a result of procedural errors/equipment failures of MSD (a) The MSD subsystem produces no odor as a result of procedural errors/equipment failures. (b) The MSD subsystem produces a noticeable odor as a result of procedural errors/equipment failures.	(5) b	(6) b
41	Heat generation for nearby personnel[(2)] due to inherent MSD design (a) As a result of inherent design features, the MSD subsystem does not generate enough heat to render its vicinity hotter than most shipboard areas containing machinery. (b) As a result of inherent design features, the MSD subsystem does generate enough heat to render its vicinity hotter than most shipboard areas containing machinery.	a	a

(1) Due to flushing medium composition, fixture design, motion of vessel (which may cause splatter, splashing, or spillage of flushing medium).

(2) For operator/maintainer/adjacent berthing and working areas.

(3) The GATX MSD, because it has a pressurized sewage collection system is more likely to expose personnel to sewage in case of a line break.

(4) Evaporator sealed.

(5) If flapper valve doesn't seat well.

(6) . If open equipment and don't reseat seals correctly, slight odor will result.
. If vapor treatment section is not functioning and is therefore in bypass mode, odor may be vented to deck.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V- HABITABILITY

MSD GATX

Sheet 3 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	HABITABILITY Attribute Data: Treat./Disposal Subsystem
42	Heat generation for nearby personnel[1] due to procedural errors/equipment failures of MSD. (a) The MSD subsystem does not generate enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinerv. (b) The MSD subsystem does generation enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery.	a	a
5	Noise level for personnel in vicinity of MSD[1] NI - Noise Index (a) The MSD subsystem is silent or nearly silent. (b) Noise level of MSD subsystem is approximately equal to background noise level of vessel. (c) The MSD subsystem is very loud, produces constant noise, drowns out vessel background noise in immediate area of the system; must shout to be heard.	b	(3) b
6	Vibration levels for nearby personnel[1] produced by MSD machinery VI - Vibration Index (a) MSD subsystem produces little or no perceptible vibration in addition to background level on vessel. (b) MSD subsysrem produces perceptible vibration, but similar to vessel background. (c) MSD subsystem produces abnormal or disturbing intensity and/or frequency of vibration.	a	(4) a
7	Effect of MSD on user housekeeping routines (restrictions on user imposed by subsystem[2]). (a) Subsystem characteristics do not impose restrictions on user. (b) Subsystem characteristics impose restrictions on user.	a	(5) b

(1) For operator/maintainer/adjacent berth and working areas.

(2) E.g. . Must use water-soluble toilet paper which is not as comfortable as usual toilet paper.
. Must use special bowl cleaner which is less effective than usual cleaner
. Cannot dump detergents down galley sink; must store and off-load at shore.

(3) . If compressed air line breaks, (c) applies
. If bearings in pumps are very worn, (c) applies.
. If steam jacket vents-steam noise is of short duration.

(4) If hard materials get into M/T pump, (b) or (c) applies.

(5) Detergent is very likely to cause foaming in evaporator.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VI - RELIABILITY

MSD GATX   Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	RELIABILITY Characteristics	RELIABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
21	MSD complexity Complexity index of MSD subsystem based on a complexity ranking from 1 to 5.	4	2
23	Extent of MSD equipment/component redundancy(1) (a) There is some significant redundancy in the MSD subsystem's major components. (b) There is no significant redundancy in the MSD subsystem's major components.	(6) a	(7) a
24	Degree of equipment failure independence(2) (a) There is a high degree of equipment failure independence in MSD subsystem. (b) There is a moderate degree of MSD equipment failure independence in MSD subsystem. (c) There is a low degree of equipment failure independence in MSD subsystem.	(8) b	(9) b
25	Adequacy of MSD equipment ratings (a) Most MSD subsystem equipments are overrated. (b) Some MSD subsystem equipment ratings are nominal, some are overrated. (c) Some MSD subsystem equipments are underrated, some are nominally rated. (d) Most MSD subsystem equipments are underrated.	(10) b	(11) b
26	Provisions for fault actuated cut-off mechanisms(3) for MSD protection (a) There are many fault actuated mechanisms in MSD subsystem, or they are not required.(4) (b) There are some fault actuated mechanisms in MSD subsystem. (c) There are no or almost no fault actuated mechanisms in MSD subsystem.	c	(12) b
3	Reliability risk for MSD(5) (a) MSD subsystem has a history of fair or better test results. (b) MSD subsystem has a history of poor test results. (c) No test results are available for MSD subsystem.	a	a

(1) Any redundancy in electronic circuitry is not considered.
(2) I.e., failure of one item will not result in failure of major component or subsystem.
(3) Includes mechanisms to: (i) alert operator/maintainer to high stress or abnormal conditions that will result in failure, and/or (ii) to correct those conditions or turn off equipment.
(4) E.g., standard commodes and urinals in a gravity drain sewage collection subsystem do not require fault actuated cut-off mechanisms.
(5) E.g., innovative design, experience.

(6) Fixtures; possibly M/T pumps.
(7) . Six electric heaters installed in steam jacket; only three used.
. Fourteen spray nozzles in evaporator
. May drain evaporator in one of two ways.

Footnotes continued on following page.

(8) If M/T pumps do not shut off, may over fill evaporator.

(9) . If vapor treatment section fails, can operate but will produce odor.
. If pumps run dry, will accelerate shaft seal wearout, stress impeller.

(10) M/T pumps overrated.

(11) Electrical heaters and sludge pump may be overrated.

(12) . Pressure relief valves on steam jacket, evaporator.
. Level, temperature and pressure sensors in vapor treatment section.
. Pressure switch in compressed air line: interlock type cannot heat evaporator or vapor treatment section without it.

. MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD GATX Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
131	Accessibility of replaceable MSD components	(4)	(5)
	(a) High degree of accessibility in MSD subsystem components.		
	(b) Moderate degree of accessibility in MSD subsystem components.		
	(c) Low degree of accessibility in MSD subsystem components.	c	c
132	Extent of MSD modularization for ease of repair/replacement		
	(a) High degree of MSD subsystem modularization.		a
	(b) Moderate degree of MSD subsystem modularization.		
	(c) Low degree of MSD subsystem modularization.	b	
133	Degree of MSD repairability on board vessel.[1]		(6)
	(a) All MSD subsystem items are repairable on vessel.	a	
	(b) Some MSD subsystem items are repairable on vessel; some must be replaced.		b
	(c) All MSD subsystem items must be replaced.		
134	Availability of manufacturer field support and training programs for MSD		
	(a) Manufacturer field support and a training program is available.		
	(b) Manufacturer field support[2] is available but no training program is available.	b	b
	(c) Manufacturer training program is available but field support is not available.		
	(d) Neither field support nor training program are available from manufacturer.		
142	Special/proprietary[3] item requirements for MSD equipment repair	(7)	(8)
	(a) No special items required for any MSD subsystem repairs.		
	(b) Some special items required for some MSD subsystem repairs.	b	b
	(c) All items required for MSD subsystem repairs are special items.		

(1) Versus necessity for replacement of failed equipment.
(2) May include some limited training support during initial MSD installation.
(3) E.g., incinerator pots, filters versus standard supply parts.

(4) . M/T parts difficult to access because of overhead location and weight of pump.
. To get at flapper valve may have to remove entire commode.

(5) To service or replace floats inside evaporator, have to remove evaporator shroud which is heavy, requiring 2 men to handle it and is held in place by 30 screw clamps.

(6) . Teflon lining of evaporator not repairable on vessel.
. Heaters not usually repairable.
. Windings in motors not usually vessel repairable.

(7) . Commodes and flush mechanism are special.
. Stainless steel M/T pumps with brass housing are special.

(8) . Catalyst and container special.
. Heater may be special.
. Nozzle and sensors in evaporator are special.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD GATX Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
23	Effect of MSD preventive maintenance on watchstander routines (a) No effect on watchstander routines.(1) (b) There is some effect on watchstander routines.	a	a
33	Special docking requirements for MSD overhauls (a) There are no special docking requirements for the MSD.(1) (b) There are special docking requirements for the MSD.	a	a
4	Logistic requirements for MSD (a) No special parts are required for the MSD subsystem. (b) Few different categories of special parts are required for the MSD subsystem and there are few parts in each category. (c) Few different categories of special parts are required for the MSD subsystem but many parts of each type are required, or many different categories of special parts are required but there are few parts in each category. (d) Many different categories of parts are required for the MSD subsystem and there is a large number of parts in each category.	b	b

(1) By C.G. direction, this applies to all MSDs considered in this study.

GATX

EQUIPMENT AND INITIAL SPARES ACQUISITION COSTS

Equipment		Equipment Cost	Cost of Associated Initial Spares Package [(a)]
Commode		$ 750	$ 50
Urinal Flushometer		150	10
Macerator/Transfer Pump (Including contactor)		Fresh W 1,500 [(b)] Salt W 3,000	1,500 (b) 50
Evaporator (With sludge pump and controls)	20 gal.	14,100	600
	40 gal.	14,400	600
	60 gal.	15,000	600
	80 gal.	15,500	600
Vapor Treatment Section (Including controls)		2,000	250

Notes

1. Please supply cost estimates for each equipment based on a production run of 100 units.
2. All cost estimates are to be based on 1976 costs.
3. Identify recommended contents of Initial Spares Package associated with each equipment.

(a) Manufacturer recommends one initial spares package for every associated equipment on board the vessel.

(b) U.S. Coast Guard policy is to use fresh water flushing and to stock one extra M/T pump per vessel regardless of the number of such pumps installed on the vessel.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD GATX

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs - Min)	Number Operators/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED — Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing Water (kwh/day)	Compressed Air (SCF/day @ p)	Annual Cost of Resource Consumed: Electric Power @ 3¢/kwh	Fuel Oil @ 33¢/gal	Fresh Water (2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.3¢/1000 gal)	Compressed Air (see formula)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	Annual Operating Cost ($)
C/T SUBSYSTEM																					
PUMPED COLLECTION SUBSYSTEM																					
Flush commode (by user)									0.75/c m	$5x10^{-6}$/c				15.49¢ k / 19¢/c	6.50¢/c						7.43/c / 0.19/c
Flush urinal (by user)									0.63/c m	$2.6x10^{-6}$		13.7¢/c k		14.56¢/c k / 16¢/c	0.41¢/c						4.56/c / 0.16/c
M/T pump operation (automatic)							1/(80) /c k														0.137/c
Mode changeover cycles***																					
- primary - overboard	-	-30	1-mk2	6.27	0.5/cy	3.14/cy															3.14/cy
- pierside - primary	-	-30	1-mk2	6.27	0.5/cy	3.14/cy															3.14/cy
		-10	2-mk2	6.27	0.33/cy	2.09/cy	(required for hose handling)														2.09/cy
T/D SUBSYSTEM																					
EVAPORATOR SUBSYSTEM																					
Evaporator (all sizes)																					
Evaporator operation (automatic)	†						5.20/c k					56.98/c k									56.98/c
Service evaporator	25,632	- 30	1-mk3	6.84	0.17/c	1.17/c	0.007/c					8¢/c									1.25/c
Vapor Treatment System (all sizes)																					
VTS operation (automatic)							1.7/c k				576/c k	18.62/c k				6.76/c					25.38/c
Drain compressed air filter/dryer	168 n	-15 n	1-mk2	6.27	15.60	97.81															97.81
Drain vapor exhaust line trap	168 n	-12 n	1-mk3 e	6.84	10.4	71.14															71.45
Test high temperature cutout	720 n	-6 n	1-mk3	6.84	1.20	8.21															8.
Vapor Treatment TOTALS					27.2 +0.17/c	177.16 +1.17/c	6.90/c				576/c	18.62/c				6.76/c					

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.
** Includes evaporator pump out and wash down.
*** It is assumed that similar effort is required for mode changeovers when a holding tank or incinerator is substituted for the evaporator.

Compressed Air Cost in ¢/Year = $(6.12268\ (14.7+p)^{0.1429} - 8.9898)$ (SCF/day) where p is in psig
/c = per capital (crew member)
/cy = per changeover cycle
SCF = standard cubic feet at 14.7 psi and $70^{o}F$
† = In man-hours. For interval in hours, divide by total crew population.

Where multiple units are designated - fixed costs are multiplied by the appropriate multiple but per capita costs are treated on a per capita basis only and are not affected by equipment multiplicity.

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD GATX

	LABOR						PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
C/T SUBSYSTEM											
PUMP COLLECTION SUBSYSTEM											
Adjust flushometer (commode/urinal) valve for proper volume flush	720	-10/unit	1-MK3	6.84	2.0/unit	13.68/unit					13.68/unit
Clean and lubricate commode flush linkage	720^{R}	-6^{E}/unit	1-MK3^{R}	6.84	1.20/unit	8.21/unit					8.21/unit
Inspect M/T pump cutter and cutter ring	870	-30/unit	2-MK4	7.42	1.00*	7.42*					7.42*
Check operation of M/T pump start/stop devices	168^{R}	-6^{E}/unit	2-MK3^{R}	6.84	10.40*	71.14*					71.14*
Check M/T pump for leakage at shaft seal	2190^{R}	-12^{R}/unit	1-MK2^{R}	6.27	0.8*	5.02*					5.02*
Renew shaft seal in M/T pump	8760^{R}	{ 2-^{R} -12^{E}	2-MK2 1-MK2	6.27 6.27	4.00* 0.20*	25.08* 1.25*	Shaft seal	1*	22.92	22.92*	49.25*
TOTALS					16.4*	109.91*		1*		22.92*	132.83*
TREATMENT SUBSYSTEM											
Evaporator (all sizes)											
Verify functioning of steam jacket safety value	720^{R}	-6^{R}	1-MK3^{R}	6.84	1.20	8.21					8.21
Drain and clean evaporator inside, outside and underneath shroud	336^{E}	$1\text{-}15^{R}$	1-MK2^{R}	6.27	32.50	203.78					203.78
Lubricate sludge pump motor	4380	-30	1-MK2	6.27	0.33	2.09					2.09
Clean level sensing tube assembly	168	-30	1-MK3	6.84	8.67	59.28					59.28
Check sludge pump for leakage at shaftseal	168^{R}	-6^{R}	1-MK2^{R}	6.27	5.20	32.60					32.60
Check sludge pump foundation bolts for tightness	8760^{R}	-6^{R}	1-MK2^{R}	6.27	0.10	0.63					0.63
Clean 3-way valve	4380^{R}	-18^{C}	1-MK3	6.84	0.60	4.10					4.10
TOTALS					48.6	310.69					310.69

* Per pump.

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD GATX

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
C/T SUBSYSTEM											
Commode											
Replace internals of flushometer (commode)	17520	-6[a]/unit	1-mk2[a]	6.27	0.05/u	0.31/u	Flushometer internals	0.5/u	7.00[m]	3.50/u	3.81/u
Repair mechanical linkage on commode	4380	-15[f]/unit	1-mk3	6.84	0.5/u	3.42/u					3.42/u
Replace flapper valve in commode	8760	2-/unit	1-mk4	7.42	2.0/u	14.84/u	Valve	1/u	4.00[b]	4.00/u	18.84/u
Commode TOTALS	3.5				2.55/u	18.57/u		1.5/u		7.50/u	26.07/u
Urinal											
Replace urinal flush solenoid valve internals	17520	-15[i]	1-EM4	7.42	0.13/u	0.93/u	Rubber seals	0.5/u	16.00[b]	8.00/u	8.93/u
Replace urinal flush stepping relay	17520	-10	1-EM4	6.50	0.08/u	0.54/u	Stepping relay	0.5/u	36.00[m]	18.00/u	18.54/u
Urinal TOTALS	1				0.21/u	1.47/u		1/u		26.00/u	27.47/u
Macerator - Transfer Pump											
Repair M/T pump											
- replace . impeller	8760	2-45[b]	2-EM2	5.45	5.5*	29.98*	Impeller	1*	77.36[b]	77.36*	107.34*
. cutter assembly	4380	2-45[b]	2-EM2	5.45	11.0*	59.95*	Cutter assembly	2*	228.31	456.62*	516.57*
. mechanical shaft seal	8760	3-	2-EM2	5.45	6.0*	32.70*	Shaft seal	1*	22.92[b]	22.92*	55.62*
. motor bearing	17520	-	2-EM2	5.45	1.0*	5.45*	Motor bearing	0.5*	8.00[m]	4.00*	9.45*
Replace motor starter (contactor)	17520	-10	1-EM4	6.50	0.08*	0.54*	Motor starter	0.5*	80.00[b]	40.00*	40.54*
M/T TOTALS	5				23.58*	128.62*		5		600.90*	729.52*

* Per pump.
/ u - per unit.

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD GATX

	LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)		Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
T/D SUBSYSTEM												
EVAPORATOR SUBSYSTEM												
Replace electric heating element in evaporator	8760	1-30[e]	1-EM4	6.50	1.5	9.75		Heating element	1	80.00[b]	80.00	89.75
Repair sludge pump motor	2176[h]	1-30[h]	1-EM5	7.22	6.0	43.32						43.32
Replace shaft seal and impeller in sludge pump	8760	1-30[a]	1-EM3	5.96	1.5	8.94		Impeller and seal	1	35.00[b]	35.00	43.94
Replace wash water hose	26280	-15	1-MK2	6.27	0.08	0.52		Hose	0.33	4.00[m]	1.33	1.85
Replace heater element in vapor treatment section	8760	-30	1-EM5	7.22	0.5	3.61		Heating element	1	70.00[b]	70.00	73.61
Replace compressed air filter	8760	-10	1-MK3	6.86	0.17	1.14		Air Filter element	1	10.00[m]	10.00	11.14
Replace thermal switch (3)	17520	-33[h]	1-MK4	7.42	0.28	2.04		Thermal switch	0.5	40.00[b]	20.00	22.04
Clean sticking level switch	725[h]	-21[h]	1-MK2	6.27	4.20	26.33						26.33
Replace level switch (3)	8760	-57[h]	1-MK4	7.42	0.95	7.05		Level switch	1	265.00[b]	265.00	272.05
Replace level control	8760	-10[h]	1-EM3	5.96	0.17	0.99		Level control	1	40.00[b]	40.00	40.99
Replace relay (5)	4380	-15	1-EM3	5.96	0.5	2.98		Relay	2	15.00[b]	30.00	32.98
Replace time delay relay (3)	4380	-5[h]	1-EM4	6.50	0.17	1.08		Time delay relay	2	36.00[b]	72.00	73.08
Replace heater relay (2)	8760	-15	1-EM3	5.96	0.25	1.49		Heater relay	1	15.00[b]	15.00	16.49
TOTALS	28				20.77	109.24			11.83		638.33	747.57

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD GATX

Overhaul Requirement	LABOR: Time Between Overhauls (Yrs)**	Estimated Time Required (Hrs)	No. Maintainers/Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	PARTS CONSUMED: Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	TOTAL: Major Overhaul Cost ($)
C/T SUBSYSTEM											
PUMPED COLLECTION SUBSYSTEM											
Replace flushometer internals (commode)		6[a]/unit	1-MKC[a]	6.27	0.1/unit	0.63/unit	Flushometer internals	1/unit	16.00	16.00/unit	16.63/unit
Replace flapper valve in commode		2/unit	1-MK4	7.42	2.0/unit	14.84/unit	Valve	1/unit	4.00[b]	4.00/unit	18.84/unit
Clean and lubricate mechanical linkage on commode		6[c]/unit	1-MK3	6.84	0.1/unit	0.68/unit					0.68/unit
Replace water supply hoses and clamps to either commode or urinal		30/unit	1-MK2	6.27	0.5/unit	3.14/unit	Hoses and clamps	1 set/unit	4.00[m]	4.00/unit	7.14/unit
TOTALS					2.7/unit	19.29/unit		3/unit		24.00/unit	43.29/unit
			1-EM5	7.22	3.0 *	21.66 *					399.71/unit
Replace M/T pump components		3*	1-MK3	6.84	3.0 *	20.52 *	Impeller	1 *	77.36[t]	77.36 *	119.54
. impeller							Cutter assembly	1 *	228.31[b]	228.31 *	228.31*
. cutter assembly							Shaft sleeve	1 *	3.00[m]	3.00 *	3.00 *
. shaft sleeve							Motor bearing	1 *	8.00[m]	8.00 *	8.00*
. motor bearing							Shaft seals	1 set *	36.52[b]	36.52 *	36.52*
. mechanical shaft seals							O-Rings	1 set *	4.34[b]	4.34 *	4.34*
. O-Rings											
Replace valve stem seals (M/T pump)		10 *	1-MK3	6.84	0.17 *	1.14 *	Stem seals	3[m]	3.00[m]	9.00 *	10.14*
TOTALS					6.17*	43.32*				366.53 *	409.85*
T/D SUBSYSTEM											
EVAPORATOR SUBSYSTEM											
Calibrate thermostat, pressure gage, pressure switch and level sensor on steam jacket		2-	1-MK5	8.13	2.0	16.26					16.26
Disassemble and clean evaporator internals		1-15[hc]	1-MK2[a]	6.27	1.25	7.84					7.84

* Per pump.

** Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD GATX

	LABOR						PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Reline evaporator with teflon		3-[m]	1-MK5	8.13	3.0	24.39	Teflon	1 lot	50.00[m]/lot	50.00	74.39
Replace internal spray nozzles		-45[m]	1-MK3	6.84	0.75	5.13	Spray nozzles	14	6.00[b]	84.00	89.13
Replace gaskets		-10[m]	1-MK3	6.84	0.17	1.14	Gaskets	1 set	20.00[m]	20.00	21.14
Replace catalyst		-30[m]	1-MK3	6.84	0.5	3.42	Catalyst	1 lb/c	15.00/[b]lb	15.00/c	3.42 + 15.00/c
Calibrate thermometer and thermal switches in Vapor Treatment section		1-[m]	1-MK5	8.13	1.0	8.13					8.13
Replace compressed air filter element		-10[m]	1-MK3	6.84	0.17	1.14	Air filter element	1	10.00[m]	10.00	11.14
Calibrate pressure switch for compressed air		-10[m]	1-MK3	6.84	0.17	1.14					1.14
Clean out vent line		1-[m]	1-MK2	6.27	1.0	6.27					6.27
TOTALS					10.01	74.86				164.00+ 15.00/c	238.86+ 15.00/c

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

Note: Where multiple units are designated, fixed costs are multiplied by the appropriate multiple, but per-capita costs are treated on a per-capita basis only, and are not affected by equipment multiplicity.

CHRYSLER "AQUA-SANS" RECIRCULATING OIL SYSTEM

PRINCIPLES OF OPERATION

The Chrysler "Aqua-Sans" is a "no discharge" MSD that differs from most systems in its use of a refined oil to flush wastes from commodes and urinals instead of water. Since the oil is immiscible with, and less dense than, the wastes, gravity separation is effective in disengaging the oil from the wastes to be destroyed. The oil is recirculated as a flush fluid for both urinals and commodes. It is purified by filtration and adsorption and chemically disinfected. The wastes are vaporized and burned in an incinerator.

The equipment is available in predesigned, functional modules of varying sizes or capacities. The modules are:

- Separation tank
- Pressurization and Fluid Maintenance package, which is separated into two modules in the larger size.
- Sludge holding tank, used in larger systems
- Incinerator.

The collection (and recirculation) subsystem, comprised of the Separation Tank and Pressurization and Fluid Maintenance (P & FM) package, is operational at all times, regardless of vessel location (i.e., in or beyond restricted waters or at pierside), in order to provide toilet facilities for the crew. For servicing, or during an emergency, the fluid maintenance portion of the P&FM package can be shut down and remain inoperative until odor becomes too objectionable. While at pierside or beyond restricted waters, collected wastes can be pumped to a pier connection or overboard from the sludge holding tank, permitting the incinerator to be nonoperational In a small system that does not have a sludge holding tank, an ejection tank can be added for just this purpose.

The Chrysler MSD is essentially automatic, requiring supervision of equipment operational status plus the following periodic efforts during normal operating conditions:

- Ash removal from the incinerator
- Addition of chlorine disinfectant tablets
- Replacement of filters (prefilter, charcoal and clay)
- Replacement of filter bag(s) in separator tank
- Addition of make up flush medium (oil)
- Complete replacement of system flush fluid.

A functional block diagram of the Chrysler "Aqua-Sans" Oil Recirculation System is presented in Figure 9.

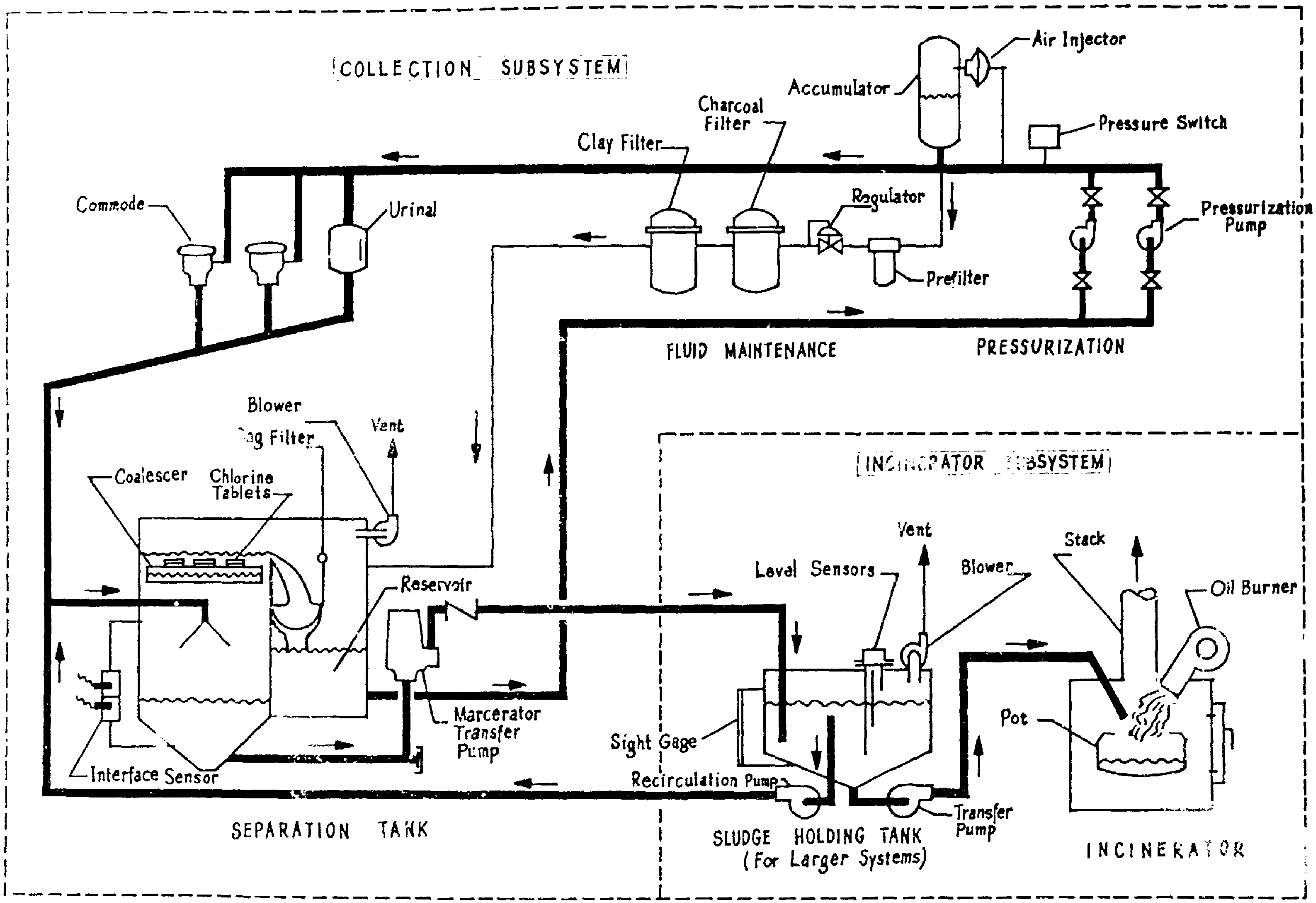

Figure 9
CHRYSLER "AQUA-SANS" RECIRCULATING OIL SYSTEM

SYSTEM DESCRIPTION

For ease of description and visualization of a hybrid WMS, the Chrysler MSD is presented in two subsystems: a collection and recirculation subsystem, and a disposal subsystem.

It is noted that in a recirculation system, the division between the waste collection, transport, treatment, and disposal subsystems is not clearcut. For purposes of describing the system, it is subdivided into two subsystems, such that the waste collection, transport and treatment functions form one subsystem, and the waste disposal function (i.e., the incinerator) forms the other subsystem. However, for purposes of analyzing some of the effectiveness characteristics, it was more convenient (mainly to preserve some similarity with the Grumman and CHT collection subsystem) to use a different subdivision. The subdivision there is such that the waste collection and transport system (consisting of the commodes, urinals and the standard drain pipes only) forms one subsystem, with the treatment and disposal functions (consisting of the remainder of the system) forming the other subsystem.

Collection and Recirculation Subsystem

The collection and recirculation subsystem is comprised of the following:

- Standard commodes and urinals
- Existing standard, sloped, gravity - drained sewer pipes
- Separation tank
- Pressurization and fluid maintenance package
- Return piping for flushing medium
- Controls

A. Commodes and Urinals

The commodes and urinals are the existing, standard, full-flush fixtures. The associated flushometers might require a change in the timing orifice in order to maintain the same flush volume, if it is so desired. Otherwise, everything remains standard.

B. Separation Tank

The separation tank is a two compartment module in which the oil disengages from the aqueous wastes, is disinfected, filtered and stored in a reservoir. The first compartment provides a quiescent volume in which oil and water (aqueous wastes) separate by gravity. The urine, feces and toilet paper settle, to be contained in the hopper shaped bottom. An external level sight gage shows the height of the interface between the aqueous phase and the oil. Valves at top and bottom provide isolation for chemical cleaning of the level gage. The transparent section of the level gage is made of a short block of acrylic in which two electrodes detect the presence of water between them. Upon signal from the level sensor, a macerator/transfer (M/T) pump, operating for about ten seconds, withdraws some of the aqueous waste from the hopper. The pump is mounted externally at one end of the separator tank and is connected to the hopper by a four inch line with a diaphragm shut off valve in it. Vertically mounted on the 1-1/4 inch discharge pipe from the pump is a ball check valve.

Inside the tank, lying horizontally at the top of the first compartment, is a fiberglass furnace filter which acts to coalesce any fine droplets of water. Larger water drops settle more readily. Keeping the coalescer in place is a piece of expanded metal plate, upon which the chemical chlorine tablets are laid. As flush fluid and wastes enter the settling compartment through a submerged pipe, separated oil is displaced upward through the coalescer and plate, dissolves some disinfectant and overflows the compartment baffle.

The falling oil is filtered through a preformed felt bag which removes particles of the chlorine tablets that might be carried over. The bag is located in the second compartment above the reserve oil level. A small blower pulls air into the tank through an inverted vent connection across the top of both compartments and discharges it into a two inch vent line. The cover is a flat lid that provides sufficient sealing to allow odor removal by the blower. It is secured by four quick release clamps.

In addition to the contactor for the M/T pump, the controls include relays and timers for the following logic functions. The signal from the level sensing electrodes must be continuous for about 20 seconds before the M/T pump will start. This avoids false signals due to sloshing caused by vessel movement. After pumping for 10 seconds, the pump is deactivated for two to three minutes before accepting another signal from the level sensor. This allows equalization of the level in the hopper and the level gage as well as permitting wet solids (e.g. pieces of toilet paper) to fall from the downward slanted electrodes. The delay helps prevent excessive withdrawal from the hopper, assuring that only aqueous fluid is removed.

Separation tanks are available from the manufacturer in five sizes, all operating on the same principles. The two largest sizes are designed with each compartment as a free standing tank to be installed close to each other. This option is available with the smaller units on a custom designed basis. The sizes of interest to this study are the three smallest separation tanks which have a maximum oil capacity and a 24-hour man-loading of:

- Model A: 81.5 gallons - 20 men
- Model A/B: 156 gallons - 50 men
- Model B: 209 gallons - 160 men

C. Pressurization and Fluid Maintenance

The Pressurization and Fluid Maintenance (P&FM) package is a pallet mounted assemblage of equipment which provides (1) the pressurization of recirculating flush oil for distribution to the commode and urinal flushometers and (2) the purification of the oil in a bypass stream.

The pressurization portion consists of the following:

- Two centrifugal pumps installed in parallel
- A vertically mounted cylindrical accumulator
- A pressure switch and pressure gage
- An automatic air injector.

Manual ball valves are used to isolate the standby pump, making pump alternation a manual procedure. The pressure switch actuates the operating pump, which serves to keep the pressure in the accumulator between the preset limit of 32 to 42 psig. An accumulator is necessary in order to accommodate peak flows when several flushometers are operated simultaneously. The original accumulator design contained a troublesome rolling diaphragm to separate the air from the oil. When it was eliminated, an air injector was added for replacing the air that dissolved in the oil (air is more soluble in oil than in water). The air injector is a single-stroke, flat diaphragm, compressor that operates once every time the pressurization pump starts up, using the oil pressure to compress air.

The fluid maintenance portion of the P&FM package is a passive system that bleeds a continuous flow of oil from the accumulator, purifies it and returns it to the reservoir compartment of the separation tank. The components, in sequence, are as follows:

- A prefilter
- A pressure regulator
- A charcoal filter
- A clay filter

The pressure regulator stabilizes the pressure, and thus the flow, from the fluctuations of the accumulator. A pressure gage helps set the flow and gives some visual indication of the condition of the purification components.

The prefilter is a corrugated, cylindrical paper filter in cartridge form. The easily replaced, throw-away element protects the regulator and the fine filters from clogging prematurely. The first filter holds activated charcoal contained in a bag of non-woven, very porous polypropylene cloth. The charcoal adsorbs organic, odor-producing compounds as well as some chlorine. The second filter contains a larger, cylindrical cartridge in which an annular layer of clay is held. The clay acts as a very fine filter for particulates as well as acting as an adsorbent.

Replacement of the filters is performed on a regular basis or when the the color, clarity or odor of the flush fluid is unacceptable. An indication of imminent need for filter replacement can be seen from the pressure reading on the regulator gage or the flow rate of the return stream inside the separation tank. A hand valve isolates all the bypass components from pressure. The prefilter element is replaced by dropping the enclosing shell after unscrewing a central post that projects through the top of the head casting. The charcoal and clay are accessible by removing the tops of their containers, after releasing a single quick-opening V-band clamp.

The pressurization and fluid maintenance functions for larger systems are provided on two pallets: one for the dual pumps and one for the purification components. The accumulator is usually custom designed and installed independently of the two pallets. The component functions are identical to those of the smaller P&FM package. The pressurization pumps are essentially the same as those for the smaller P&FM package but the fluid maintenance components are larger and have different methods for closure. The prefilter elements are accessible after dropping the shell which is held up by four screws. The charcoal filter housing uses a cover plate fastened to the body flange by six bolts. The housing for the clay cartridges is separated in the middle, after releasing a single V-band clamp.

D. Return Piping

The return piping for the flushing medium is simple, ordinary piping but is mentioned separately to emphasize that in an existing vessel, it will require additional piping. At some point or points on the way back to the commodes and urinals, it joins to, and makes use of, the piping, already in place, that leads to the flushometers. At the point(s) of juncture, complete separation from the previous flush water supply must be effected.

E. Controls

Controls for the separation tank and the P&FM have been described. They are located with the module that they serve. There are some interconnecting control functions between the separation tank and the disposal subsystem, which are described with the latter.

Disposal Subsystem

The disposal subsystem consists of an incinerator only for the smaller systems, but includes an intermediate sludge holding tank in larger systems.

A. Sludge Holding Tank

The sludge holding tank (called a waste holding tank in the manufacturer's catalog) is a rectangular, hopper bottom tank that primarily accommodates the mismatch in instantaneous flow rates between the separation tank discharge and the incinerator input. Its other function is as a secondary separator to remove any oil that might be carried over from the separation tank.

The tank is supplied with its own stand on which is mounted a close-coupled centrifugal pump-motor, a belt driven progressing cavity pump, and the necessary interconnecting piping. Ancillary items on the tank are: 1) three level sensors, 2) external level sight gage, 3) exhaust blower and motor, and 4) electrical controls. The centrifugal pump periodically recirculates the top layer of liquid in the tank back to the separation tank carrying with it any oil that has separated out. The progressing cavity pump feeds the incinerator in short, timed, batches.

The middle level sensor signals the incinerator to warm up in preparation for receiving wastes, and the lowest sensor stops the cyclic transfer of wastes to the incinerator. The uppermost sensor indicates an overfill situation and can actuate an alarm. The level sight gage gives the operator a visual indication of the tank status. The exhaust blower pulls odor bearing air from the tank interior and discharges it to a two inch vent line.

Two sizes of sludge holding tanks are available and both are considered for this study. The Model B holds 100 gallons and the Model C holds 200 gallons and are identical in function and ancillary equipment. The difference lies in the physical dimensions of the tank and structure.

B. Incinerator

The incinerator is a free standing, rectangular unit with a weather resistant enclosure, in which the concentrated sewage is dehydrated and burned. The wastes are piped from above into a metal pot where the water is evaporated and the organic residue is burned. A downward-firing oil burner assembly directs the flame into the pot from which the hot gases must pass up, around, and under the pot, before exiting the chamber. A short Metalbestos section, rising vertically from the top of the unit, is supplied as the start of the exhaust stack. A hinged, insulated door on the end permits withdrawal of the pot for ash removal.

The pot was originally a rectangular box, welded up from stainless steel sheet. Rapid corrosion failures of the pot prompted development through a series of designs that included welded reinforcements and exotic metals. The current design, apparently successful, is spun from two pieces of SS309 plate with only one circumferential weld. Failure seemed to be due to stress corrosion which is substantially reduced with the current method of fabrication.

Controls include solenoid fuel valves, ignition transformer, temperature controller, thermocouple probe, overtemperature sensor and timer. The sequence of actions is as follows: The level sensor in the separator tank (or the sludge holding tank) signals a high level, when the electrodes become wet with aqueous waste. At this time, the incinerator timer and blower start. If the high level signal is continuous for 64 seconds, the incinerator burner ignites. When the temperature reaches 1100°F the burner begins to cycle in order to maintain this temperature. At the start of the second cycle, sludge is pumped into the incinerator. The incinerator burns for approximately 34 minutes and then shuts down. If the temperature reaches 1250°F, the overtemperature sensor actuates visible and audible alarms and shuts down the burner.

A larger incinerator is available with twice the capacity for human waste (8 gallons per hour vs. 4 gallons per hour). Aside from being physically bigger, the unit has two burners and a two stage temperature controller. One burner fires into the pot from above, as in the smaller unit, and one fires horizontally, below the pot level. The controller actuates one or two burners depending upon the heat demand (difference between set point and actual temperature).

Scaling

Because of the modularity and the predesign of the major pieces of equipment comprising the Chrysler MSD, various combinations are available for differing capacity requirements. For example, 152 men can be accommodated by three Model A separation tanks or one Model B. Pressurization and fluid maintenance can be provided by three Model A packages or one Model B pressurization unit and one Model B fluid maintenance unit. The smallest system package is designed for 20 men on a 24 hour basis.

CHRYSLER

COMPONENT PHYSICAL CHARACTERISTICS

Components	Capacity	Weight (lbs)		Volume (cu ft)	Dimensions (inches)		
		Dry	Filled		Height	Length	Width
Chrysler Model A	20 men						
Separation Tank *		635	1370	51.9	68	55	24
Pump and Fluid Maintenance Pkg.		435	540	59.6	67	48	32
Incinerator		575	588	27.1	47	36.5	27.3
Chrysler Model A/B	50 men						
Separation Tank *		1000	2400	79.1	68	67	30
Pump and Fluid Maintenance Pkg.		435	540	59.6	67	48	32
Incinerator		575	588	27.1	47	36.5	27.3
Chrysler Model B	160 men						
Separation Tank *		1060	3120	116.7	77	77	34
Fluid Maint. Pkg.		325	555	22.0	49	31	25
Pump Pkg.		245	250	10.6	18	34	30
Sludge Holding Tank		610	1445	40.8	49	40	36
Incinerator		575	588	27.1	47	36.5	37.3
Chrysler Model C							
Sludge Holding Tank		980	2650	75.6	80	43	38
Incinerator		1600	1626	79.2	41	63	53

NOTE: Control panel is decentralized on current production models. Individual controls are located on separation tank, pump or pump and fluid maintenance package, waste holding tank and incinerator.

* Separation tank normally has two vertical compartments which can be furnished as two individual tanks. This may help placement in tight quarters.

CHRYSLER

STANDARD COMPONENT PIPE CONNECTION SIZES

Chrysler WMS Components	Pipe Connection Size
Separation Tank (for Models A, A/B, B)	
Waste Inlet:	4 in. NPT
Waste Outlet (Pump discharge)	1 in. NPT
Flush Fluid Outlet	1 1/2 in. NPT
Flush Fluid Return	1/2 in. NPT
Vent Blower Outlet	2 in.
Pump and Fluid Maintenance System (for Models A, A/B)	
Flush Fluid Inlet	1 1/2 in. NPT
Flush Fluid Supply	1 1/2 in. NPT
Bypass Fluid Return	1/2 in. NPT
Flush Fluid Pump Package (for Model B)	
Flush Fluid Inlet	1 1/2 in. NPT
Flush Fluid Supply	1 1/4 in. NPT
Fluid Maintenance Module (for Model B)	
Fluid Inlet	3/4 in. NPT
Bypass Fluid Return	1/2 in. NPT
Sludge Holding Tank (for Models B, C)	
Waste Inlet	1 in. NPT
Transfer Pump Outlet	1 in. NPT
Recirculation Pump Outlet	1 in. NPT
Vent Blower Outlet	2 in.
Incinerator (for Models A, A/B, B)	
Waste Inlet	1 in. NPT
Fuel Suction and Return	3/8 OD tubing
Stack	8 in. ID Metalbestos*
Incinerator (for Model C)	
Waste Inlet	1 in. NPT
Fuel Suction and Return	1/2 in. NPT
Stack	12 in. ID Metalbestos*
Sludge Ejection Tank	
Waste Inlet	1 in. NPT
Vent Blower Outlet	2 in.

*Stack may vary from connection size depending upon installation.

CHRYSLER

COMPONENT VESSEL RESOURCE REQUIREMENTS

WMS COMPONENTS	HP	Watts	Volts	Phase	Hertz	Amp.	Ambient Air CFM	Fuel Oil (gph)	COMMENTS
Separation Tank (A, B/B, B)									
Macerator Pump Motor	1-1/2		230	1	60				10 sec on, 2 min. off until level sensor in tank is satisfied.
		Optional	208	3	60				
			230	3	60				
			460	3	60				
Blower Motor	1/16		115	1	60		150		Continuous
Controls		250 max							
Pump & Fluid Maint. Sys. (A, A/B)									
Fluid Pump Motor (2)	2		115/230	1	60				One pump operates continuously - manual switchover
		Optional	208	3	60				
			230	3	60				
			460	3	60				
Flush Fluid Pump Pkg.* (B)									
Fluid Pump Motor (2)	2		230	1	60				One pump operates continuously - manual switchover
		Optional	208	3	60				
			230	3	60				
			460	3	60				
Sludge Holding Tank (B, C)			230	1	60	11			
Recirculation Pump Motor	3/4								Runs about 20 minutes when level is high
Transfer Pump Motor	1/3								10 sec on, 2 min. off until level is satisfied
Blower Motor	1/16								
Incinerator (A)									
Fuel Pump/Blower Motor Unit			115	1	60	5	32	1.25	Operates during combustion sequence. Waste to fuel ration, 3:1
Incinerator (C)									
Fuel Pump/Blower Motor Units (2)			115	1	60	10	64	2.50	Operates during combustion sequence. Waste to fuel ration, 3:1
Sludge Ejection Tank			230	1	60	4			
Discharge Pump Motor	1/3								Operates once a day
Blower Motor	1/16								

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E ______ SHIPBOARD INSTALLATION

MSD ___CHRYSLER___ Sheet _1_ of _4_

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin	Treat./Disposal Subsystem: With Holding Tank
12	MSD materials disallowed or not recommended.[1] (a) No disallowed or not recommended materials present[2] in MSD subsystem. (b) Some disallowed or not recommended materials present in MSD subsystem, but resultant problems can be solved or compensated for. (c) Presence of disallowed or not recommended materials in MSD subsystem presents problems with no feasible solutions.	a	a	a
13	Extent of additional support systems or equipment required to accommodate MSD[3] Identification of support system requirements for MSD subsystem.	(7)	(8)	(9)
21	Extent of fixture modifications required for MSD installation. (a) MSD uses standard commodes and urinals. (b) MSD uses non-standard commodes and special equipment is associated with the urinals. (c) MSD uses non-standard commodes, special equipment is associated with the urinals and each fixture has additional hook-up requirements.	a	N/A	
22	Extent of flush medium supply modifications required for MSD installation. (a) MSD uses sea water for flushing fixtures. (b) MSD uses fresh water for flushing fixtures. (c) MSD uses a non-aqueous for flushing fixtures.	c	N/A	
231	Hookup requirements[4] for MSD Collection/Transport subsystem installation. (a) MSD uses standard Collection/Transport subsystem. (b) MSD uses recirculating Collection/Transport subsystem.[5] (c) MSD uses non-standard and centralized Collection/Transport subsystem. (d) MSD uses non-standard and non-centralized Collection/Transport subsystem.[6]	(10) b	N/A	

(1) As specified in subchapters J&F of Merchant Marine Code and C.G. MSD regulations.
(2) For purposes of this study, C.G. directs choice (a) for all MSDs.
(3) Examples:
- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(4) Drain piping; electric cables for connecting commodes, M/T pump and control panel, compressed air, etc.
(5) In existing gravity drain system.
(6) Includes conversion from reduced flush vacuum collection to a standard gravity drain system with or without recirculation.
(7) Possibly fire fighting equipment in head spaces.
(8) Fire fighting equipment; ventilation.
(9) Bilge alarm if necessary.
(10) Recirculating oil return hookup required, standard drains used.

MSD EFFECTIVENESS ATTRIBUTE DATA

I - ADAPTABILITY FOR

M/E SHIPBOARD INSTALLATION

MSD CHRYSLER

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	INSTALLATION Attribute Data: Treat./Disposal Subsystem (With Incin. / With Holding Tank)
232	Routing flexibility for drain piping modifications[1] associated with MSD Collection/Transport subsystem installation[2]	(3)	
	(a) Routing of MSD Collection/Transport piping is highly flexible.		
	(b) Routing of MSD Collection/Transport piping is moderately flexible with some restrictions.		N/A
	(c) Routing of MSD Collection/Transport piping is highly inflexible.	c	
233	Space requirements for MSD Collection/Transport subsystem installation	(4)	
	(a) Space required for MSD Collection/Transport subsystem is little or no greater than that required for standard Collection/Transport subsystem.		
	(b) Space required for MSD Collection/Transport subsystem is moderately increased over that required for standard Collection/Transport subsystem.	b	N/A
	(c) Space required for MSD Collection/Transport subsystem is much greater than that required for standard Collection/Transport subsystem.		
234	Modularity of MSD Collection/Transport subsystem (as it affects installation).	(5)	
	(a) Collection/Transport subsystem is highly modular.	a	N/A
	(b) There is an option for some decentralization of the MSD Collection/ Transport subsystem.		
	(c) The MSD Collection/Transport subsystem is highly centralized.		
235	Vent requirements for MSD Collection/Transport subsystem installation.	(6)	
	(a) MSD Collection/Transport subsystem requires no vents.		N/A
	(b) MSD Collection/Transport subsystem requires few vents.		
	(c) MSD Collection/Transport subsystem requires many vents.	c	

(1) Of the three relevant categories of routing lines (piping, ventilation, electrical), piping is the most important for assessing ease of MSD installation.

(2) Notes:

- With gravity drainage, lines must always slope downward and require venting.
- Smaller size lines are inherently more flexible.
- With pump or vacuum Collection/Transport subsystem, sharp bends, risers and long runs can be accommodated in piping.

(3) Gravity drainage through standard drain lines. Routing of return lines (pressurized and filled) is highly flexible. Answer applies to new installation only; if standard drain lines already installed in vessel, then (a) applies.

(4) Components for pressurized return (e.g., accumulator).

(5) . Pressurization of fluid maintenance package is separated into two modules in the larger (100 man) Model B of the Chrysler MSD.

. MSD available as packaged subsystems.

(6) As for standard drain lines (i.e. all traps must be vented). Answer applies to new installation only; if standard drain line already installed in vessel, then (a) applies.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD CHRYSLER   Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem: With Incin.	Attribute Data: Treat./Disposal Subsystem: With Holding Tank
242	Hookup requirements[1] for MSD waste Treatment/Disposal subsystem installation		(5,6)	(5)
	(a) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are minimal.	N/A	b	b
	(b) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are moderate.			
	(c) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are extensive.			
243	Degree of modularity of MSD waste Treatment/Disposal subsystems (as it affects installation)[2]		(7,8)	(7)
	(a) MSD Treatment/Disposal subsystem is highly modular.	N/A	a	a
	(b) There is an option for some decentralization of the MSD Treatment/Disposal subsystem.			
	(c) MSD Treatment/Disposal subsystem is highly centralized.			
244	Vent requirements for MSD waste Treatment/Disposal subsystem installation[3]	N/A	(9)	(9,10)
	(a) No vents are required for MSD Treatment/Disposal subsystem.			
	(b) Vents are required for MSD Treatment/Disposal subsystem.		b	b
245	Exhaust stack requirements for MSD waste Treatment/Disposal subsystem installation.[4]	N/A		a
	(a) Exhaust stack not required for MSD Treatment/Disposal subsystem.			
	(b) Small exhaust stack required for MSD Treatment/Disposal subsystem.			
	(c) Large exhaust stack required for MSD Treatment/Disposal subsystem.		c	

(1) Piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote panels, etc.; ducting for ventilation, etc.
(2) Decentralization of components may require additional hookups and piping runs.
(3) Vents that are only internal to the compartment in which subsystem is located are not considered here.
(4) Notes:
- Electric incinerator requires small (2") exhaust.
- Fuel incinerator requires large (10") exhaust.

(5) Electric power; electrical controls (each package in subsystem has its own control panel); no compressed air.

(6) Fuel supply for incinerator.

(7) Subsystem comes in package units.

(8) Incinerator separable from treatment subsystems; may be mounted in any convenient location.

(9) Separation tank requires small vent.

(10) Sludge holding tank requires vent.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD CHRYSLER   Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	INSTALLATION Attribute Data: Treat./Disposal Subsystem – With Incin.	INSTALLATION Attribute Data: Treat./Disposal Subsystem – With Holding Tank
25	Ease of installing MSD support equipment[1]	(2)		
	Extent of additional support equipment required to accommodate MSD			
	(a) No additional support equipment required for MSD subsystem.		(3)	(4)
	(b) Some additional support equipment required for MSD subsystem.	b	b	b
	(c) Much additional support equipment required for MSD subsystem.			

(1) <u>Examples:</u>

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(2) Fire fighting equipment in heads.

(3) Fire fighting equipment; ventilation.

(4) Bilge alarm if required.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHRYSLER Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem — With Incin.	Attribute Data: Treat./Disposal Subsystem — With Holding Tank
311	Effect of peak hydraulic loads in black(1) water stream on MSD performance(2) (a) No significant effect of black water peaks on MSD subsystem performance. (b) Effect of black water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water peaks.	(4) b	(5) b	(5) b
312	Effect of peak hydraulic loads in gray(1) water stream on MSD performance (2) (a) No significant effect of gray water peaks on MSD subsystem performance. (b) Effect of gray water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water peaks, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water peaks.	N/A System cannot handle gray water	N/A	
321	Effect of low flow conditions/long idle times in black water stream on MSD performance(3) (a) No significant effect of black water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of black water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water low flow conditions/long idle times.	b	(6, 7) b	(6) b

(1) Includes instantaneous, hourly and daily loads.

(2) Peak load handling ability depends on C/T subsystem. The ability of an MSD which employs an influent surge tank to handle peaks usually depends almost entirely on the sizing of this tank.

(3) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(4) Lot of flushing may temporarily reduce supply of flushing medium.

(5) . Hydraulically, system can handle peaks, but it would degrade the quality of receive oil for several hours by rendering separation tank less efficient; filtration would clean up receive oil gradually after several hours.
. If separation tank is full or almost full when peak arrives, it may not be able to accept more input.
. If separation tank is full and recirculating pump tries to recirculate, there may not be any mechanism to stop recirculation.
. Accumulator pressurization pumps are large (45 gpm) and have good capacity for peak handling.

(6) . Many lines could get packed; advisable to flush out lines with water before letting stand idle.
. Line from bottom of separation tank to M/T pump could get hardened.
. For long idle times must drain system to clean out separation tank; residue may cake up.

(7) . Sludge tank (associated with incinerator) positive displacement transfer pump tends to suck out sludge (even caked sludge).
. Line from M/T pump is sludge filled but high velocity tends to clear line.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHRYSLER

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem — With Incin.	Attribute Data: Treat./Disposal Subsystem — With Holding Tank
322	Effect of low flow conditions/long idle times in gray water stream on MSD performance(1)			
	(a) No significant effect of gray water low flow conditions/long idle times on MSD subsystem performance.			
	(b) Effect of gray water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome.	N/A System cannot handle gray water	N/A System cannot handle gray water	N/A System cannot handle gray water
	(c) Long-term effect of gray water low flow conditions/long idle times, difficult to overcome with long-term implications for MSD subsystem performance.			
	(d) No ability of MSD subsystem to handle gray water low flow conditions/long idle times.			
331	Ability of black water portion of MSD to handle additional personnel (on a long-term basis)(2)		(4)	(4)(5)
	(a) MSD black water subsystem will handle additional personnel with little or no degradation in performance.	a		
	(b) MSD black water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance.		b	b
	(c) MSD black water subsystem will not handle additional personnel			
332	Ability of gray water portion of MSD to handle additional personnel (on a long-term basis)(3)			
	(a) MSD gray water subsystem will handle additional personnel with little or no degradation in performance.	N/A System cannot handle gray water	N/A System cannot handle gray water	N/A System cannot handle gray water
	(b) MSD gray water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance.			
	(c) MSD gray water subsystem will not handle additional personnel.			

(1) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(2) Resulting in long-term increase in average black water stream hydraulic loading. The ability of an MSD which employs a black water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(3) Resulting in long-term increase in average gray water stream hydraulic loading. The ability of an MSD which employs a gray water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(4) Handles additional personnel with some degradation of oil quality, so filtration elements may have to be changed more often.

(5) . Cannot handle additional personnel and meet maximum holding time requirements.
. May take additional personnel for short time (tank sized in man days) if required, tank capacity is accommodated by installation.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHRYSLER Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
41	Ability of black water handling portion of MSD to operate for sustained time periods			
	(a) MSD black water subsystem can operate for indefinite period of time if no components fail.(1)	a	a	
	(b) MSD black water subsystem can operate for only limited period of time, even if no components fail.(2)			b
42	Ability of gray water handling portion of MSD to operate for sustained time period			
	(a) MSD gray water subsystem can operate for indefinite period of time if no components fail.(1)	N/A	N/A	
	(b) MSD gray water subsystem can operate for only limited period of time, even if no components fail.(2)	System cannot handle gray water		
51	Ability of MSD to handle ground garbage in black water stream	(4)	(5)	(5)
	(a) MSD black water subsystem will handle ground garbage in black water stream on a long-term basis.			
	(b) MSD black water subsystem will handle ground garbage in black water stream on at least a short-term basis.			
	(c) MSD black water subsystem will not handle ground garbage in black water stream.	c	c	c
52	Ability of MSD to handle foreign materials/objects(3) in black water stream	(6)	(7)	(7)
	(a) MSD subsystem will handle foreign materials/objects in black water stream on a long-term basis.	a		
	(b) MSD subsystem will handle foreign materials/objects in black water stream on at least a short-term basis.		b	b
	(c) MSD subsystem will not handle foreign materials/objects in black water stream.			

(1) Applies to a T/D subsystem with an incinerator.
(2) Applies to a T/D subsystem without an incinerator.
(3) Examples:
- Long, narrow objects (pens, pencils, toothpicks, etc.)
- Small hard objects (nut shells, pull tab from a flip top can, bottle caps, paper clips, coins, nuts/bolts/screws/nails, cuff links, etc.)
- Large soft objects (paper towels, newspaper page, stiff and shiny magazine page, strings from a floor mop, rag, tampons and sanitary napkins, etc.)

(4) Ground garbage not collected by sewage C/T subsystem; it goes by separate line to either sludge holding tank or incinerator feed tank.

(5) Ground garbage not processed by T/D subsystem; it goes by separate line to either sludge holding tank or incinerator feed tank, in which case (a) applies.

(6) A rag could plug up pumps.

(7) M/T pump will handle if object not too hard; a nut or bolt will stay in the line preceding the M/T pump.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHRYSLER Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem, With Incin.	Treat./Disposal Subsystem, With Holding Tank
53	Ability of MSD to handle detergents/surfactants in black water stream on a long-term basis.			
	(a) MSD subsystem will handle detergents/surfactants in black water stream on a long-term basis.		(1, 2)	(1)
	(b) MSD subsystem will handle detergents/surfactants in black water stream on at least a short-term basis.			
	(c) MSD subsystem will not handle detergents/surfactants in black water stream.	c	c	c
54	Ability of MSD to handle toxic materials in black water stream			
	(a) MSD subsystem will handle toxic materials in black water stream on a long-term basis.	a	a	a
	(b) MSD subsystem will handle toxic materials in black water stream on at least a short-term basis.			
	(c) MSD subsystem will handle toxic materials in black water stream.			
61	Ability of MSD secondary emissions to meet applicable standards for the discharge of air pollutants		(3)	
	(a) No possibility of discharge of significant air pollution from MSD subsystem.	a		a
	(b) MSD subsystem will meet standards for air pollutants under normal operating conditions.		b	
	(c) MSD subsystem will meet standards for air pollutants under normal operating conditions and there is a strong possibility of non-conformance to standards under unusual operating conditions.			
62	Ability of MSD secondary emissions to meet applicable standards for disposal of oil-contaminated residues at sea			
	(a) MSD subsystem has no potential for producing oil-contaminated residues at sea.			
	(b) MSD subsystem has a potential for producing oil-contaminated residues at sea.	b	b	b
71	Performance risk for black water handling portion of MSD		(4)	(5)
	(a) MSD black water subsystem has a history of fair or better test results.	a		a
	(b) MSD black water subsystem has a history of poor test results.		b	
	(c) No test results are available for the MSD black water subsystem.			
72	Performance risk for gray water water handling portion of MSD			
	(a) MSD gray water subsystem has a history of fair or better test results.	N/A		N/A
	(b) MSD gray water subsystem has a history of poor test results.	System cannot handle gray water		
	(c) No test results are available for the MSD gray water subsystem.			

(1) Degrades quality of oil necessitating early change of oil.

(2) Detergents may cause some oil to get through to incinerator, cutting the amount of fuel oil needed to burn the sludge.

(3) . If blower goes off and incinerator continues to burn, may result in pollution.
. If oil is in incinerator, may yield sooty air.

(4) Problems with incinerator (pot).

(5) Level sensor interconnects must be worked out.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD CHRYSLER Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem With Incin.	 With Holding Tank
11	Degree of automation for MSD operation (1) (a) MSD subsystem is almost fully automatic. (b) MSD subsystem is semi-automatic: requires infrequent operator attention. (c) MSD subsystem is semi-automatic: requires a moderate degree of operator attention. (d) MSD subsystem is semi-automatic: requires frequent operator attention. (e) MSD subsystem is operated manually.	a	(4) c	(4) c
12	Ease of disposal of MSD residue(s) (1)(2) (a) MSD subsystem has no residues, or disposal of residues from MSD subsystem is very convenient. (b) Disposal of residues from MSD subsystem is moderately convenient. (c) Disposal of residues from MSD subsystem is inconvenient.	a	(5, 6) b	(6) b
14	Likelihood of violating effluent standards because of procedural errors in MSD operation. (3) (a) There is virtually no chance of violating effluent standards because of procedural errors in MSD operation. (b) There is a low likelihood of violating effluent standards because of procedural errors in MSD operation. (c) There is a fair to moderate chance of violating effluent standards because of procedural errors in MSD operation. (d) There is a high likelihood of violating effluent standards because of procedural errors in MSD operation.	a	(7, 8) c	(7) c
23	Skill level requirements for operator of MSD MSD subsystem complexity ranking from 1 to 5	3	4	3
24	Training requirements for operator of MSD MSD subsystem complexity ranking from 1 to 5	3	4	3

(1) Residue is any by-product of normal MSD operation, disposal of which is regular operating task. Examples are ash produced by an incinerator, seal water used by vacuum pumps, wastewater or sludge held in a tank, evaporator residue, etc.

(2) Length of time required for disposal is the main factor considered; other factors are ease of access of area of MSD containing the residue, amount of residue to be disposed of, and ease of storing residue on board or taking it off vessel, as appropriate.

(3) By dumping overboard effluent which doesn't meet standards, flush oil, evaporator residue, air pollutants from incinerator, etc.

(4) Filter changes must be made moderately frequently.

(5) Incinerator ash removal (must remove pot, scrape out ash).

(6) Bag filter change (to remove residue of chlorine tablets).

(7) May pump oil overboard.

(8) Improper operation of incinerator may result in discharge of air pollutants.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD CHRYSLER Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem	
			With Incin.	With Holding Tank
25	Effect of MSD operation on vessel work routine/schedules (a) MSD operation has minimal or no effect on work routines/schedules. (1) (b) Effect of MSD operation on work routines/schedules is more than minimal (i.e., is moderate or extensive).	a	a	a
32	Availability of specialized or unique consumables/expendables required for MSD operation (a) No specialized or unique consumables or expendables required for MSD subsystem operation. (b) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from ship's inventory. (c) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from Federal Stock System. (d) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from a commercial source.	a	(5, 6) d	(5) d
33	Operating requirements for special or unique MSD support equipment (a) No special or unique support equipment required by MSD subsystem. (b) Some special or unique support equipment required by MSD subsystem; equipment requires only minimal and infrequent attention(2) to keep operational.(3) (c) Some special or unique support equipment required by MSD subsystem; requires more than infrequent attention to keep operational.(4)	a	(7) b	(8) b

(1) By C.G. direction, (a) applies to all MSDs considered in this study.
(2) No more frequently than weekly with a duration not greater than 10 minutes; or more frequently than semi-annually with a duration of 2 hours.
(3) E.g., firefighting equipment, special transformers, ozone detector, bilge alarm.
(4) E.g., compressor installed to support MSD operation.

(5) Filters: charcoal, clay, bag; possibly pre-filter.
(6) Incinerator related items (pot) available from manufacturer only.
(7) Firefighting equipment; ventilation.
(8) Bilge alarm may be required.

. MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHRYSLER

Sheet 1 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem With Incin.	
		(2)	(2, 3)	With Holding Tank (2, 3)
11	Hazard of contact with/spillage of toxic/dangerous substances[1] due to MSD inherent design			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	c	c
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Examples:
- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (form hands).

(2) . Oil is very high grade (mineral oil used in food and cosmetics).
. Contact with flush fluid by user; there may be some bacterial activity in fluid.

(3) . In servicing fluid maintenance packages, it is possible to come into contact with oil, e.g., in changing filters; there is a skid tray to catch oil drippings.
. Whole system is pressurized and a low pressure may start up a pump making any leak worse.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHRYSLER Sheet 2 of 6

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem (2)	Attribute Data: Treat./Disposal Subsystem — With Incin. (3)	Attribute Data: Treat./Disposal Subsystem — With Holding Tank (4)
12	Hazard of contact due with/spillage of toxic/dangerous substances[1] due to procedural error/equipment failures of MSD			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	c	c	c
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	b	b
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	b	b	b

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

(2) If too much chlorine has been put in system, flush fluid would burn (very unlikely)
. Contact with oil not unlikely (whole system is pressurized), especially due to procedural error during maintenance.

(3) . Hot oil has greater potential for causing injury.
. Need interfacing controls to stop garbage grinder input.
. Leakage of fumes from incinerator possible.

(4) Hydrogen sulfide may be generated in sludge holding tank.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHRYSLER

Sheet 3 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin. (1)	Treat./Disposal Subsystem: With Holding Tank
21	Hazard of explosive potential for operator/maintainer due to inherent MSD design			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a
22	Hazard of explosive potential for operator/maintainer due to procedural errors/equipment failures of MSD	(2)	(3)	
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	c	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	b	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) . Pressures low, vapors minimal.
. Blower purges incinerator before ignition.

(2) If a pipe leaks oil onto a hot surface, explosive vapors may be produced.

(3) . If oil gets through while incinerator pot is still warm, there is a potential for explosion.
. If operator/maintainer opens incinerator while smoking.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHRYSLER Sheet 4 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
31	Hazard of fire ignition potential[1] due to inherent MSD design	(2)	(2, 3)	(2)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	c	c	c
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	b	b	b
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	b
32	Hazard of fire ignition potential[1] due to procedural errors/equipment failure of MSD	(2)	(2, 3)	(2)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	c	c	c
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited (c) Results in severe injury or death.	b	b	b
	C - Hazard correction (a) Hazardous situtation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	b	b	b

(1) Oil used for flushing is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

(2) If there is a fire already, it will feed it; or if it drips onto hot surfaces.

(3) Presence of fuel oil and flush oil.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHRYSLER Sheet 5 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
4	Hazard of electrical shock potential[1] for operator/maintainer of MSD			
	L - Likelihood of hazard		(3)	(3)
	(a) No chance	a		
	(b) Highly unlikely		b	b
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a		
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b	b
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			
51	Physical hazards associated with MSD due to sharp edges[2]		(4)	(4)
	L - Likelihood of hazard			
	(a) No chance	a	a	a
	(b) Highly unlikely			
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a	a	a
	(b) Results in injury of low to moderate severity requiring first air or limited medical treatment.			
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			

(1) Electric shock may result in severe burns and/or death; in addition, reaction to electric shock may casue affected individual to be thrown aside, possibly subjecting him to severe impact injuries and/or contact with sharge edges/hot surfaces.

(2) Combined effect of injury due to sharp edges/points and sewage contamination may introduce harmful pathogens into the bloodstream of an affected individual.

(3) Inside electrical control panels, in servicing electric pumps there is always some hazard if operator/maintainer is not sufficiently careful.

(4) Expanded metal plate on top of which chlorine tablets rest is de-burred.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHRYSLER Sheet 6 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With. Incin.	Treat./Disposal Subsystem: With Holding Tank
52	Physical hazards associated with MSD due to hot surfaces		(1, 2)	(1)
	L - Likelihood of hazard			
	(a) No chance	a		
	(b) Highly unlikely		b	a
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			a
	(a) No resultant injury.	a		
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b	
	(c) Results in severe injury or death.			
	C - Hazard correction	a	a	a
	(a) Hazardous situation can be easily corrected.			
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			
53	Physical hazard for maintainer of MSD due to rotating machinery		(3, 4)	(3)
	L - Likelihood of hazard			
	(a) No chance	a		
	(b) Highly unlikely		b	b
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a		
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment		b	b
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			

(1) No hot surfaces; only if motors overheat or electrical controls burn out.

(2) Incinerator outside temperature supposed to be under 145°F; maintainer could try to empty ash while it is too hot.

(3) Possible to put fingers on rotating shaft of flush fluid pumps.

(4) Belt drive on transfer pump is guarded; blower blades almost inaccessible (blower or sludge tank); blower for oil burner inside a housing and well protected, but maintainer might get into it.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD CHRYSLER Sheet 1 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data Collect./Transp Subsystem	Treat./Disposal Subsystem Incin.	 With Holding Tank
11	Habitability problems[(1)] associated with bacterial contamination due to MSD inherent design (a) There is no bacterial contamination habitability problem due to MSD subsystem inherent design features. (b) There is a bacterial contamination habitability problem due to MSD subsystem inherent design features.	a	b	b
12	Habitability problems[(1)] associated with bacterial contamination due to procedural errors/equipment failures of MSD[(2)] (a) A bacterial contamination problem due to procedural errors/equipment failures of MSD subsystem is highly unlikely. (b) Procedural errors/equipment failures of MSD subsystem are likely to cause a bacterial contamination problem	(3) b	(3) b	(3) b
21	MSD fixture comfort (a) Commodes and urinals are comfortable and easy to use even under ship's motion. (b) Commodes and urinals are not comfortable and easy to use under ship's motion.	a	N/A	
22	Flushing procedure requirements for MSD fixture (a) There are no "non-standard" requirements for flushing. (b) There are "non-standard" requirements for flushing.	a	N/A	
23	Waste retention in MSD commode bowl (a) The amount of waste that remains in the bowl after flushing is less than that remaining after flushing a standard full water flushed fixture. (b) The amount of waste that remains in the bowl after flushing is the same as that remaining after flushing a standard full water flushed fixture. (c) The amount of waste that remains in the bowl after flushing is more than that remaining after flushing a standard full water flushed fixture.	b	N/A	

(1) As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

(2) A vacuum waste collection subsystem is less likely to expose personnel to sewage in case of a line break than a pressurized waste collection subsystem; fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply.

(3) Due to the pressurized oil return line, in case of a line break, will expose personnel to sewage and to bacteria contaminated oil.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD CHRYSLER   Sheet 2 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
24	Likelihood of user contact[1] with MSD fixture flushing medium (a) User is unlikely to come into contact with flushing medium. (b) User is more likely to come into contact with flushing medium than with standard water flushed fixture.	(3) b	N/A	
25	Appearance of MSD fixture flushing medium (a) The color and general appearance of the flushing medium is as acceptable as clear water. (b) The color and general appearance of the flushing medium are acceptable, but clear water is preferable. (c) The color and general appearance of the flushing medium are not acceptable.	b	N/A	
26	Noise produced in flushing MSD fixtures (a) The noise produced in flushing fixtures is less than that of a standard commode/urinal. (b) The noise produced in flushing fixtures is the same as that of a standard commode/urinal. (c) The noise produced in flushing fixtures is greater than that of a standard commode/urinal.	b	N/A	
31	Odors produced as a result of inherent MSD design (a) The MSD subsystem produces no odor as a result of inherent design. (b) The MSD subsystem produces a noticeable odor as a result of inherent design.	a	(4) b	(4) b
32	Odors produced as a result of procedural errors/equipment failures of MSD (a) The MSD subsystem produces no odor as a result of procedural errors/equipment failures. (b) The MSD subsystem produces a noticeable odor as a result of procedural errors/equipment failures.	b	(5, 6) b	(6) b
41	Heat generation for nearby personnel[2] due to inherent MSD design (a) As a result of inherent design features, the MSD subsystem does not generate enough heat to render its vicinity hotter than most shipboard areas containing machinery. (b) As a result of inherent design features, the MSD subsystem does generate enough heat to render its vicinity hotter than most shipboard areas containing machinery.	a	b	a

(1) Due to flushing medium composition, fixture design, motion of vessel (which may cause splatter, splashing, or spillage of flushing medium).

(2) For operator/maintainer/adjacent berthing and working areas.

(3) Due to the pressurized oil return line. In case of a line break, will expose personnel to sewage and to bacteria contaminated oil.

(4) Vent from sludge tank quite odiferous.

(5) . If blower not working.
 . If sludge in incinerator pot not completely burned.

(6) . If filters don't work.
 . If chlorine not added.
 . If not properly vented.

. MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V- HABITABILITY

MSD CHRYSLER Sheet 3 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
42	Heat generation for nearby personnel[1] due to procedural errors/equipment failures of MSD. (a) The MSD subsystem does not generate enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery. (b) The MSD subsystem does generation enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery.	a	b	a
5	Noise level for personnel in vicinity of MSD[1] NI - Noise Index (a) The MSD subsystem is silent or nearly silent. (b) Noise level of MSD subsystem is approximately equal to background noise level of vessel. (c) The MSD subsystem is very loud, produces constant noise, drowns out vessel background noise in immediate area of the system; must shout to be heard.	b	(3) b	(3) b
6	Vibration levels for nearby personnel[1] produced by MSD machinery VI - Vibration Index (a) MSD subsystem produces little or no perceptible vibration in addition to background level on vessel. (b) MSD subsysrem produces perceptible vibration, but similar to vessel background. (c) MSD subsystem produces abnormal or disturbing intensity and/or frequency of vibration.	a	a	a
7	Effect of MSD on user housekeeping routines (restrictions on user imposed by subsystem[2]). (a) Subsystem characteristics do not impose restrictions on user. (b) Subsystem characteristics impose restrictions on user.	(4) b	(4) b	(4) b

(1) For operator/maintainer/adjacent berth and working areas.

(2) E.g. . Must use water-soluble toilet paper which is not as comfortable as usual toilet paper.
. Must use special bowl cleaner which is less effective than usual cleaner
. Cannot dump detergents down galley sink; must store and off-load at shore.

(3) Pumps and blowers make some noise.

(4) Special cleaners required for fixtures; should not dump deck swabbings into commodes.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VI - RELIABILITY

MSD CHRYSLER

Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	RELIABILITY Characteristics	RELIABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
21	MSD complexity Complexity index of MSD subsystem based on a complexity rankig from 1 to 5.	3	4	3
23	Extent of MSD equipment/component redundancy(1) (a) There is some significant redundancy in the MSD subsystem's major components. (b) There is no significant redundancy in the MSD subsystem's major components.	(6) a	(7, 8) b	(8) b
24	Degree of equipment failure independence(2) (a) There is a high degree of equipment failure independence in MSD subsystem. (b) There is a moderate degree of MSD equipment failure independence in MSD subsystem. (c) There is a low degree of equipment failure independence in MSD subsystem.	a	(9, 10) b	(10) b
25	Adequacy of MSD equipment ratings (a) Most MSD subsystem equipments are overrated. (b) Some MSD subsystem equipment ratings are nominal, some are overrated. (c) Some MSD subsystem equipments are underrated, some are nominally rated. (d) Most MSD subsystem equipments are underrated.	b	(11, 12) c	(12) c
26	Provisions for fault actuated cut-off mechanisms(3) for MSD protection (a) There are many fault actuated mechanisms in MSD subsystem, or they are not required.(4) (b) There are some fault actuated mechanisms in MSD subsystem. (c) There are no or almost no fault actuated mechanisms in MSD subsystem.	a	(13, 14) b	(14) b
3	Reliability risk for MSD(5) (a) MSD subsystem has a history of fair or better test results. (b) MSD subsystem has a history of poor test results. (c) No test results are available for MSD subsystem.	a	(15) b	(16) a

(1) Any redundancy in electronic circuitry is not considered.
(2) i.e., failure of one item will not result in failure of major component or subsystem.
(3) Includes mechanisms to: (i) alert operator/maintainer to high stress or abnormal conditions that will result in failure, and/or (ii) to correct those conditions or turn off equipment.
(4) E.g., standard commodes and urinals in a gravity drain sewage collection subsystem do not require fault actuated cut-off mechanisms.
(5) E.g., innovative design, experience.

(6) Fixtures, piping.
(7) No redundancy in incinerator package.

Footnotes continued on following page.

(8) . In larger configurations, possible redundancy of major components, e.g., feed of one line into three separate tanks.
. Two pressurization pumps manually switched-real redundancy.
. Interface sensors not redundant since they perform different functions (e.g. M/T pump has two associated sensors).
. No filter redundancy.
. In large separation tank there are three filters in parallel; all are used unless degraded performance acceptable.

(9) . If temperature sensor fails and indicates temperature is high enough but it isn't, sludge will be sent to incinerator and not burn.
. If recirculating pump fails and oil accumulates in sludge tank, may get some oil into incinerator resulting in overtemperature.

(10) . Pressurization and fluid maintenance package failure results in loss of oil to leads.
. Prefilter fails closed then other filters fail, no flow through - oil degrades.
. Prefilter fails open - regulator fails, oil degrades.
. Charcoal, clay or bag filter fails - degrades oil.

(11) . Transfer pump adequate.
. Oil burner adequate or possibly a bit overrated.
. Pot inadequate.

(12) . Pressure pumps overrated, sized adequately for peaks.
. M/T pumps oversized.
. Filters, sensors adequate.
. Recirculating pump - oversized.

(13) . Incinerator fire eye, overtemperature cut off, time limit on burner operation.

(14) . Time delay on M/T pump to prevent over operation.
. Sludge tank - high level cut off to stop M/T pump.

(15) . Problems with incinerator pot.

(16) . Interface sensing to be worked out.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD CHRYSLER Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
131	Accessibility of replaceable MSD components (a) High degree of accessibility in MSD subsystem components. (b) Moderate degree of accessibility in MSD subsystem components. (c) Low degree of accessibility in MSD subsystem components.	b	b	b
132	Extent of MSD modularization for ease of repair/replacement (a) High degree of MSD subsystem modularization. (b) Moderate degree of MSD subsystem modularization. (c) Low degree of MSD subsystem modularization.	a	(5) a	(5) a
133	Degree of MSD repairability on board vessel.(1) (a) All MSD subsystem items are repairable on vessel. (b) Some MSD subsystem items are repairable on vessel; some must be replaced. (c) All MSD subsystem items must be replaced.	a	(6) b	a
134	Availability of manufacturer field support and training programs for MSD (a) Manufacturer field support and a training program is available. (b) Manufacturer field support(2) is available but no training program is available. (c) Manufacturer training program is available but field support is not available. (d) Neither field support nor training program are available from manufacturer.	b	b	b
142	Special/proprietary(3) item requirements for MSD equipment repair (a) No special items required for any MSD subsystem repairs. (b) Some special items required for some MSD subsystem repairs. (c) All items required for MSD subsystem repairs are special items.	a	(7, 8) b	(8) b
23	Effect of MSD preventive maintenance on watchstander routines (a) No effect on watchstander routines.(4) (b) There is some effect on watchstander routines.	a	a	a
33	Special docking requirements for MSD overhauls (a) There are no special docking requirements for the MSD.(4) (b) There are special docking requirements for the MSD.	a	a	a

(1) Versus necessity for replacement of failed equipment.
(2) May include some limited training support during initial MSD installation.
(3) E.g., incinerator pots, filters versus standard supply parts.
(4) By C.G. direction, this applies to all MSDs considered in this study.

(5) Modularization of subsystems.
(6) Fire eye is not repairable - a throw away item.
(7) Pots
(8) Air injector, level sensors.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD CHRYSLER　　　　Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
4	Logistic requirements for MSD (a) No special parts are required for the MSD subsystem. (b) Few different categories of special parts are required for the MSD subsystem and there are few parts in each category. (c) Few different categories of special parts are required for the MSD subsystem but many parts of each type are required, or many different categories of special parts are required but there are few parts in each category. (d) Many different categories of parts are required for the MSD subsystem and there is a large number of parts in each category.	a	b	b

CHRYSLER

EQUIPMENT AND INITIAL SPARES ACQUISITION COSTS

Equipment		Equipment Cost	Cost of Associated Initial Spares Package [a]
Separator Tank (Including controls)	Model A	$4,750	$275
	Model A/B	5,694	275
	Model B	6,647	275
Pressurization and Fluid Maintenance Package(s) (Including Controls)	Model A	3,319 [b]	198 [b]
	Pump Package	1,585	N/R
	Accumulator	512	26
	Fluid Maint. Pkg.	1,664	26
	Total Model B	4,196 [c]	487 [c]
Sludge Surge Tank (Including controls)	Model B	5,041	350
	Model C	5,200	350
Incinerator (Including controls)	Model A	5,462	600
	Model C	9,174	550

Notes

1. Please supply cost estimates for each equipment based on a production run of up to 100 units.
2. All cost estimates are to be based on 1976 costs.
3. Identify recommended contents of Initial Spares Package associated with each equipment.

(a) Manufacturer recommends one initial spares package for every 4 associated equipments on board the vessel.

(b) Includes the cost of flush fluid and expendables ($145) which was not included in cost provided by manufacturer.

(c) Includes the cost of flush fluid and expendables ($435) which was not included in cost provided by manufacturer.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs - Min)	Number Operators/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED — Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing Water (kwh/day)	Compressed Air (SCF/day @ P)	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 39¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Vector (@ 1.83¢/100 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Material	TOTAL: Annual Operating Cost ($)
C/T SUBSYSTEM																					
COLLECTION AND RECIRCULATION SUBSYSTEM																					
Flush commode (by user)										①					①						
Flush urinal (by user)										①					①						
Mode changeover cycles**																					
. primary - overboard		-20	1-mk2	6.27	0.33/cy	2.09	2.09														2.09/cy
. Pierside - primary		-25	1-mk2	6.27	0.41/cy	2.61	(required for hose handling)														2.61/cy
		-10	2-mk2	6.27	0.33/cy	2.09															2.09/cy
Separation Tank Model A																					
Clean out interface level sensor pipe assembly on separation tank	168	-20	1-mk2	6.27	17.33	108.68															108.68
Replace coalescer	720[e]	-5	1-mk2	6.27	1.00	6.27											Coalescer	1	$3.79[b]	$45.48[k]	51.75
Replace bag filter	720[e]	-5	1-mk2	6.27	1.00	6.27											bag	1	$5.04[b]	$60.48[k]	66.75
Add chlorine tablets	504	-5	1-mk2	6.27	1.42	8.88											Tablets	#12/3mo	$29.76[d] / 12#[b]	$119.04[h]	127.92
Operate separation tank (automatic)	24	-5	1-mk2	6.27	30.42	190.71	0.5[k]					$5.50[k]									196.21
Add flush fluid	1080[e]	-5	1-mk2	6.27	0.67	4.18											Oil	5 gal/1.5mo[e]	$1.30/gal[d]	$52.00[k]	56.18
TOTALS					51.84	324.99						$5.50								$277.00	$607.49

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

** It is assumed that similar effort is required for mode changeover when a holding tank is substituted for an incinerator.

Compressed Air Cost in ¢/Year= $\left(6.12268\ (14.7 + p)^{0.1429} - 8.9898\right)$ (SCF/day) where p is in psig.

/cy = per changeover cycle

① = Power for flushing commodes and urinals included in Pressurization and Fluid Maintenance Package, and is thus not reflected in Collection Subsystem.

SCF = standard cubic feet at 14.7 psi and 70°F.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs • Min)	Number Operators/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED — Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing water (kwh/day)	Compressed Air (SCF/day @ P)	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 33¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.89¢/1000 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	TOTAL: Annual Operating Cost ($)
Separation Tank Model A/B																					
Add Flush fluid	1080[c]	-5	1-mk2	6.27	0.67	4.18											oil	22.5gal[k] / 1.5 mo	$1.30/gal[d]	$130.00	134.18
Clean out interface level sensor pipe assembly on separation tank	168	-20	1-mk2	6.27	17.33	108.68															108.68
Replace coalescer	720[c]	-5	1-mk2	6.27	1.00	6.27											Coalesc.	1	$3.79[b]	$45.48[k]	51.75
Replace bag filter	720[c]	-5	1-mk2	6.27	1.00	6.27											Bag	1	$5.04[b]	$60.48[k]	66.75
Add chlorine tablets	504	-5	1-mk2	6.27	1.42	8.88											Tablets	20/2mo[b]	$29.76/120[b]	$178.56[k]	187.44
Operate separation tank (automatic)	24	-5	1-mk4	7.42	30.42	225.59	0.5[k]					$5.50[k]									231.19
TOTALS					51.84	359.97						$5.50								$414.52	779.99
Separation Tank Model B																					
Clean out interface level sensor pipe assembly on separation tank	168	-20	1-mk2	6.27	17.33	108.68															108.68
Replace coalescer	720[c]	-10	1-mk2	6.27	2.00	12.54											Coal.	12	$7.58[b]	$90.96[k]	103.50
Replace bag filter	720[c]	-10	1-mk2	6.27	2.00	12.54											Bag	2	$10.08[b]	$120.96[k]	133.50
Add chlorine tablets	504	-5	1-mk2	6.27	1.42	8.88											Tablets	2 ea/3mo[b]	$59.51/24[b]	$238.04[k]	246.92
Add flush fluid	1080[c]	-5	1-mk2	6.27	0.67	4.18											Oil	60 gal[k] / 1.5mo	$1.30/gal[d]	$416.00[k]	420.18
Operate separation tank (automatic)	24	-5	1-mk4	7.42	30.42	225.69	0.51					$5.60[k]									
TOTALS					53.84	372.51	0.53					$5.60								$865.96	1244.07

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

Compressed Air Cost in ¢/Year = $\left(6.12268\,(14.7 + p)^{0.1429} - 8.9896\right)\left(SCF/day\right)$ where p is in psig.

SCF = standard cubic feet at 14.7 psi and 70°F.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs. - Min)	Number Operators/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED: Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing Water (kwh/day)	Compressed Air (SCF/day @ P)	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 39¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.8¢/1000 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	TOTAL: Annual Operating Cost ($)
Pressurization & Fluid Maintenance Package Model A																					
Replace prefilter element	72.^c	-15	1-mk3	6.84	3.9	20.52											Element	1	$3.21[b]	$38.52[k]	59.04
Replace carbon filter bag	720[c]	-15	1-mk3	6.84	3.0	20.52											Bag	1	$18.14[b]	$2[illegible].68[k]	238.20
Replace clay filter element	720[c]	-15	1-mk3	6.84	3.0	20.52											Element	1	$14.85[b]	$178.20[k]	198.72
Add air to accumulator (automatic)											4@50[d]					8¢[k]					0.08
Operate P & FM package (automatic)							0.46[b] + [illegible]					$4.56[k] + 58¢/c									4.96 + 58¢/c
TOTALS					9.0	61.56					4	$4.56 + $0.058/c				8¢				$434.40	$501.00 + $.058/c
Pressurization & Fluid Maintenance Package Model B																					
Replace prefilter element	720[c]	-15	1-mk3	6.84	3.0	20.52											Element	1	$6.78[b]	$81.36[k]	101.88
Replace carbon filter bag	720[c]	-15	1-mk3	6.84	3.0	20.52											Bag	3	$[illegible].40[b]	$1094.40[k]	1114.92
Replace clay filter element	720[c]	-15	1-mk3	6.84	3.0	20.52											Element	2	$14.85[b]	$356.40[k]	376.92
Add air to accumulator (automatic)											8@50[m]					16¢[k]					0.16
Operate P & FM package (automatic)							1.71[k†]					$16.74[k]									18.74
TOTALS					9.0	61.56	1.71				8	$18.74				$.016				$[illegible]	1612.82

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

† 152 men.

Compressed Air Cost in ¢/Year = $\left(6.12268\ (14.7 + p)^{0.1429} - 8.9898\right)\left(SCF/day\right)$ where p is in psig.

SCF = standard cubic feet at 14.7 psi and 70°F.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs)	Number Operators/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED — Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing Water (kwh/day)	Compressed Air (SCF/day @ P)	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 39¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.8¢/1000 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Material	TOTAL: Annual Operating Cost ($)
T/D SUBSYSTEM																					
INCINERATOR SUBSYSTEM																					
Sledge Surge Tank Model B																					
Tank operation (automatic)							1.06[k]					$11.61[k]									11.61
Clean level sensors (3)	720	-15	1-mk2	6.27	3.00	18.81															18.81
Clean sight glass	720	-5	1-mk2	6.27	1.00	6.27															6.27
TOTALS					4.00	25.08	1.06					$11.61									36.69
Sludge Surge Tank Model C																					
Tank operation (automatic)							1.24[k]					$13.53[k]									13.53
Clean level sensors (3)	720	-15	1-mk2	6.27	3.00	18.81															18.81
Clean sight glass	720	-5	1-mk2	6.27	1.00	6.27															6.27
TOTALS					4.00	25.08	1.24					$13.53									38.61
Incinerator Model A																					
Incinerator operation (automatic)							0.576[k] + 0.069/c	0.65/c[k]				$6.30 + 75¢/c	$93.00/c								6.30 + 93.75/c
Remove ash	168[e]	-10[e]	1-mk2	6.27	8.67	54.34															54.34
Incinerator Model C																					
Incinerator operation (automatic)							0.576[k] + 0.069/c	0.65/c[k]				$6.30 + 75¢/c	$93.00/c[k]								6.30 + 93.75/c
Remove ash	168	-10[e]	1-mk2	6.27	8.67	54.34															54.34

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

/c = per capita

Compressed Air Cost in ¢/Year $=\left(6.12268\ (14.7 + p)^{0.1429} - 8.9898\right)(SCF/day)$ where p is in psig.

SCF = standard cubic feet at 14.7 psi and 70°F.

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Preventive Maintenance Requirement	LABOR: Scheduled Interval for Maintenance Action (Hrs)	LABOR: Estimated Time Required (Hrs-Min)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Annual Labor Required (Man-Hrs)	LABOR: Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	PARTS CONSUMED: No. of Parts Used/Year	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Annual Cost of Parts ($)	TOTAL: Annual Preventive Maintenance Cost ($)
C/T SUBSYSTEM											
COLLECTION AND RECIRCULATION SUBSYSTEM											
Separation Tank Models A, A/B & B											
Lubricate vent blower motor	1440	-2	1-mk2	6.27	0.2	1.25					1.25
Clean vent blower fan and housing	4380	-20	1-mk2	6.27	0.67	4.18					4.18
Clean external surfaces and check for leaks	2190	-30	1-mk3	6.84	2.0	13.68					13.68
Clean tank of hardened sludge	8760[e]	2-30[e]	1-mk2	6.27	2.5	15.68					15.68
TOTALS					5.37	34.79					34.79
Pressurization & Fluid Maintenance Package Models A & B											
Clean fan, fan shield and body fins of pressurization pump motors (2)	4380	-30	1-mk2	6.27	1.0	6.27					6.27
Check and adjust pressurization unit pressure switch	4380	-15	1-mk5	8.13	0.5	4.07					4.07
Clean external surfaces and check for leaks	2190	-30	1-mk3	6.84	2.0	13.68					13.68
TOTALS					3.5	24.02					24.02

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs.-(Min))	No. Maintainers/Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
T/D SUBSYSTEM											
INCINERATOR SUBSYSTEM											
Sludge Surge Tank Model B & C											
Lubricate vent blower motor	1440	-2	1-mk2	6.27	0.20	1.25					1.25
Clean vent blower fan and housing	4380	-20	1-mk2	6.27	0.67	4.18					4.18
Clean external surfaces and check for leaks	2190	-30	1-mk3	6.84	2.0	13.68					13.68
Adjust chain belt tension for transfer pump	2190	-5	1-mk3	6.84	0.33	2.28					2.28
TOTALS					3.2	21.39					21.39
Incinerator Models A & C											
Clean fuel nozzle orifice(s)	1440	-10	1-mk2	6.27	1.00	6.27					6.27
Clean combustion air blower fan and housing	4380	-20	1-mk2	6.27	0.67	4.18					4.18
Lubricate blower motor(s)	1440	-2	1-mk2	6.27	0.20	1.25					1.25
Verify set point of overtemperature sensor	4380	-20	1-mk5	8.13	0.67	5.42					5.42

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs - (Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
Check chamber and door liner for defects	168	-3	1-mk5	8.13	2.60	21.14					21.14
Check pot for cracks	168	-2	1-mk5	8.13	1.73	14.09					14.09
Check out chamber (below pot) of soot, loose and caked ash	720	-10	1-mk3	6.84	2.00	13.68					13.68
Clean and inspect fire eye(s)	720	-10	1-mk2	6.27	2.00	12.54					12.54
TOTALS					10.87	76.57					78.57

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs - (Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
C/T SUBSYSTEM											
COLLECTION AND RECIRCULATION SUBSYSTEM											
Replace flushometer internals	17520	-6[n]/unit	1-mi2[r]	6.27	0.05/unit	0.31/unit	Flushometer internals	0.5/unit	7.00/unit[m]	3.50/unit	3.81/unit
Separator Tank Models A, A/B & B											
Replace interface level sensor	17520	-15	1-em2	5.45	0.13	0.68	Interface sensor	0.5	39.40[b]	19.70	20.38
Replace sensor pipe hose and clamps	17520	-15	1-mk2	6.27	0.13	0.78	Hose and clamps	0.5	2.00[m]	1.00	1.78
Replace diaphragm on waste shutoff valve	26280	4- *	1-mk3	6.84	1.33	9.12	Molded diaphragm	0.33	40.00[d]	13.33	22.45
Replace gaskets for waste shutoff valve	26280	4- *	1-mk3	6.84	1.33	9.12	Gaskets	0.33	2.00[m]	0.67	9.79
Clean out waste line under separation tank	8760	4- *	1-mk2	6.27	4.0	25.08					25.08
Replace ball in waste check valve	17520	-15	1-mk2	6.27	0.13	0.78	Ball	0.5	20.00[d]	10.00	10.78
Replace blower motor	26280	-15	1-em3	5.96	0.08	0.50	Motor	0.33	10.00[d]	3.33	3.83
Repair M/T pump											
replace . impeller	8760	2-45	2-em2	5.45	5.5	29.98	Impeller	1	77.36[b]	77.36	107.34
. cutter assembly	4380	2-45[h]	2-em2	5.45	11.0	59.95	Cutter Assy	2	228.31[b]	456.62	516.57
. mechanical shaft seal	8760	3-	2-em2	5.45	6.0	32.70	Shaft seal	1	22.92[b]	22.92	55.62
. motor bearing	17520	1-	2-em2	5.45	1.0	5.45	bearing(s)	0.5	8.00[m]	4.00	9.45

* Requires shutting down flush system and emptying tank.

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	LABOR: Estimated Time Required (Hrs - Min)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Annual Labor Required (Man-Hrs)	LABOR: Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	PARTS CONSUMED: Estimated No. of Parts Used/Year	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
Replace mechanical relay (2)	17520	-10	1-em3	5.96	0.08	0.50	Relay	0.5	16.20[m]	8.10	8.60
Replace solid state relay (2)	21900	-10	1-em4	6.50	0.07	0.43	Relay	0.4	72.00[m]	28.80	29.23
Replace motor starter	26280	-10	1-em4	6.50	0.06	0.36	Relay	0.33	16.20[m]	5.40	5.76
Replace 15VDC power supply	26280	-10	1-em5	7.22	0.06	0.40	Power Supply	0.33	60.00[m]	20.00	20.40
TOTALS	9.55				30.09	175.83		8.55		671.23	847.06
Pressurization and Fluid Maintenance Package Models A & B											
Repair fluid pump motor -replace bearings	17520	1-	1-em5	7.22	0.5	3.61	Motor bearing	1	8.00[m]	4.00	7.61
Replace fluid pump mechanical seal	17520	-40	1-mk5	8.13	0.33	2.71	Mechanical seal	0.5	7.00[d]	3.50	6.21
Replace valve seats and stem seal	4380	-15	1-mk3	6.84	0.5	3.42	Seats and Seal	2	4.00[m]	8.00	11.42
Replace pressure switch (2)	13140	-15	1-em5	7.22	0.17	1.20	Pressure switch	0.67	51.32[b]	34.21	35.42
Replace flush medium	17520	4-	1-mk3	6.50	2.0	13.00	Marcol 52	100 gal	1.30/gal[d]	130.00	143.00
Replace solid state relay	21900	-10	1-em4	6.50	0.07	0.43	Relay	0.4	72.00[m]	28.90	29.33
Replace motor starter	26286	-10	1-em3	5.96	0.06	0.33	Relay	0.33	16.20[m]	5.40	5.73
TOTALS	4.89				3.63	24.70		4.9+ 100 gal.		213.91	238.72

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	LABOR: Estimated Time Required (Hrs - Min)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Annual Labor Required (Man-Hrs)	LABOR: Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	PARTS CONSUMED: Estimated No. of Parts Used/Year	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
INCINERATOR SUBSYSTEM											
Sludge Surge Tank Models B & C											
Replace blower motor	26280	-15	1-em3	5.96	0.08	0.50	Blower motor	0.33	10.00[d]	3.33	3.83
Replace level sensor control	17520	-15[d]	1-em2	5.45	0.13	0.68	Level Sensor Control	0.5	75.00[d]	37.50	38.18
Replace sight glass	26280	-15	1-mk2	6.27	0.08	0.52	Sight glass	0.33	25.00[d]	8.33	8.86
Replace sight glass hose and clamps	26280	-10	1-mk2	6.27	0.06	0.35	Hose and clamps	0.33	3.00[d]	1.00	1.35
Replace transfer pump motor bearing	17520	-45	1-em5	7.22	0.38	2.71	Motor bearing	0.5	8.00[m]	4.00	[illegible]
Replace transfer pump stator	17520	-45	1-mk5	8.13	0.38	3.05	Pump stator	0.5	80.00[d]	40.00	43.05
Replace transfer pump shaft seal	17520	-30	1-mk5	8.13	0.25	2.03	Shaft Seal	0.5	2.00[m]	1.00	3.03
Replace recirculation pump shaft seal	17520	-30	1-mk5	8.13	0.25	2.03	Shaft Seal	0.5	5.00[d]	2.50	4.53
Replace recirculation pump motor bearing	17520	-45	1-em5	7.22	0.38	2.71	Motor bearing	0.5	8.00[m]	4.00	6.71
Replace chain drive	26280	-20	1-mk3	6.84	0.11	0.76	Chain drive	0.33	15.00[d]	5.00	5.76
Replace valve-seat and stem seal (3)	8760	-20	1-mk3	6.84	0.33	2.28	Seat and seal	1	3.00[m]	3.00	5.28
Replace mechanical relay(2)	17520	-10	1-em3	5.96	0.08	0.50	Relay	0.5	16.20[m]	8.10	8.60
Replace level probe (3)	26280	-15	1-em3	5.96	0.08	0.50	Probe	0.33	60.00[d]	20.00	20.50
TOTALS	6.15				2.59	18.62		6.15		137.76	156.39

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs - Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
Incinerator Model A											
Replace chamber insulation and door lining	8760	4-[d]	1-mk5	8.13	4.0	32.52	Lining and insulation	1	300.00[m]	300.00	332.52
Replace door seal	8760	-15	1-mk4	7.42	0.25	1.86	Door seal	1	10.00[d]	10.00	11.86
Replace blower/fuel pump motor	26280	-45	1-mk5	8.13	0.25	2.03	Burner motor	0.33	25.00[d]	8.33	10.37
Replace fuel nozzle	8760	-5[d]	1-mk3	6.84	0.08	0.57	Nozzle	1	2.00[d]	2.00	2.57
Replace fuel pump	26280	-20	1-mk5	8.13	0.11	0.90	Pump	0.33	10.00[d]	3.33	4.24
Replace fuel solenoid valve (2)	8760	-10	1-mk3	6.84	0.17	1.14	Solenoid valve	1	10.00[d]	10.00	11.14
Replace thermocouple	4380	-25[e]	1-em4	6.50	0.83	5.42	Thermocouple	2	52.06[d]	104.12	109.54
Replace overtemperature sensor	13140	-15	1-em5	7.22	0.17	1.20	O.T. Sensor	0.67	165.24[b]	110.16	111.36
Replace incinerator pot **	1020M-d*	-5	1-mk2	6.27	0.02/c	0.13/c	Pot	0.36/c	200.00[d]	71.57/c	71.70/c
Replace temperature controller	26280	-10	1-em5	7.22	0.06	0.40	Temp. Controller	0.33	100.00[d]	32.33	33.73
Repair stack (liner, insulation, leaks)	8760	2-	1-mk5	8.13	2.0	16.26	Stack section (2.5ft)	2	30.00[d]	60.00	76.26
Replace timer clock	26280	-10	1-em5	7.22	0.06	0.40	Timer	0.33	50.00[m]	16.67	17.07
Replace transformer	26280	-5	1-em3	5.56	0.03	0.17	Transformer	0.33	5.13[b]	1.71	1.88
Replace solid state relay	26280	-10	1-em5	7.22	0.06	0.40	Relay	0.33	72.00[m]	24.00	24.40
Replace fire eye	17520[d]	-15[e]	1-em5	7.22	0.13	0.90	Fire eye	0.5[d]	10.00[d]	5.00	5.90
TOTALS					8.2+ 0.02/c	64.17+ 0.13/c		10.67		688.65+ 71.57/c	752.84+ 71.70/c

* Incinerator Liner: $500 \frac{\text{burn hours}^{(g)}}{\text{pot}} \times \frac{4\text{ gal.}}{\text{burn hour}} \times \frac{\text{man-day}}{[0.46\text{ (sanitary)} + 1.5\text{ (garbage grinder)}]} = 1,020$ man-days per liner

** Chrysler is currently marketing a redesigned pot (spun and round shaped versus welded and square shaped quoted at $100 for Model A Incinerator and $300 for Model C Incinerator) with a manufacturing expected life of 2-3 years based upon (1) 8 burn hours per day, (2) slightly lower combustion temperature, and (3) controlled quantity and temperature of wastes. These are currently in use at 2 sites.

/c = per capita (crew member)

Where multiple units are designated, fixed costs are multiplied by the appropriate multiple but per capita costs are treated on a per capita basis only and are not affected by equipment multiplicity.

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Chrysler

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	LABOR: Estimated Time Required (Hrs - Min)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Annual Labor Required (Man-Hrs)	LABOR: Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	PARTS CONSUMED: Estimated No. of Parts Used/Year	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
Incinerator Model C											
Replace chamber and door lining	8760	4-[d]	1-mk5	8.13	4.0	32.52	Lining and insulation	1	1300.00[m]	1300.00	1332.52
Replace door seal	8760	-15	1-mk4	7.4[illegible]	0.25	1.86	Seal	1	10.00[d]	10.00	11.86
Replace blower/fuel pump motor (2)	13140	-45	1-mk5	8.13	0.50	4.07	Burner	0.67	25.00[d]	16.67	20.73
Replace fuel nozzle (2)	4380	-5[d]	1-mk3	6.8[illegible]	0.17	1.14	Nozzle	2	2.00[d]	4.00	5.14
Replace fuel pump (2)	13140	-20	1-mk5	8.13	0.22	1.81	Pump	0.67	10.00[d]	6.67	8.47
Replace fuel solenoid valve (3)	8760	-10	1-mk3	6.94	0.17	1.14	Seat and seal	1	10.00[d]	10.00	11.14
Replace thermocouple	4380	-25[e]	1-em4	6.50	0.83	5.42	Thermocouple	2	52.06[b]	104.12	109.54
Replace overtemperature sensor	13140	-15	1-em5	7.22	0.17	1.20	Sensor	0.67	165.24[b]	110.16	111.36
Replace incinerator pot **	2040m-d*	-5	2-mk2	6.27	0.02/c	0.12/c	Pot	0.18/c	400.00[d]	71.57/c	71.69/c
Replace temperature controller	26280	-10	1-em5	7.22	0.06	0.40	Temp. Controller	0.33	150.00[d]	50.00	50.40
Repair stack (liner, insulation, leaks)	8760	2-	1-mk5	8.13	2.0	16.26	Stack section (2.5ft)	2	30.00[d]	60.00	76.26
Replace timer clock	26280	-10	1-em5	7.22	0.06	0.40	Timer	0.33	50.00[m]	16.67	17.07
Replace transformer	26280	-5	1-em3	5.96	0.03	0.17	Transformer	0.33	5.13[b]	1.71	1.88
Replace solid state relay (2)	13140	-10	1-em5	7.22	0.11	0.80	Relay	0.67	72.00[m]	48.00	48.80
Replace fire eye (2)	8760	-15[e]	1-em5	7.22	0.25	1.81	Fire eye	1.0[m]	10.00[d]	10.00	11.81
TOTALS					8.82+ 0.02/c	69.00+ 0.12/c		13+ 0.18/c		1748+ 71.57/c	1816.96+ 71.69/c

* Incinerator Lining: $500 \frac{\text{burn hours}^{(g)}}{\text{pot}} \times \frac{8 \text{ gal.}}{\text{burn hour}} \times \frac{\text{man-day}}{1.96 \text{ gal.}} = 2,040$ man-days per liner

** Chrysler is currently marketing a redesigned pot (spun and round shaped versus welded and square shaped quoted at $100 for Model A Incinerator and $300 for Model C Incinerator) with a manufacturing expected life of 2-3 years based upon (1) 8 burn hours per day, (2) slightly lower combustion temperature, and (3) controlled quantity and temperature of wastes. These are currently in use at 2 sites.

/c = per capita (crew member

Where multiple units are designated, fixed costs are multiplied by the appropriate multiple but per capita costs are treated on a per capita basis only and are not affected by equipment multiplicity.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD Chrysler

Page 1 of 4

Overhaul Requirement	LABOR: Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs - Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	PARTS CONSUMED: Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	TOTAL: Major Overhaul Cost ($)
C/T SUBSYSTEM											
COLLECTION AND RECIRCULATION SUBSYSTEM											
Replace flushometer internals		-6/unit [n]	1-mk2	6.27	0.1/unit	0.63/unit	Flushometer internal	1/unit	7.00/unit [m]	7.00/unit	7.63/unit
Drain entire system of oil and wastewater		3-	1-mk5	3.13	3.0	24.39					24.39
Separation Tank Models A, A/B & B											
Clean refinish inside of both chambers in tank		4-	1-mk3	6.84	4.00	27.36					27.36
Clean out waste line under separation tank		-30	1-mk2	6.27	0.50	3.14					3.14
Replace interface sensor		-10	1-mk2	6.27	0.17	1.05	Interface sensor	1	39.40 [b]	39.40	40.45
Replace sensor pipe hose and clamps		-5	1-mk2	6.27	0.08	0.52	Hose and Clamps	1 set	2.00 [m]	2.00	2.52
Replace diaphragm and gaskets for waste shutoff valve		-45	1-mk3	6.84	0.75	5.13	Valve diaphragm and gaskets	1 set	42.00 [d]	42.00	47.13
Replace ball in waste check valve		-15	1-mk2	6.27	0.25	1.57	Valve seat	1	20.00 [d]	20.00	21.57
Clean blower and housing		-20	1-mk2	6.27	0.33	2.09					2.09
Replace all internal parts of M/T pump except motor stator, armature & shaft		3- 3-	1-em5 1-mk3	7.22 6.84	3.0 3.0	21.66 20.52	M/T pump internals	1 set	357.26 [b]	357.26	399.44
TOTALS					12.08	83.04		5		460.66	543.70

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD Chrysler

Overhaul Requirement	LABOR: Time Between Overhauls (Yrs) *	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	PARTS CONSUMED: Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	TOTAL: Major Overhaul Cost ($)
Pressurization & Fluid Maintenance Package											
Models A & B											
Replace pump mechanical seal		-40	1-mk5	8.13	0.67	5.42	Shaft seal	2	7.00[d]	14.00	19.42
Fill system with flush medium		1-	1-mk5	8.13	1.00	8.13	Flushing oil	A=100gal[d] A/B=150gal B=300gal	1.30/gal[d]	130.00 196.00 390.00	138.13 204.13 398.13
Calibrate oil pressure switch		-30	1-mk5	8.13	0.50	4.07					4.07
TOTALS					2/17	17.62		2		730.00	763.86

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD Chrysier

Overhaul Requirement (LABOR)	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required (PARTS CONSUMED)	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($) (TOTAL)
T/D SUBSYSTEM											
INCINERATOR SUBSYSTEM											
Sludge Surge/Ejection Tank Models B & C											
Clean inside of tank and refinish		3-	1-mk3	6.84	3.00	20.52					20.5[illegible]
Clean level sensors (3)		-20	1-mk2	6.27	0.33	2.09					2.0[illegible]
Clean sight glass		-10	1-mk2	6.27	0.17	1.05					1.0[illegible]
Replace sight glass hose and clamps		-5	1-mk2	6.27	0.08	0.52	Hose and clamps	1 set	3.00[d]	3.00	3.5[illegible]
Clean and lubricate chain drive		-15	1-mk3	6.84	0.25	1.71					1.71
Replace stator and shaft seal in transfer pump		1-	1-mk5	8.13	1.00	8.13	Stator and shaft seal	1	80.00[d]	80.00	88.1[illegible]
Replace shaft seal and impeller in recirculation pump		-40	1-mk5	8.13	0.67	5.42	Impeller and shaft seal	1	75.00[m]	75.00	80.4[illegible]
Replace seats and stem seals in valves (3)		-30	1-mk3	6.84	0.50	3.42	Seats and seals	3	3.00[m]	9.00	12.[illegible]
Clean blower and housing		-20	1-mk2	6.27	0.33	2.09					2.[illegible]
TOTALS					6.33	44.95		6		167.00	211.[illegible]

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD Chrysler

	LABOR						PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs) *	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Incinerator Model A											
Replace fuel oil pump		-30	1-mk5	8.13	0.5	4.07	Fuel oil pump	1	10.00[d]	10.00	14.07
Clean fan and housing for combustion air blower		-20	1-mk2	6.27	0.33	1.09					1.09
Replace fuel nozzle		-5[d]	1-mk3	6.84	0.08	0.57	Fuel nozzle	1	2.00[d]	2.00	2.57
Replace fuel solenoid valves (2)		-20	1-mk3	6.84	0.33	2.28	Solenoid valve	2	10.00[d]	20.00	22.28
Replace thermocouple		-25[e]	1-em4	6.50	0.42	2.71	Thermocouple	1	52.06[b]	52.06	54.77
Replace overtemperature sensor		-15	1-em5	7.22	0.25	1.81	O.T. Sensor	1	165.24[d]	165.24	167.05
Replace incinerator pot		-5	1-mk2	6.27	0.08	0.52	Incinerator pot	1	200.00[d]	200.00	200.52
Calibrate temperature controller		-30	1-em6	9.73	0.50	4.87					4.87
TOTLAS					2.49	17.92		7		449.30	467.22
Incinerator Model C											
Replace fuel oil pump		-30	1-mk5	8.13	0.5	4.07	Pump	1	10.00[d]	10.00	14.07
Clean fan and housing for combustion air blower (2)		-30	1-mk2	6.27	0.5	3.14					3.14
Replace fuel nozzles (2)		-10[d]	1-mk3	6.84	0.17	1.14	Nozzles	2	2.00[d]	4.00	5.14
Replace fuel solenoid valves (3)		-30	1-mk3	6.84	0.5	3.42	Solenoid valve	3	10.00[d]	30.00	33.42
Replace thermocouple		-25[e]	1-em4	6.50	0.42	2.71	Thermocouple	1	52.06[b]	52.06	54.77
Replace overtemperature sensor		-15	1-em5	7.22	0.25	1.81	O. T. Sensor	1	165.24[b]	165.24	167.05
Replace incinerator pot		-5	2-mk2	6.27	0.17	1.05	Incinerator pot	1	400.00[d]	400.00	401.05
Calibrate temperature controller		-30	1-em6	9.73	0.5	4.87					4.87
TOTALS					3.01	22.21		9		661.30	683.51

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2-year overual interval is assumed for all subsystems.

GRUMMAN FLOW THROUGH SYSTEM

PRINCIPLES OF OPERATION

The Grumman MSD is a flow-through system, the only MSD of this type considered for this study. Sewage is treated in a two-stage process consisting of physical separation of liquids and solids by centrifugal force, followed by ozonation treatment. The effluent water is continually discharged overboard. The contaminants removed from the waste stream are dehydrated and burned in an incinerator. The MSD utilizes the standard, existing, full volume flush commodes and urinals, draining by gravity, but it can be adapted for use with reduced flush commodes and urinals.

The Grumman MSD was developed under a U.S. Coast Guard contract, but the version considered for this study eliminates two major items found to be of marginal value: the Hydrasieve and the disk centrifuge. This version also substitutes a Thiokol incinerator, due to operational difficulties with the Grumman unit.

It is an automatic system; although complex, it normally requires operator attention mainly for ash removal and filling of the fuel oil day tank. The only expendable that it uses other than fuel oil is ozone, which is made from air (drawn from the atmosphere) by one of the component equipments.

The Grumman MSD, as developed, is unique among the (commercial) MSD's considered for this study in another respect: it receives and treats combined black and gray water. (Although a CHT can also handle black and gray water, it is not a prepackaged commercially available MSD but instead is custom fitted to the vessel.) However, in applying this MSD to a cost-effectiveness analysis, other combinations of input streams are examined: full flush black water only, gray water only and gray water input with reduced flush black water going directly to the incinerator. In all cases, there is a continual discharge overboard of treated water during operation.

When the vessel is at pierside or beyond the restricted zone, the treatment subsystem can be shut off and bypassed. Wastes can be pumped off the vessel from the influent surge tank located at the end of the collection subsystem. The surge tank is normally used for smoothing out peak flows, since the treatment subsystem only accepts a continuous one gallon per minute input.

Only one size of Grumman MSD is available, designed for up to 20 men when receiving combined black and gray wastewaters, using full flush commodes and urinals. For larger capacities, multiple MSD's are required. With some combinations of waste stream inputs on larger vessels, more incinerators may be required than the number of decontamination/disinfection sections. The extra incinerators can be located adjoining or remote from the MSD.

A functional block diagram of the Grumman Flow Through System is presented in Figure 10.

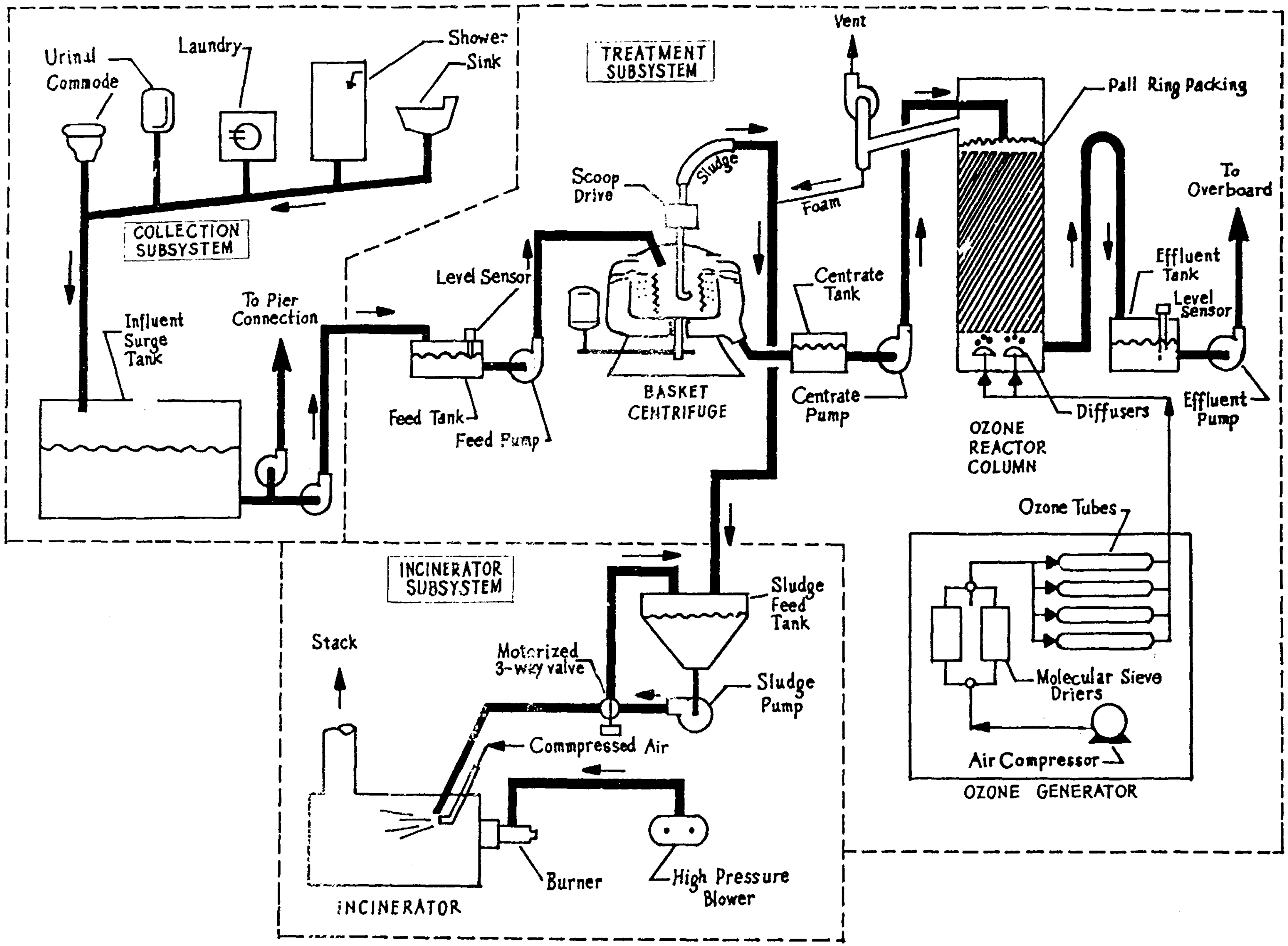

Figure 10

GRUMMAN FLOW THROUGH SYSTEM

SYSTEM DESCRIPTION

The description given below of the Grumman MSD (modified) is based upon its operation with combined black and gray wastewaters, for which it was originally designed. The MSD is divided into three subsystems: (1) collection, (2) treatment and (3) incineration. The latter two are often grouped under the general heading of treatment/disposal.

Collection Subsystem

The standard commodes, urinals, flushometers and the standard sloped, gravity-drained sewer pipes that exist on board are used as is. This assumes that the sewer lines have already been routed to a central location in the vessel for centralized treatment and/or disposal. On a larger vessel, multiple systems may be employed.

An influent surge tank and dual transfer pumps are the last components of the collection subsystem. The tank is custom designed for the particular installation and would be expected to hold about half a day's incoming sewage or combined black and gray wastewaters. Since the associated pumps transfer the sewage under pressure, the tank and pumps can be located remotely from the rest of the MSD. On larger vessels with multiple drainage systems, multiple influent surge tanks are required.

The transfer pump is a marine sewage pump whose detailed specifications are dependent upon the installation. It is a non-macerating centrifugal type. The two pumps are piped in parallel so that either pump can perform one of two functions, namely: sewage transfer to the treatment subsystem, or discharge to a pier connection or overboard. The collection subsystem is always operational, but while the vessel is at pierside or beyond restricted waters, the treatment and incineration subsystems can be shut down and bypassed. At these times, collected sewage is discharged off the vessel from the influent surge tank(s).

Treatment Subsystem

The treatment subsystem (1) receives the combined black and gray wastewaters, (2) removes particulate (suspended) solids from the water, (3) partially oxidizes dissolved contaminants, (4) disinfects the water, (5) discharges the treated water overboard, and (6) transfers the removed solids (sludge) to the incineration subsystem. The process components in the treatment subsystem, all mounted within a structural framework are:

- A feed tank
- A metering feed pump
- A basket centrifuge
- A centrate pump
- An ozone generator
- An ozone reactor
- An effluent tank
- An effluent pump

A. Feed Tank

The feed tank is a 30 gallon, stainless steel tank that receives batches of sewage from the influent surge tank whose transfer pump is controlled by the low and high liquid level sensors mounted in the top of the feed tank. The tank is a horizontal cylinder with a flattened top and mounting legs on the bottom. The level sensors are of the conductivity type, i.e., a small current flows through the sewage in contact with the bottom of the probe. This current activates a solid state relay which controls the motor contactor of the influent tank transfer pump. The low level sensor starts the pump and the high level sensor stops it. Transfer takes place in a minute or so.

B. Metering Feed Pump

The metering feed pump is a low speed, flexible vane pump (Jabsco type) that acts as a positive displacement pump. Each revolution of the impeller discharges a fixed volume of liquid. Except for minor fluid bypass around the vanes at moderate pressures, the pumping rate is proportional to rotational speed, regardless of discharge pressure (within limits). The motor is coupled to the pump through an adjustable speed reducer, whose setting can be changed while in operation. The specified flow rate is 1.0 gallon per minute (gpm).

C. Basket Centrifuge

The essential part of the basket centrifuge is a stainless steel bowl, rapidly spinning about a vertical centerline. The bowl has a flat bottom and a straight cylindrical sidewall, the top of which is curved inward. While it is spinning, centrifugal force will keep about one gallon of liquid in an annulus against the side wall. Incoming sewage that impinges on the bottom of the bowl, is spun outward, joins the liquid annulus, migrates upward through the annulus and then is flung radially outward when it overflows the top. The bowl spins at 3600 RPM, developing a minimum force on the liquid of 1400 times gravity (1400 G's). Particulate solids that settle out of the sewage, due to the difference in density from that of water, are retained against the sidewall where the centrifugal force of 2100 G's compacts them. The net overall action involving the centrifuge bowl is that sewage flows in at a steady rate of one gpm and overflows the top at the same rate, leaving nearly 95% of the particulate solids (by weight) accumulating on the sidewall. The removal of collected solids will be discussed below.

The bowl is connected to the upper end of a vertical spindle having V-belt pulleys on the bottom. The bowl is completely surrounded by a fiberglass shell and cover which captures the overflow from the bowl. A large port drains the chamber. Incoming sewage enters through an inlet in the removable cover. An electric motor, mounted vertically outside the chamber, drives the spindle by V-belts. The centrifuge spins continuously under normal conditions, whether sewage is flowing or not.

Removal of settled solids from the spinning bowl is accomplished periodically by a "stationary" scoop in the shape of a formed pipe. The tip of the scoop is always inside the bowl but normally does not touch the annulus of water at the wall of the bowl. The scoop mechanism, consisting of a gearmotor, chain drive, limit switches and scoop pivot, are mounted on the centrifuge chamber cover.

Upon a signal, a gearmotor drives the scoop tip outward in a generally radial direction until the tip is close to the wall and the pipe opening is facing the oncoming annulus of water. The momentum of the spinning water carries it into the scoop opening, up the pipe, and out of the centrifuge. Before this desludging operation, the incoming sewage is halted and resumes immediately after the operation has been completed. The desludging operation takes less than 20 seconds and is set to occur at 30 to 60 minute intervals, depending upon the sludge loading experience. Too frequent actuation burdens the disposal equipment with excess water (about a gallon for each desludging operation) and too infrequent actuation can result in a discharge line clogged with solids. Infrequent operation also reduces the efficiency of separation.

D. Centrate Pump

The centrate pump is a close-coupled centrifugal pump that takes the centrate (overflow from the centrifuge basket) and transfers it to the ozone reactor column. The pump body and impeller is penton plastic. The pump has double mechanical seals, suitable for use with particulate-contaminated fluids. In order to keep the mechanical shaft seals from overheating and wearing out prematurely because the centrate flow ceases periodically, a small flow (about one quarter gpm) of cooling water is continuously supplied to the pump. The maximum pumping rate is 1-1/4 gallons per minute.

E. Ozone Generator

The ozone generator is a repackaged and physically strengthened version of a commercial unit, capable of producing about one pound per day of ozone from ambient air. The generated ozone is used to (1) disinfect, (2) oxidize some of the contaminants, and (3) help remove fine particulates and dissolved solids from the sewage already processed in the centrifuge. Ozone is a moderately stable form of oxygen which, upon breaking up, yields an oxygen molecule and a very active oxygen atom. The single atom, in contact with bacteria and viruses, is capable of destroying them. The resultant disinfection is the primary reason for employing ozone in the MSD. Since air is the source of oxygen, no chemical expendables are required for disinfection of the effluent wastewater.

Ozone is produced by a high voltage corona discharge (no sparks) between electrodes, separated by a flowing stream of dry air. The ozone generator produces and controls the high voltage electricity and distributes it among four ozone generating tube assemblies, receiving parallel streams of dry air. The dry air is produced within the generator housing by an air compressor and two molecular sieve dryers. Molecular sieve pellets absorb moisture from the compressed air and, when saturated, are heated to drive the moisture off into a vented, bleed stream of air. One dryer dehumidifies the air stream while the other one is being thermally regenerated. Periodically, the dryer functions are reversed. Controls and instrumentation are included in the ozone generator for the high voltage electricity, compressed air, and cooling water for the ozone tube assemblies.

F. Ozone Reactor Column

The ozone reactor column is a stainless steel cylinder, 10 inches in diameter and about five feet high filled for most of its height with plastic "Pall rings". The Pall rings are short cylinders of patented design which enhance the contact of ozonated air bubbles with the sewage in the column. The column operates filled with sewage.

Incoming sewage enters at the top of the column, flows downward to a bottom exit, up an external pipe to a controlled height, and then overflows into the effluent tank. The height of the overflow point sets the height of the liquid in the column. Ozonated air under pressure enters the column at the bottom. It is broken up into small bubbles and distributed by four porous stainless steel diffusers. As the bubbles rise through the sewage, ozone diffuses into the liquid, where it disinfects and decolorizes the sewage stream and oxidizes some of the dissolved contaminants. Air, with some unreacted ozone, is drawn off the top of the column by an exhaust fan and is ducted away for discharge above the weatherdeck.

The ozonated air produces a foam on top of the liquid in the column which is allowed to overflow into the incinerator. The foam contains fine particulate contaminants and dissolved chemicals in greater concentration than in the sewage in the column. This helps to further purify the sewage to be discharged overboard.

G. Effluent Tank

The effluent tank is a rectangular, stainless steel tank with a maximum capacity of 10 gallons, which receives the overflow of treated sewage from the ozone reactor column. It serves as a feed tank for the effluent pump. High-low sensors control the on-off operation of the pump. The level sensors are of the conductance type, like those in the centrifuge feed tank. A solid state relay converts the sensor signals into signals which actuate the pump motor relay.

H. Effluent Pump

The effluent pump is a close-coupled centrifugal pump that withdraws treated sewage from the effluent tank and discharges it overboard. The pump body and impeller is penton plastic. This pump is similar to the centrate pump except that it has a single mechanical seal. Its capacity is approximately 7 gpm.

Incinerator Subsystem

The incinerator subsystem receives sludge from the centrifuge (scoop), and foam from the ozone reactor column, which it dehydrates and burns. Hot exhaust gases and ashes are the resulting products. The subsystem was designed by Thiokol Corporation and was adapted for use in the Grumman MSD as a substitute for Grumman's MSD incinerator. The component parts of the subsystem are:

- A sludge feed tank
- A recirculating sludge pump
- An incinerator, with high pressure burner head
- A high pressure blower

The incinerator subsystem has not yet been mated with the Grumman MSD for testing. Since an Operation and Maintenance Manual is not available, details of the subsystem may not be as extensive as for the rest of the MSD. Available sketches show that the Thiokol incinerator subsystem, using vessel service air, fits within the original framework of the Grumman MSD, except for a 20-inch wide control panel box, projecting 10 inches past the frame, and the incinerator burner head which extends a few inches beyond the frame. Space is available for this subsystem after the removal of the Grumman incinerator, hydrasieve and disk centrifuge.

The incinerator subsystem does not have its own support structure but is incorporated into the MSD structure. For some applications of the entire MSD system with varying types of wastewater feed on larger vessels, more incinerator subsystems than the number of treatment subsystems are required. In these cases, the components of the incinerator subsystem are mounted individually in any convenient arrangement.

A. Sludge Feed Tank

The sludge feed tank is fabricated of fiber glass reinforced plastic, shaped like an oblique pyramid with extended rectangular sides. One side flat for hanging on a wall. It will hold about 20 gallons. The influent connection, the recirculating sludge connection and the vent are at the top and the bottom of the hopper. Recirculation of sludge keeps the contents aerated and the solids in suspension.

B. Recirculating Sludge Pump

The sludge pump is a positive displacement unit that recirculates centrifuge sludge and reactor foam, from the feed tank through a three-way motor driven valve, and back to the feed bank. It is driven by a quarter horsepower motor. Upon actuation of the three-way valve, the circulating sludge is diverted to the incinerator.

C. Incinerator

The incinerator is a horizontal rectangular chamber with a high pressure burner firing in line with the long horizontal centerline. A high pressure burner, using air at two psig, was chosen to alleviate flameout problems due to fluctuations in compartment atmospheric pressure. The sludge enters the combustion chamber via a tube which drops the sludge into a horizontally directed stream of compressed air. The air atomizes the sludge, which commingles with the flame. A vertical stack rising at the end opposite the burner, exhausts the combustion gases. Ash removal requires opening the hinged end on which the burner is mounted. Controls include a flame (failure) detector.

D. High Pressure Blower

The high pressure blower is a twin shaft, lobed blower of the Rootes type, and is belt driven. It supplies 80-100 SCFM at two psig to the incinerator burner head. It is mounted on the shelf of the MSD structure that formerly held the disk centrifuge.

GRUMMAN

COMPONENT PHYSICAL CHARACTERISTICS

Component	Weight (lbs)		Volume	Dimensions (inches)		
	Dry	Filled	(cu ft)	Height	Length	Width
Main Structure		4,380	236	85	63 *	76 †

* Plus 10 inches for control panel, 20 in W x 30

† Plus projection of incinerator nozzle.

GRUMMAN

INTERCONNECTING PIPE SIZES

From	To	Size (inches)
Influent Surge Tank Pump	Feed Tank	2 NPT
Effluent Pump	Riser	3/4 to 1 NPT
Fuel Oil Pump	Incinerator	1/4 NPT
Incinerator	Atmosphere	7-1/2 ID x 14 OD* Insulated stack

* Stack may vary in size depending upon installation.

GRUMMAN

COMPONENT VESSEL RESOURCE REQUIREMENTS

Component	HP	Watts	Volts	Phase	Hertz	Amp.	Ambient Air SCFM	Compressed Air SCFM	Fuel Oil gph	Cooling Water gpm
GAC System			120/208	3	60					
Basket Centrifuge	2		208	3	60					
Scoop Motor		115	120	1	60					
Ozone Generator		2100	120/208	3	60		2			1
Effluent Pump	1/3		115	1	60					
Centrate Pump	1/8		115	1	60					1/4
Blower	2		208	3	60					
		Opt.	460							
Incinerator		Opt.	460	3	60		100	12	1-1/2	
Fuel Oil Pump	est. 1/4		120	1	60					
Sludge Pump	1-1/2		208	3	60					
Controls (GAC)		est. 200	120	1	60					
Controls (Thiokol)		est. 200	120	1	60					

MSD EFFECTIVENESS ATTRIBUTE DATA

I - ADAPTABILITY FOR

M/E SHIPBOARD INSTALLATION

MSD GRUMMAN

Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin	Treat./Disposal Subsystem: With Holding Tank
12	MSD materials disallowed or not recommended.(1) (a) No disallowed or not recommended materials present(2) in MSD subsystem. (b) Some disallowed or not recommended materials present in MSD subsystem, but resultant problems can be solved or compensated for. (c) Presence of disallowed or not recommended materials in MSD subsystem presents problems with no feasible solutions.	a	a	a
13	Extent of additional support systems or equipment required to accommodate MSD(3) Identification of support system requirements for MSD subsystem.		(7)(8)	(7)(9)
21	Extent of fixture modifications required for MSD installation. (a) MSD uses standard commodes and urinals. (b) MSD uses non-standard commodes and special equipment is associated with the urinals. (c) MSD uses non-standard commodes, special equipment is associated with the urinals and each fixture has additional hook-up requirements.	a	N/A	
22	Extent of flush medium supply modifications required for MSD installation. (a) MSD uses sea water for flushing fixtures. (b) MSD uses fresh water for flushing fixtures. (c) MSD uses a non-aqueous for flushing fixtures.	a	N/A	
231	Hookup requirements(4) for MSD Collection/Transport subsystem installation. (a) MSD uses standard Collection/Transport subsystem. (b) MSD uses recirculating Collection/Transport subsystem.(5) (c) MSD uses non-standard and centralized Collection/Transport subsystem. (d) MSD uses non-standard and non-centralized Collection/Transport subsystem.(6)	(10) a	N/A	

(1) As specified in subchapters J&F of Merchant Marine Code and C.G. MSD regulations.
(2) For purposes of this study, C.G. directs choice (a) for all MSDs.
(3) Examples:
- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(4) Drain piping; electric cables for connecting commodes, M/T pump and control panel, compressed air, etc.
(5) In existing gravity drain system.
(6) Includes conversion from reduced flush vacuum collection to a standard gravity drain system with or without recirculation.
(7) Ozone detector.
(8) Firefighting equipment; ventilation
(9) Bilge Alarm for sludge holding tank, if required.
(10) Influent surge tank required.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GRUMMAN   Sheet 2 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	INSTALLATION Attribute Data: Treat./Disposal Subsystem — With Incin	INSTALLATION Attribute Data: Treat./Disposal Subsystem — With Holding Tank
232	Routing flexibility for drain piping modifications(1) associated with MSD Collection/Transport subsystem installation(2) (a) Routing of MSD Collection/Transport piping is highly flexible. (b) Routing of MSD Collection/Transport piping is moderately flexible with some restrictions. (c) Routing of MSD Collection/Transport piping is highly inflexible.	(3) c	N/A	
233	Space requirements for MSD Collection/Transport subsystem installation (a) Space required for MSD Collection/Transport subsystem is little or no greater than that required for standard Collection/Transport subsystem. (b) Space required for MSD Collection/Transport subsystem is moderately increased over that required for standard Collection/Transport subsystem. (c) Space required for MSD Collection/Transport subsystem is much greater than that required for standard Collection/Transport subsystem.	(4) b	N/A	
234	Modularity of MSD Collection/Transport subsystem (as it affects installation). (a) Collection/Transport subsystem is highly modular. (b) There is an option for some decentralization of the MSD Collection/ Transport subsystem. (c) The MSD Collection/Transport subsystem is highly centralized.	a	N/A	
235	Vent requirements for MSD Collection/Transport subsystem installation. (a) MSD Collection/Transport subsystem requires no vents. (b) MSD Collection/Transport subsystem requires few vents. (c) MSD Collection/Transport subsystem requires many vents.	(5) c	N/A	

(1) Of the three relevant categories of routing lines (piping, ventilation, electrical), piping is the most important for assessing ease of MSD installation.

(2) Notes:

- With gravity drainage, lines must always slope downward and require venting.
- Smaller size lines are inherently more flexible.
- With pump or vacuum Collection/Transport subsystem, sharp bends, risers and long runs can be accommodated in piping.

(3) Gravity drainage through standard drain lines. Answer applies to new installation only; if standard drain lines already installed in vessel, then (a) applies.

(4) Influent surge tank and associated pumps occupy additional space. Space taken is proportional to number of men subsystem serves.

@ 40.5 gals/man/day; want half day's supply: $\left[\left(\frac{40.5}{2}\right)/7.4\right] = 2.7$

2.7 cu. ft + 20% overage = 3.25 cu ft/man

(5) As for standard drain lines (i.e., all traps must be vented). In addition, vent required for influent surge tank. Answer applies to new installation only; if standard drain lines already installed in vessel than (b) applies.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GRUMMAN Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	Attribute Data		
		Collect./Transp. Subsystem	Treat./Disposal Subsystem With Incin.	Treat./Disposal Subsystem With Holding Tank
242	Hookup requirements(1) for MSD waste Treatment/Disposal subsystem installation (a) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are minimal. (b) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are moderate. (c) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are extensive.	N/A	(5, 6) b	(5) b
243	Degree of modularity of MSD waste Treatment/Disposal subsystems (as it affects installation)(2) (a) MSD Treatment/Disposal subsystem is highly modular. (b) There is an option for some decentralization of the MSD Treatment/ Disposal subsystem. (c) MSD Treatment/Disposal subsystem is highly centralized.	N/A	(7, 8) c	(7) c
244	Vent requirements for MSD waste Treatment/Disposal subsystem installation(3) (a) No vents are required for MSD Treatment/Disposal subsystem. (b) Vents are required for MSD Treatment/Disposal subsystem.	N/A	(9) b	(9, 10) b
245	Exhaust stack requirements for MSD waste Treatment/Disposal subsystem installation.(4) (a) Exhaust stack not required for MSD Treatment/Disposal subsystem. (b) Small exhaust stack required for MSD Treatment/Disposal subsystem. (c) Large exhaust stack required for MSD Treatment/Disposal subsystem.	N/A	c	a

(1) Piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote panels, etc.; ducting for ventilation, etc.
(2) Decentralization of components may require additional hookups and piping runs.
(3) Vents that are only internal to the compartment in which subsystem is located are not considered here.
(4) Notes:
- Electric incinerator requires small (2") exhaust.
- Fuel incinerator requires large (10") exhaust.

(5) Compressed air; electric power, electrical controls, cooling water; air for ozone generator taken from atmosphere.

(6) Fuel required. Electrical supply for the T/D subsystem is usually together in one package; more electrical connections near surge tank.

(7) All components (of waste treatment portion) mounted within a structural framework.

(8) Incinerator part of treatment subsystem package; however, may be separated and mounted in any convenient location.

(9) For ozone reactor column.

(10) Sludge holding tank requires vent.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD GRUMMAN — Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin. (2, 3)	Treat./Disposal Subsystem: With Holding Tank (2, 4)
25	Ease of installing MSD support equipment[1]			
	Extent of additional support equipment required to accommodate MSD			
	(a) No additional support equipment required for MSD subsystem.	a		
	(b) Some additional support equipment required for MSD subsystem.		b	b
	(c) Much additional support equipment required for MSD subsystem.			

(1) Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(2) Ozone detector (must be near ozone reactor and generator).

(3) Firefighting equipment; ventilation.

(4) Bilge alarm for sludge holding tank, if required.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GRUMMAN

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem — With Incin.	Attribute Data: Treat./Disposal Subsystem — With Holding Tank
311	Effect of peak hydraulic loads in black(1) water stream on MSD performance(2) (a) No significant effect of black water peaks on MSD subsystem performance. (b) Effect of black water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water peaks.	(4) a	(5, 6) c	(5) c
312	Effect of peak hydraulic loads in gray(1) water stream on MSD performance (2) (a) No significant effect of gray water peaks on MSD subsystem performance. (b) Effect of gray water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water peaks, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water peaks.	N/A C/T for black water only	(5, 6) c	(5) c
321	Effect of low flow conditions/long idle times in black water stream on MSD performance(3) (a) No significant effect of black water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of black water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water low flow conditions/ long idle times.	(7) b	(8, 9) b	(8) b

(1) Includes instantaneous, hourly and daily loads.
(2) Peak load handling ability depends on C/T subsystem. The ability of an MSD which employs an influent surge tank to handle peaks usually depends almost entirely on the sizing of this tank.
(3) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(4) If influent surge tank is properly sized - sizing of tank is vessel dependent. If installation will not accommodate required tank size, (b) or (c) will apply.
(5) The subsystem must be fed at a steady rate and in that sense, has no peak load ability.
(6) Incinerator fed by sludge feed tank which has a very limited peak capability (25 gals. capacity).
(7) Possibly a problem if influent surge tank is left unaerated. This could cause odors - less of a problem for gray water than for black water.
(8) . If idle time is long, basket centrifuge sludge might get hard; may require disassembly for cleaning.
. Ozone column and generator work during low flow and idle times, so there is no problem with them.
(9) Batch operation; no problem with low flow during long idle times.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GRUMMAN Sheet 2 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem — With Incin.	Treat./Disposal Subsystem — With Holding Tank
322	Effect of low flow conditions/long idle times in gray water stream on MSD performance(1) (a) No significant effect of gray water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of gray water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water low flow conditions/long idle times, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water low flow conditions/long idle times.	N/A C/T for black water only	(4, 5) b	(4) b
331	Ability of black water portion of MSD to handle additional personnel (on a long-term basis)(2) (a) MSD black water subsystem will handle additional personnel with little or no degradation in performance. (b) MSD black water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance. (c) MSD black water subsystem will not handle additional personnel	a	(6, 7) a	(6, 8) b
332	Ability of gray water portion of MSD to handle additional personnel (on a long-term basis)(3) (a) MSD gray water subsystem will handle additional personnel with little or no degradation in performance. (b) MSD gray water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance. (c) MSD gray water subsystem will not handle additional personnel.	N/A C/T for black water only	(6, 7) a	(6, 8) b

(1) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(2) Resulting in long-term increase in average black water stream hydraulic loading. The ability of an MSD which employs a black water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(3) Resulting in long-term increase in average gray water stream hydraulic loading. The ability of an MSD which employs a gray water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(4) . If idle time is long, basket centrifuge sludge might get hard; may require disassembly for cleaning.
. Ozone column and generator work during low flow idle times, so there is no problem with them.

(5) Batch operation; no problem with low flow during long idle times

(6) 20 man Grumman could handle up to 40 people (handles 1.25 gals/min; with 40 people will run 21.6 hrs/day).

(7) Incinerator limits number of men which can be handled (full flush black and gray water combined → 40.5 gals per capita day); with 40 men, incinerator will run 22.5 hrs/day since incinerator can take 6 gals/hr.

(8) . Cannot handle additional personnel and meet maximum holding time requirements.
. May take additional personnel for short time (tank sized in man days) if required tank capacity is accommodated by installation.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GRUMMAN Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem — With Incin.	Attribute Data: Treat./Disposal Subsystem — With Holding Tank
41	Ability of black water handling portion of MSD to operate for sustained time periods			
	(a) MSD black water subsystem can operate for indefinite period of time if no components fail. (1)	a	a	
	(b) MSD black water subsystem can operate for only limited period of time, even if no components fail. (2)			b
42	Ability of gray water handling portion of MSD to operate for sustained time period			
	(a) MSD gray water subsystem can operate for indefinite period of time if no components fail. (1)	N/A C/T for black water only	a	
	(b) MSD gray water subsystem can operate for only limited period of time, even if no components fail. (2)			b
51	Ability of MSD to handle ground garbage in black water stream		(4)	
	(a) MSD black water subsystem will handle ground garbage in black water stream on a long-term basis.	a		a
	(b) MSD black water subsystem will handle ground garbage in black water stream on at least a short-term basis.		b	
	(c) MSD black water subsystem will not handle ground garbage in black water stream.			
52	Ability of MSD to handle foreign materials/objects (3) in black water stream	(5)	(6)	(6)
	(a) MSD subsystem will handle foreign materials/objects in black water stream on a long-term basis.	a	a	a
	(b) MSD subsystem will handle foreign materials/objects in black water stream on at least a short-term basis.			
	(c) MSD subsystem will not handle foreign materials/objects in black water stream.			

(1) Applies to a T/D subsystem with an incinerator.
(2) Applies to a T/D subsystem without an incinerator.
(3) Examples:
- Long, narrow objects (pens, pencils, toothpicks, etc.)
- Small hard objects (nut shells, pull tab from a flip top can, bottle caps, paper clips, coins, nuts/bolts/screws/nails, cuff links, etc.)
- Large soft objects (paper towels, newspaper page, stiff and shiny magazine page, strings from a floor mop, rag, tampons and sanitary napkins, etc.)

(4) Particles in garbage (pieces of bone, melon pits, pieces of meat, etc.) may clog feed line or spray nozzle in incinerator necessitating shutdown or cleanout.
(5) A rag could plug up pumps.
(6) Large objects or rags probably won't get through influent surge and feed tanks.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD GRUMMAN Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem — With Incin.	Attribute Data: Treat./Disposal Subsystem — With Holding Tank
53	Ability of MSD to handle detergents/surfactants in black water stream on a long-term basis. (a) MSD subsystem will handle detergents/surfactants in black water stream on a long-term basis. (b) MSD subsystem will handle detergents/surfactants in black water stream on at least a short-term basis. (c) MSD subsystem will not handle detergents/surfactants in black water stream.	a	a	a
54	Ability of MSD to handle toxic materials in black water stream (a) MSD subsystem will handle toxic materials in black water stream on a long-term basis. (b) MSD subsystem will handle toxic materials in black water stream on at least a short-term basis. (c) MSD subsystem will handle toxic materials in black water stream.	a	a	a
61	Ability of MSD secondary emissions to meet applicable standards for the discharge of air pollutants (a) No possibility of discharge of significant air pollution from MSD subsystem. (b) MSD subsystem will meet standards for air pollutants under normal operating conditions. (c) MSD subsystem will meet standards for air pollutants under normal operating conditions and there is a strong possibility of non-conformance to standards under unusual operating conditions.	a	(1, 2) b	(1) a
62	Ability of MSD secondary emissions to meet applicable standards for disposal of oil-contaminated residues at sea (a) MSD subsystem has no potential for producing oil-contaminated residues at sea. (b) MSD subsystem has a potential for producing oil-contaminated residues at sea.	a	(3) b	(3) b
71	Performance risk for black water handling portion of MSD (a) MSD black water subsystem has a history of fair or better test results. (b) MSD black water subsystem has a history of poor test results. (c) No test results are available for the MSD black water subsystem.	a	(4) b	(4) b
72	Performance risk for gray water water handling portion of MSD (a) MSD gray water subsystem has a history of fair or better test results. (b) MSD gray water subsystem has a history of poor test results. (c) No test results are available for the MSD gray water subsystem.	N/A C/T for black water only	(4) b	(4) b

(1) Continuous emission of ozone - no standards against it.

(2) Under extraordinary or improper conditions, incinerator may exhaust pollutants.

(3) . If discharge overboard from influent surge tank. While accepting galley wastes, may discharge (biodegradable) oils.
. If ozone reactor not operating properly, may discharge vegetable oil in effluent.

(4) Poor test results with and without incinerator; worse with incinerator.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD GRUMMAN   Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
11	Degree of automation for MSD operation (1)			
	(a) MSD subsystem is almost fully automatic.	a	(4)	a (5)
	(b) MSD subsystem is semi-automatic; requires infrequent operator attention.		b	
	(c) MSD subsystem is semi-automatic; requires a moderate degree of operator attention.			
	(d) MSD subsystem is semi-automatic; requires frequent operator attention.			
	(e) MSD subsystem is operated manually.			
12	Ease of disposal of MSD residue(s) (1)(2)			(6)
	(a) MSD subsystem has no residues, or disposal of residues from MSD subsystem is very convenient.	a		
	(b) Disposal of residues from MSD subsystem is moderately convenient.		b	b
	(c) Disposal of residues from MSD subsystem is inconvenient.			
14	Likelihood of violating effluent standards because of procedural errors in MSD operation. (3)		(7, 8)	(7)
	(a) There is virtually no chance of violating effluent standards because of procedural errors in MSD operation.	a		
	(b) There is a low likelihood of violating effluent standards because of procedural errors in MSD operation.			
	(c) There is a fair to moderate chance of violating effluent standards because of procedural errors in MSD operation.			c
	(d) There is a high likelihood of violating effluent standards because of procedural errors in MSD operation.		d	
23	Skill level requirements for operator of MSD			
	MSD subsystem complexity ranking from 1 to 5	2	5	5
24	Training requirements for operator of MSD			
	MSD subsystem complexity ranking from 1 to 5	2	5	5

(1) Residue is any by-product of normal MSD operation, disposal of which is regular operating task. Examples are ash produced by an incinerator, seal water used by vacuum pumps, wastewater or sludge held in a tank, evaporator residue, etc.

(2) Length of time required for disposal is the main factor considered; other factors are ease of access of area of MSD containing the residue, amount of residue to be disposed of, and ease of storing residue on board or taking it off vessel, as appropriate.

(3) By dumping overboard effluent which doesn't meet standards, flush oil, evaporator residue, air pollutants from incinerator, etc.

(4) Ash removal not more frequently than every 3 days. (May have same amount of ash with 30 men as with 20 men.)

(5) Operator attention required to start up ozone generator.

(6) If system used W/CHT rather than incinerator, the inconvenience of ash removal is exchanged for CHT pump and rinse out.

(7) If ozone generator is not generating ozone (only blowing air) can violate effluent standards.

(8) Improper operation of incinerator may result in discharge of air pollutants.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD GRUMMAN

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
25	Effect of MSD operation on vessel work routines/schedules (a) MSD operation has minimal or no effect on work routines/schedules. (1) (b) Effect of MSD operation on work routines/schedules is more than minimal (i.e., is moderate or extensive).	a	a	a
32	Availability of specialized or unique consumables/expendables required for MSD operation (a) No specialized or unique consumables or expendables required for MSD subsystem operation. (b) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from ship's inventory. (c) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from Federal Stock System. (d) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from a commercial source.	a	(5) d	a
33	Operating requirements for special or unique MSD support equipment (a) No special or unique support equipment required by MSD subsystem. (b) Some special or unique support equipment required by MSD subsystem; equipment requires only minimal and infrequent attention (2) to keep operational. (3) (c) Some special or unique support equipment required by MSD subsystem; requires more than infrequent attention to keep operational. (4)	a	(6, 8) b	(7, 8) b

(1) By C. G. direction, (a) applies to all MSDs considered in this study.

(2) No more frequently than weekly with a duration not greater than 10 minutes; or more frequently than semi-annually with a duration of 2 hours.

(3) E.g., firefighting equipment, special transformers, ozone detector, bilge alarm.

(4) E.g., compressor installed to support MSD operation.

(5) Incinerator related items (pot) obtainable from manufacturer only.

(6) Fire fighting equipment; ventilation.

(7) Bilge alarm may be required.

(8) Ozone detector.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GRUMMAN

Sheet 1 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
11	Hazard of contact with/spillage of toxic/dangerous substances(1) due to MSD inherent design	(2)	(3)	(3)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - .. The following pathogens may be transmitted though sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (form hands).

(2) Only by contact with sewage in commodes.

(3) . Centrifuge is fully enclosed - no change of contact with sewage.
. If end of vent line for ozone generator is on deck and wind is blowing in direction of personnel, ozone may irritate mucous membranes of respiratory tract.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GRUMMAN Sheet 2 of 6

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
12	Hazard of contact due with/spillage of toxic/dangerous substances(1) due to procedural error/equipment failures of MSD	(2)	(3, 4)	(4, 5)
	L - Likelihood of hazard			
	(a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	c	c
	S - Severity of hazard			
	(a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	a	a
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - .. The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

(2) If commode breaks or if there is leakage from influent surge tanks and pumps.

(3) . Sludge feed tank overflow.
. Wet ash from incinerator, if incinerator does not burn input completely.
. Leakage of fumes from incinerator possible.

(4) . Since equipment is complex, it may be reassembled incorrectly more readily than less complex equipment.
. Ozone generator may malfunction and pour ozone into the air.

(5) Hydrogen sulfide may be generated in sludge holding tank.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GRUMMAN

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem — With Incin.	SAFETY Attribute Data: Treat./Disposal Subsystem — With Holding Tank
21	Hazard of explosive potential for operator/maintainer due to inherent MSD design		(1)	
	L - Likelihood of hazard			
	(a) No chance	a		a
	(b) Highly unlikely		b	
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a		a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b	
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a		a
	(b) Hazardous situation is difficult to correct.		b	
	(c) Hazardous situation cannot be corrected.			
22	Hazard of explosive potential for operator/maintainer due to procedural errors/ equipment failures of MSD	(2)	(1)	
	L - Likelihood of hazard			
	(a) No chance			a
	(b) Highly unlikely	b		
	(c) Fair to even chance		c	
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.			a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.	b		
	(c) Results in severe injury or death.		c	
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.			a
	(b) Hazardous situation is difficult to correct.	b	b	
	(c) Hazardous situation cannot be corrected.			

(1) Incinerator uses fuel oil.

(2) If influent surge tank goes septic and methane gas is generated.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GRUMMAN

Sheet 4 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
31	Hazard of fire ignition potential[(1)] due to inherent MSD design			
	L - Likelihood of hazard		(2, 3)	(2)
	(a) No chance	a		a
	(b) Highly unlikely		b	
	(c) Fair to even chance			
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a		a
	(b) Results in injury of low to moderate severity requiring first air or limited medical treatment.		b	
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a		a
	(b) Hazardous situation is difficult to correct.		b	
	(c) Hazardous situation cannot be corrected.			
32	Hazard of fire ignition potential[(1)] due to procedural errors/equipment failure of MSD	(4)	(3, 5)	(5)
	L - Likelihood of hazard			
	(a) No chance			
	(b) Highly unlikely	b		b
	(c) Fair to even chance		c	
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury			a
	(b) Results in injury of low to moderate severity requiring first aid or limited	b		
	(c) Results in severe injury or death.		c	
	C - Hazard correction			
	(a) Hazardous situtation can be easily corrected.			a
	(b) Hazardous situation is difficult to correct.	b	b	
	(c) Hazardous situation cannot be corrected.			

(1) Oil used for flushing is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

(2) At low concentrations, ozone not combustible.

(3) Due to incinerator use of fuel oil.

(4) If influent surge tank goes septic and methane gas is generated.

(5) . Motor may overheat

. Electrical fire.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GRUMMAN | Sheet 5 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin. (3)	Treat./Disposal Subsystem: With Holding Tank (3)
4	**Hazard of electrical shock potential[1] for operator/maintainer of MSD**			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	b	b
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a
51	Physical hazards associated with MSD due to sharp edges[2]			
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a	a

(1) Electric shock may result in severe burns and/or death; In addition, reaction to electric shock may casue affected individual to be thrown aside, possibly subjecting him to severe impact injuries and/or contact with sharge edges/hot surfaces.

(2) Combined effect of injury due to sharp edges/points and sewage contamination may introduce harmful pathogens into the bloodstream of an affected individual.

(3) Interlock on ozone generator door may not operate.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD GRUMMAN

Sheet 6 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
52	Physical hazards associated with MSD due to hot surfaces			
	L - Likelihood of hazard		(1)	(1)
	(a) No chance	a		
	(b) Highly unlikely			b
	(c) Fair to even chance		c	
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.	a		
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.		b	b
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			
53	Physical hazard for maintainer of MSD due to rotating machinery	(2)	(3, 4)	(4)
	L - Likelihood of hazard			
	(a) No chance			
	(b) Highly unlikely	b		b
	(c) Fair to even chance		c	
	(d) Highly likely			
	S - Severity of hazard			
	(a) No resultant injury.			
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment	b	b	b
	(c) Results in severe injury or death.			
	C - Hazard correction			
	(a) Hazardous situation can be easily corrected.	a	a	a
	(b) Hazardous situation is difficult to correct.			
	(c) Hazardous situation cannot be corrected.			

(1) Molecular sieve dryer has heaters and has safety interlock on its door. If careless, could touch hot surface.
(2) In servicing pumps.
(3) High pressure blower is belt driven.
(4) Centrifuge enclosed, scoop is slow, motor is enclosed; smooth inside.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD GRUMMAN

Sheet 1 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	HABITABILITY Attribute Data: Treat./Disposal Subsystem — With Incin.	HABITABILITY Attribute Data: Treat./Disposal Subsystem — With Holding Tank
11	Habitability problems(1) associated with bacterial contamination due to MSD inherent design (a) There is no bacterial contamination habitability problem due to MSD subsystem inherent design features. (b) There is a bacterial contamination habitability problem due to MSD subsystem inherent design features.	a	b	b
12	Habitability problems(1) associated with bacterial contamination due to procedural errors/equipment failures of MSD(2) (a) A bacterial contamination problem due to procedural errors/equipment failures of MSD subsystem is highly unlikely. (b) Procedural errors/equipment failures of MSD subsystem are likely to cause a bacterial contamination problem	b	b	b
21	MSD fixture comfort (a) Commodes and urinals are comfortable and easy to use even under ship's motion. (b) Commodes and urinals are not comfortable and easy to use under ship's motion.	a	N/A	
22	Flushing procedure requirements for MSD fixture (a) There are no "non-standard" requirements for flushing. (b) There are "non-standard" requirements for flushing.	a	N/A	
23	Waste retention in MSD commode bowl (a) The amount of waste that remains in the bowl after flushing is less than that remaining after flushing a standard full water flushed fixture. (b) The amount of waste that remains in the bowl after flushing is the same as that remaining after flushing a standard full water flushed fixture. (c) The amount of waste that remains in the bowl after flushing is more than that remaining after flushing a standard full water flushed fixture.	b	N/A	

(1) As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

(2) A vacuum waste collection subsystem is less likely to expose personnel to sewage in case of a line break than a pressurized waste collection subsystem; fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD GRUMMAN

Sheet 2 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem	
			With Incin.	With Holding Tank
24	Likelihood of user contact[1] with MSD fixture flushing medium (a) User is unlikely to come into contact with flushing medium. (b) User is more likely to come into contact with flushing medium than with standard water flushed fixture.	a	N/A	
25	Appearance of MSD fixture flushing medium (a) The color and general appearance of the flushing medium is as acceptable as clear water. (b) The color and general appearance of the flushing medium are acceptable, but clear water is preferable. (c) The color and general appearance of the flushing medium are not acceptable.	a	N/A	
26	Noise produced in flushing MSD fixtures (a) The noise produced in flushing fixtures is less than that of a standard commode/urinal. (b) The noise produced in flushing fixtures is the same as that of a standard commode/urinal. (c) The noise produced in flushing fixtures is greater than that of a standard commode/urinal.	b	N/A	
31	Odors produced as a result of inherent MSD design (a) The MSD subsystem produces no odor as a result of inherent design. (b) The MSD subsystem produces a noticeable odor as a result of inherent design.	a	a (3)	a (3)
32	Odors produced as a result of procedural errors/equipment failures of MSD (a) The MSD subsystem produces no odor as a result of procedural errors/equipment failures. (b) The MSD subsystem produces a noticeable odor as a result of procedural errors/equipment failures.	(4) b	(5, 6) b	(6) b
41	Heat generation for nearby personnel[2] due to inherent MSD design (a) As a result of inherent design features, the MSD subsystem does not generate enough heat to render its vicinity hotter than most shipboard areas containing machinery. (b) As a result of inherent design features, the MSD subsystem does generate enough heat to render its vicinity hotter than most shipboard areas containing machinery.	a	b	a

(1) Due to flushing medium composition, fixture design, motion of vessel (which may cause splatter, splashing, or spillage of flushing medium).

(2) For operator/maintainer/adjacent berthing and working areas.

(3) . Even with ozone
. Odor milder when treating gray water only.

(4) . Odor milder when treating gray water only.
. In the event that leakage occurs.

(5) Due to fuel oil leakage; leakage of sewage; wet ash in incinerator

(6) If leakage and ozone odor occur simultaneously, there may not be any detectable odor.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V- HABITABILITY

MSD GRUMMAN

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
4	Heat generation for nearby personnel(1) due to procedural errors/equipment failures of MSD. (a) The MSD subsystem does not generate enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery. (b) The MSD subsystem does generation enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery.	a	b	a(3)
5	Noise level for personnel in vicinity of MSD(1) NI = Noise Index (a) The MSD subsystem is silent or nearly silent. (b) Noise level of MSD subsystem is approximately equal to background noise level of vessel. (c) The MSD subsystem is very loud, produces constant noise, drowns out vessel background noise in immediate area of the system; must shout to be heard.	(4) b	(5, 6) b	(6) b
6	Vibration levels for nearby personnel(1) produced by MSD machinery VI = Vibration Index (a) MSD subsystem produces little or no perceptible vibration in addition to background level on vessel. (b) MSD subsystem produces perceptible vibration, but similar to vessel background. (c) MSD subsystem produces abnormal or disturbing intensity and/or frequency of vibration.	a	(7) b	(7) b
7	Effect of MSD on user housekeeping routines (restrictions on user imposed by subsystem(2)). (a) Subsystem characteristics do not impose restrictions on user. (b) Subsystem characteristics impose restrictions on user.	a	a	a

(1) For operator/maintainer/adjacent berth and working areas.
(2) E.g. . Must use water-soluble toilet paper which is not as comfortable as usual toilet paper.
. Must use special bowl cleaner which is less effective than usual cleaner
. Cannot dump detergents down galley sink; must store and off-load at shore.

(3) Even with heater for molecular sieve.
(4) Due to pumps.
(5) High pressure blower makes some noise (83-84 dbA at 3ft.).
(6) . Scoop makes some noise (periodically, for 10 seconds at a time).
. Compressor in ozone generator not loud.
(7) Centrifuge vibrates somewhat.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VI - RELIABILITY

MSD GRUMMAN   Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	RELIABILITY Characteristics	RELIABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
21	MSD complexity Complexity index of MSD subsystem based on a complexity ranking from 1 to 5.	2	5	5
23	Extent of MSD equipment/component redundancy(1) (a) There is some significant redundancy in the MSD subsystem's major components. (b) There is no significant redundancy in the MSD subsystem's major components.	(6) a	(7) b	(7) a
24	Degree of equipment failure independence(2) (a) There is a high degree of equipment failure independence in MSD subsystem. (b) There is a moderate degree of MSD equipment failure independence in MSD subsystem. (c) There is a low degree of equipment failure independence in MSD subsystem.	a	(8, 9) c	(9) c
25	Adequacy of MSD equipment ratings (a) Most MSD subsystem equipments are overrated. (b) Some MSD subsystem equipment ratings are nominal, some are overrated. (c) Some MSD subsystem equipments are underrated, some are nominally rated. (d) Most MSD subsystem equipments are underrated.	(10) b	(11, 12) c	(12) c
26	Provisions for fault actuated cut-off mechanisms(3) for MSD protection (a) There are many fault actuated mechanisms in MSD subsystem, or they are not required.(4) (b) There are some fault actuated mechanisms in MSD subsystem. (c) There are no or almost no fault actuated mechanisms in MSD subsystem.	a	(13, 14) b	(14) b
3	Reliability risk for MSD(5) (a) MSD subsystem has a history of fair or better test results. (b) MSD subsystem has a history of poor test results. (c) No test results are available for MSD subsystem.	a	b	b

(1) Any redundancy in electronic circuitry is not considered.
(2) i.e., failure of one item will not result in failure of major component or subsystem.
(3) Includes mechanisms to: (i) alert operator/maintainer to high stress or abnormal conditions that will result in failure, and/or (ii) to correct those conditions or turn off equipment.
(4) E.g., standard commodes and urinals in a gravity drain sewage collection subsystem do not require fault actuated cut-off mechanisms.
(5) E.g., innovative design, experience.
(6) Fixtures, transfer pumps
(7) . Ozone diffusers are all used, but could get by with little degredation of performance, on fewer diffusers.
. There are 4 ozone tubes, all used, but could get by on fewer, with degraded performance.

Footnotes continued on following page.

(8) . If the high pressure blower fails, the incinerator cannot operate.
. If motorized 3-way valve fails, may get just a spill from sludge feed tank. If valve locks open, could cause incinerator lining to fail.
(9) . If basket centrifuge fails, reactor column may get plugged up.
. If scoop fails, centrifuge performance may be degraded to point where no solids separation occurs.
. If ozone generator fails, performance of ozone column may degrade significantly.
(10) Some pumps may be overrated.
(11) Incinerator:
Adequate-sludge pump and high pressure blower; underrated - motorized valve.
(12) . Basket centrifuge overrated.
. Feed pump overrated (now uses gear reducer to reduce its speed).
. Centrate pump overrated.
. Ozone generator and air compressor adequate.
(13) Fire eye, overtemperature switch.
(14) High level sensors: fail safe for equipment upstream of sensor.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD GRUMMAN

Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem: With Incin.	Treat./Disposal Subsystem: With Holding Tank
131	Accessibility of replaceable MSD components (a) High degree of accessibility in MSD subsystem components. (b) Moderate degree of accessibility in MSD subsystem components. (c) Low degree of accessibility in MSD subsystem components.	a	(4) c	(4) c
132	Extent of MSD modularization for ease of repair/replacement (a) High degree of MSD subsystem modularization. (b) Moderate degree of MSD subsystem modularization. (c) Low degree of MSD subsystem modularization.	a	b	b
133	Degree of MSD repairability on board vessel.(1) (a) All MSD subsystem items are repairable on vessel. (b) Some MSD subsystem items are repairable on vessel; some must be replaced. (c) All MSD subsystem items must be replaced.	b	(5) b	(5) b
134	Availability of manufacturer field support and training programs for MSD (a) Manufacturer field support and a training program is available. (b) Manufacturer field support(2) is available but no training program is available. (c) Manufacturer training program is available but field support is not available. (d) Neither field support nor training program are available from manufacturer.	b	b	b
142	Special/proprietary(3) item requirements for MSD equipment repair (a) No special items required for any MSD subsystem repairs. (b) Some special items required for some MSD subsystem repairs. (c) All items required for MSD subsystem repairs are special items.	a	(6, 7) b	(7) b

(1) Versus necessity for replacement of failed equipment.
(2) May include some limited training support during initial MSD installation.
(3) E.g., Incinerator pots, filters versus standard supply parts.

(4) . Centrifuge accessible.
. Packaging of equipment in framework sometimes makes access difficult, e.g., pumps and tanks are placed low.
. Difficult to get inside ozone generator.
. Diffusers may have to be disassembled; if they get plugged up, this is not easy.
. Ozone tubes slide out on racks, must then disconnect wires to service them.

(5) . Ozone tubes not repairable.
. High voltage transformer in ozone generator is not repairable.

(6) . Sludge feed tank is a formed fiberglas tank.
. Incinerator pot special.

(7) . Ozone tubes are special.
. Ozone reactor column is proprietary.
. Ozone generator has some special parts.
. Basket centrifuge is special (can be obtained from original manufacturer - not Grumman).

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD GRUMMAN Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data		
		Collect./Transp. Subsystem	Treat./Disposal Subsystem	
			With Tank	With Holding Tank
23	Effect of MSD preventive maintenance on watchstander routines (a) No effect on watchstander routines. (1) (b) There is some effect on watchstander routines.	a	a	a
33	Special docking requirements for MSD overhauls (a) There are no special docking requirements for the MSD. (1) (b) There are special docking requirements for the MSD.	a	a	a
4	Logistic requirements for MSD (a) No special parts are required for the MSD subsystem. (b) Few different categories of special parts are required for the MSD subsystem and there are few parts in each category. (c) Few different categories of special parts are required for the MSD subsystem but many parts of each type are required, or many different categories of special parts are required but there are few parts in each category. (d) Many different categories of parts are required for the MSD subsystem and there is a large number of parts in each category.	a	b	b

(1) By C.G. direction, this applies to all MSDs considered in this study.

GRUMMAN

EQUIPMENT AND INITIAL SPARES ACQUISITION COSTS

Equipment	Equipment Cost*	Cost of Associated Initial Spares Package*
Treatment Subsystem (Including Controls)	$25,000	$2,500
Incinerator Subsystem - Thiokol (Including Controls)	25,000	2,500

Notes:

1. Please supply cost estimates for each equipment based on a production run of up to 100 units.
2. All cost estimates are to be based on 1976 costs.
3. Identify recommended contents of Initial Spares Package Associated with each equipment.

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* Estimates provided by U.S. Coast Guard.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

	LABOR						VESSEL RESOURCES USED										MATERIALS CONSUMED				TOTAL
							Resource Usage Rate					Annual Cost of Resource Consumed									
Operational Requirement	Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs - Min)	Number Operators/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing Cooling Water (kwh/day)	Compressed Air (SCF/day @ P)	Electric Power (@ 3¢/kwh)	Fuel Oil (@ 39¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.83¢/1000 gal)	Compressed Air (see footnote)	Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	Annual Operating Cost ($)
C/T SUBSYSTEM																					
COLLECTION SUBSYSTEM																					
Flush commode (by user)										0.0025k/c				$43.80k/$1.53/c	4.0¢k						43.84/c
Flush urinal (by user)										0.001k/c											1.57/c
Mode Changeover Cycles														$18.25k/64¢/c	1.6¢k						18.27k/66¢/c
· primary - overboard	~20	1-mk2	1-mk2	6.27	0.33/cy	2.09/cy								$2.09/cy for primary - overboard							
· pierside - primary	~25	1-mk2	1-mk2	6.27	0.41/cy	2.61/cy								$4.70/cy for pierside - primary							
	~10	2-mk2	2-mk2	6.27	0.33/cy	2.09/cy	(required for hose handling)														
T/D SUBSYSTEM																					
TREATMENT SUBSYSTEM																					
Check setting on feed tank metering pump	168^a	~2	1-mk2	6.27	1.73	10.87															10.87
Clean sludge accumulation in pipe from ozone reactor to incinerator feed tank	168^a	~5	1-mk2	6.27	4.33	27.17															27.17
Check humidity indicator in ozone generator	24^a	~1	1-mk3	6.84	6.08	41.61															41.61
Lubricate cam and follower in ozone detector	24^a	~2	1-mk3	6.84	12.17	83.22															83.22
Lubricate air pump piston and cylinder in ozone detector	168^a	~2	1-mk4	7.42	1.73	12.86															12.86
Cooling Water {1 gpm - ozone gen.; 1/4 gpm - centrate pump}																					

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

** It is assumed that similar effort is required for mode changeovers when a holding tank is substituted for an incinerator.

Compressed Air Cost in ¢/Year = $\left(6.12268\,(14.7 + p)^{0.1429} - 8.9898\right)\,(SCF/day)$ where p is in psig

SCF = standard cubic feet at 14.7 psi and 70°F.

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs-Min)	Number Operators/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED – Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing water (kwh/day)	Compressed Air (SCF/day @ P)	Annual Cost of Resource Consumed: Electric Power (@ 3¢/kwh)	Fuel Oil (@ 39¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.83¢/1000 gal)	Compressed Air (see footnote)	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	TOTAL: Annual Operating Cost ($)
Check ozone detector sensing solution level	720[a]	-5	1-mk2	6.27	1.6	6.27											Chemical Solution	0.5liter per 3 day		$70.75[m]	77.02
Check control panel indicator lights, meter settings and failure alarm.	24[a]	-5	1-mk2	6.27	30.42	190.71											lamps	2/mo[m]	0.40ea[m]	$9.60	200.31
Check air flow to ozone generator cells	24[a]	-1	1-mk3	6.84	6.08	41.61															41.61
Operate treatment subsystem (auto.)							99.873[k]					$1093.61[k]									1093.61
TOTALS					63.54	414.32	99.873					$1093.61								$80.35	1588.28
INCINERATOR SUBSYSTEM (Thiokol)																					
Remove ashes	336	-30	1-mk2	6.27	13.90	81.51															81.51
Clean sludge nozzle	168	-10	1-mk2	6.27	8.67	54.34															54.34
Clean fuel oil nozzle	1440	-10	1-mk2	6.27	1.00	6.27															6.27
Clean compressed air filter element	1440	-10	1-mk2	6.27	1.00	6.27															10.87
Drain water trap in compressed air line	168	-2	1-mk2	6.27	1.73	10.87															149.24b
Operate incinerator subsystem(auto.)							[illegible]/c[k]	3.87/c[k]			418/≈35	128.24/c[k]	323.85/c[k]			57.15/c[k]					146.94
TOTALS					25.4	159.26	1.668				413/c	128.24/c	323.85/c			57.15/c					159.26 + 149.24b

* 2¢/gal for vessel generated fresh water and 0.07¢/gal for stored fresh water.

Compressed Air Cost in ¢/Year = $\left(6.12268\,(14.7 + p)^{0.1423} - 8.9898\right)\left(\text{SCF/day}\right)$ where p is in psig.

SCF = standard cubic feet at 14.7 psi and 70°F.

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

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LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
C/T SUBSYSTEM											
COLLECTION SUBSYSTEM											
None											
T/D SUBSYSTEM											
TREATMENT SUBSYSTEM											
Clean level sensors in centrifuge feed tank and effluent tank	1440	-30	1-mk2	6.27	3.00	16.81					16.81
Check basket centrifuge mounting bolts	720[a]	-2	1-mk2	6.27	0.40	2.51					2.51
Check V-belt tension on centrifuge	720[a]	-5	1-mk2	6.27	1.00	6.27					6.27
Check tip of sludge scoop for wear	720[a]	-5	1-mk4	7.42	1.00	7.42					7.42
Check chain tension on sludge scoop drive	720[a]	-2	1-mk4	7.42	0.40	2.97					2.97
Clean centrifuge bowl and drum	720[a]	-20	1-mk3	6.84	4.00	27.36					27.36
Replace compressor inlet air filter element in ozone generator	4380[a]	-10	1-mk2	6.27	0.33	2.09	Air filter element	2	5.20[d]	10.40	12.49
Replace water strainer in ozone generator	4380[a]	-10	1-mk2	6.27	0.33	2.09	Strainer Screen	2	13.85[d]	27.70	29.79
Lubricate air pump drive motor in ozone detector	4380[a]	-10	1-mk3	6.84	0.33	2.28					2.28
Lubricate air pump drive motor speed reducer	2190[a]	-10	1-mk3	6.84	0.67	4.56					4.56
Clean out sediment from ozone reactor	4380	1-	1-mk5	8.13	2.0	16.26					16.26
Lubricate compressor motor in ozone generator	2190	-5	1-mk2	6.27	0.33	2.09					2.09

MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES

(Based on 100% Utilization Factor)

MSD Grumman

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs/Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
Check pump impellers for wear	2190[4]	~45	1-mk5	8.13	3.00	24.39					24.39
Lubricate motor and speed reducer on metering feed pump	2190	~5	1-mk3	6.84	0.33	2.28					2.28
Lubricate motors for centrate and effluent pumps	4380	~5	1-mk2	6.27	0.17	1.05					1.05
TOTALS					17.03	122.43		4		38.10	160.53
INCINERATOR SUBSYSTEM											
Inspect M/T pump cutter and cutter ring	2190	~30	1-mk5	8.13	2.0	16.26					16.26
Clean fan, fan shield and body fins on blower motor	4380	~15	1-mk2	6.27	0.50	3.14					3.14
Lubricate blower motor and fuel oil pump motor	2190	~5	1-mk3	6.84	0.33	2.25					2.28
Calibrate incinerator temperature sensor(s)	2190	~30	1-mk5	8.13	2.0	16.26					16.26
Adjust V-belt tension on blower	2190	~10	1-mk3	6.84	0.67	4.56					4.56
Replace compressed air filter element	4380	~10	1-mk2	6.27	0.33	2.09	Air filter element	2	10.00[m]	20.00	22.09
Lubricate motor driven valve motor	2190	~5	1-mk2	6.27	0.33	2.09					2.09
Lubricate blower gear box	2190	~5	1-mk2	6.27	0.33	2.09					2.09
Check incinerator chamber lining for defects	336	~10	1-mk5	8.13	4.33	35.23					35.23
TOTALS					10.82	84.00		2		20.00	104.00

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
C/T SUBSYSTEM											
COLLECTION SUBSYSTEM											
Replace flushometer internals	17520	-6/unit [a]	1-mk2 [a]	6.27	0.05/unit	0.31/unit	Flushometer internals	0.5/unit	7.00/unit [m]	3.50/unit	3.81/unit
Clean out salt cake deposition in drain piping	4080	1-		7.42	2.0	14.84					14.84
T/D SUBSYSTEM											
TREATMENT SUBSYSTEM											
Replace level sensor in centrifuge feed tank (2)	8760	-10	1-mk3	6.84	0.17	1.14	Level Sensor	1	23.60 [d]	23.60	24.74
Repair metering feed pump											
- replace motor	43800	-15	1-em4	6.50	0.05	0.33	Motor	0.2	25.00 [m]	5.00	5.33
- replace motor bearings	26280	-30	1-em5	7.22	0.17	1.20	Bearings	0.33	9.00 [m]	3.00	4.20
- replace gears in speed reducer	17520	1-	1-mk5	8.13	0.50	4.07	Gear set	0.5	8.00 [m]	4.00	8.07
- replace impeller	8760	-30	1-mk4	7.42	0.50	3.71	Impeller	1	3.00 [m]	3.00	6.71
Repair centrifuge motor											
- replace bearings	26280	-30	1-em5	7.22	0.17	1.20	Motor bearings	0.67	7.00 [m]	4.67	5.87
Repair sludge scoop drive											
- replace motor	17520	-15	1-em4	6.50	0.13	0.81	Motor	0.5	20.00 [m]	10.00	10.81
- replace limit switches (2)	17520	-20	1-em4	6.50	0.17	1.08	Limit switch	1	4.00 [m]	4.00	5.08
Repair centrifuge											
- replace V-belts	17520	-10	1-mk2	6.27	0.08	0.52	V-belts	0.5 set	13.10 [d]	6.55	7.07
- replace spindle bearings	13140	-45	2-mk3	6.84	1.00	6.84	Spindle bearings	0.67 set	40.40/set [d]	26.93	33.77
- replace scoop tip	8760	-30	1-mk3	6.84	0.50	3.42	Scoop tip	1	54.65 [d]	54.65	58.07

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Repair centrate pump											
- replace motor bearings	17520	-20	1-mk5	8.13	0.17	1.36	Motor bearings	1	7.00[m]	7.00	8.36
- replace mechanical shaft seal	17520	-20	1-mk5	8.13	0.17	1.36	Shaft seal	0.5	12.00[m]	6.00	7.36
- replace impeller	8760	-15	1-mk4	7.42	0.25	1.86	Impeller	1	8.00[m]	8.00	9.86
Repair effluent pump											
- replace motor bearings	17520	-20	1-mk5	8.13	0.17	1.36	Motor bearings	1	7.00[m]	7.00	8.36
- replace mechanical shaft seal	17520	-20	1-mk5	8.13	0.17	1.36	Shaft seal	0.5	12.00[m]	6.00	7.36
- replace impeller	8760	-15	1-mk4	7.42	0.25	1.86	Impeller	1	8.00[m]	8.00	9.86
Replace air diffuser in ozone reactor (4)	17520	2-	1-mk5	8.13	1.0	8.13	Air diffuser	2	25.00[m]	50.00	58.13
Replace seats and stem seal in valve	4380	-15	1-mk3	6.84	0.5	3.42	Seats and seal	2	4.00[m]	8.00	11.42
Replace effluent flow switch (2)	17520	-20	1-mk4	7.42	0.17	1.14	Flow switch	0.5	35.00[m]	17.50	18.64
Replace effluent check valve seat and seal	8760	-15	1-mk3	6.84	0.25	1.71	Seat and Seal	1	10.00[m]	10.00	11.71
Replace timer (4)	8760	-15	1-em4	6.50	0.25	1.63	Timer	1	65.00[m]	65.00	66.63
Replace cooling water solenoid valve	17520	-10	1-mk4	7.42	0.08	0.62	Solenoid valve	0.5	10.00[m]	5.00	5.62
Replace thermal delay relay (5)	3504	-5	1-em3	5.96	0.21	1.24	Thermal delay relay	2.5	3.60[d]	9.00	10.24
Replace solenoid relay (23)	1523	-5	1-em3	5.96	0.48	2.86	Solenoid relay	5.75	12.70[d]	73.03	75.89
Replace induction relay	35040	-10	1-em3	5.96	0.04	0.25	Induction relay	0.25	15.00[m]	3.75	4.00
Replace centrifuge motor starter	26280	-10	1-em4	6.50	0.06	0.36	Motor starter	0.33	35.50[m]	11.67	12.03
Replace level switch in effluent tank	8760	-10	1-mk4	7.42	0.17	1.14	Level switch	1	23.60[d]	23.60	24.74
TOTALS						55.98				463.95	519.93

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

	LABOR						PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs/Man)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Ozone Generator											
Repair motor/compressor											
- replace motor bearings	17520	-20	1-mk5	8.13	0.17	1.36	Motor bearings	1	7.00[m]	7.00	8.36
- replace compressor piston rings and valves	13140	2-	1-mk6	11.16	1.33	14.88	Piston rings and valves	0.67	25.00[m]	16.67	31.55
- replace inlet air filter element	8760	-10	1-mk2	6.27	0.17	1.05	Air filter element	1	13.85[b]	13.85	14.90
Replace solenoid valve (4)	4380	-10	1-mk6	7.42	0.33	2.47	Solenoid valve	2	10.00[m]	20.00	22.47
Replace molecular sieve in dryers	26280	-45	1-mk4	7.42	0.25	1.82	Molecular sieve	8 lb	6.00/lb[m]	48.00	49.86
Replace dryer heating element (2)	17520	-30	1-em5	7.22	0.25	1.81	Heating element	0.5	51.95[d]	25.98	27.78
Replace corona discharge tube assembly (4)	26280	-30	1-em6	9.73	0.17	1.62	Discharge tube assy	0.75	[illegible][d]	324.63	326.25
Replace high voltage transformer	35040	-20	1-em5	7.22	0.08	0.60	Transformer	0.25	432.75[d]	108.19	108.79
Replace high voltage wiring	17520	-10	1-em5	7.22	0.08	0.60	H.V. wire	0.5 set	50.00/set[m]	25.00	25.60
Replace humidity indicator	17520	-10	1-mk3	6.84	0.08	0.57	Humidity indicator	0.5	2.00[m]	1.00	1.57
Replace air pressure limit switch	26280	-10	1-em4	6.50	0.06	0.36	Pressure switch	0.33	30.00[m]	10.00	10.36
Replace air temperature limit switch	26280	-10	1-em4	6.50	0.06	0.36	Temp. switch	0.33	18.00[m]	6.00	6.36

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD Grumman

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	LABOR: Estimated Time Required (Hrs/Min)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Annual Labor Required (Man-Hrs)	LABOR: Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	PARTS CONSUMED: Estimated No. of Parts Used/Year	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
Replace rubber hose(s) (9)	4380	-10	1-mk2	6.27	0.33	2.09	Hose	2	12.76[d] (ave)	25.52	27.61
Replace SS flexible hose	35040	-10	1-mk3	6.84	0.04	0.29	Hose	0.25	47.15[d]	11.79	12.08
Replace interlock contactor (6)	8760	-10	1-em4	6.50	0.17	1.08	Contactor	1	12.70[m]	12.70	13.78
Replace relay (8)	4380	-10	1-em3	5.96	0.33	1.99	Relay	2	12.70[d] (ave)	25.40	27.39
Replace motor contactor	35040	-10	1-em4	6.50	0.04	0.27	Motor Contactor	0.25	30.00[m]	7.50	7.77
Replace generator contactor	43800	-10	1-em6	6.50	0.03	0.22	Generator Contactor	0.2	40.00[m]	8.00	8.22
Replace timer	26280	-10	1-em4	6.50	0.06	0.36	Timer	0.33	60.00[m]	20.00	20.36
Ozone Detector											
Replace solution pump internals	8760	-40	1-mk6	11.16	0.67	7.44	Pump internals	1	25.00[m]	25.00	32.44
Clean sensor element	2190	-10	1-mk6	11.16	0.67	7.44					7.44
Replace air pump	8760	-15	1-mk6	11.16	0.25	2.79	Air pump	1	25.00[m]	25.00	27.79
TOTALS					12.07	107.45				1431.18	

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES

(Based on 100% Utilization Factor)

MSD Grumman

LABOR							PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
INCINERATOR SUBSYSTEM											
Repair M/T pump. Replace:											
. impeller	8760	2-45	2-em2	5.45	5.5	29.98	Impeller	1	77.36[b]	77.36	107.34
. cutter assembly	4380	2-45[b]	2-em2	5.45	11.0	59.95	Cutter Assembly	2	228.31[b]	456.62	516.57
. mechanical shaft seal	8760	3-	2-em2	5.45	6.0	32.70	Shaft Seal	1	22.92[d]	22.92	55.62
. motor bearing	17520	1-	2-em2	5.45	1.0	5.45	Motor bearing	0.5	8.00[m]	4.00	9.45
Replace valve seats and stem seal	8760	-15	1-mk3	6.84	0.25	1.71	Seats and Seal	1	4.00[m]	4.00	5.71
Replace limit switches in motorized valve	17520	-20	1-em4	6.50	0.17	1.08	Limit Switch	1	4.00[m]	4.00	5.08
Replace fuel oil pump	26280	-20	1-mk5	8.13	0.11	0.90	Pump	0.33	15.00[m]	5.00	5.90
Repair fuel oil pump motor											
- replace bearings	17520	-20	1-em4	3.50	0.17	1.08	Motor bearings	0.5	6.00[m]	3.00	4.08
Replace blower inlet screen	17520	-5	1-mk2	6.27	0.04	0.26	Screen	0.5	3.00[m]	1.50	1.76
Replace blower bearings	17520	-25	1-mk5	8.13	0.21	1.69	Motor bearings	1	8.00[m]	8.00	9.69
Replace fuel oil nozzle	8760	-10	1-mk3	6.84	0.17	1.14	Oil nozzle	1	2.00[m]	2.00	3.14
Replace sludge nozzle	8760	-10	1-mk3	6.84	0.17	1.14	Sludge nozzle	1	6.00[m]	6.00	7.14
Replace incinerator chamber lining	8760	3-	1-mk5	8.13	3.00	24.39	Incinerator lining	1	800.00[m]	800.00	824.39
Replace incinerator temperature sensor	4380	-15	1-em5	7.22	0.50	3.61	Temp. Sensor	2	35.00[m]	70.00	73.61
Replace flame detector element	17520[d]	-15[e]	1-em5	7.22	0.13	0.90	Flame detector element	0.5	10.00[m]	5.00	5.90

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES

(Based on 100% Utilization Factor)

MSD Grumman

	LABOR						PARTS CONSUMED				TOTAL
Corrective Maintenance Requirement	Estimated Time Between Failures (Hrs)	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	Estimated No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Corrective Maintenance Cost ($)
Replace temperature controller	26280	-10	1-em5	7.22	0.06	0.40	Temp. Controller	0.33	125.00[m]	41.67	42.07
Replace relay	8760	-10	1-em3	5.96	0.17	0.99	Relay	1	12.06[m]	12.00	12.99
Replace timer	26280	-10	1-em5	7.22	0.06	0.40	Timer	0.33	50.00[m]	16.67	17.07
Replace fuel oil solenoid valve	17520	-10	1-mh4	7.42	0.08	0.62	Solenoid Valve	0.5	10.00[m]	5.00	5.62
TOTALS	16				28.79	168.39		16.5		1544.74	1713.13

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

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Overhaul Requirement	LABOR: Time Between Overhauls (Yrs)*	LABOR: Estimated Time Required (Hrs)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Total Labor Required (Man-Hrs)	LABOR: Total Cost of Labor ($)	PARTS CONSUMED: Part Required	PARTS CONSUMED: No. of Parts Required for Overhaul	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Cost of Parts for Overhaul ($)	TOTAL: Major Overhaul Cost ($)
C/T SUBSYSTEM											
COLLECTION SUBSYSTEM											
Replace flushometer valve internals		-6m/unit	1-mk2	6.27	0.17/unit	1.07/unit	Flushometer	1/unit	7.00/unit	7.00/unit	8.07/unit
Clean sanitary drain lines od deposited salt cake		16-	2-mk4	7.42	32.0	237.44					118.72
T/D SUBSYSTEM											
TREATMENT SYSTEM											
Clean inside of centrifuge feed tank		2-	1-mk2	6.27	2.0	12.54					12.54
Clean and calibrate level sensors in centrifuge feed tank		-30	1-mk4	7.42	0.5	3.71					3.71
Regrease speed reducer in metering feed pump		-10	1-mk3	6.84	0.17	1.14					1.14
Clean and lubricate motor in metering feed pump		-10	1-mk3	6.84	0.17	1.14					1.14
Replace impeller in metering feed pump		-10	1-mk3	6.84	0.17	1.14	Impeller	1	3.00m	3.00	4.14
Replace seats and stem seals in all valves		2-	1-mk3	6.84	2.0	13.68	Seats and Seals	10m	4.00m	40.00	53.68
Clean centrifuge inside and outside		-45	1-mk2	6.27	0.75	4.70					4.70
Adjust centrifuge sludge scoop positioning		-10	1-mk4	7.42	0.16	1.24					1.24
Replace hose and clamps on sludge scoop		-10	1-mk2	6.27	0.16	1.05	Hose and Clamps	1	4.00m	4.00	5.05
Clean and lubricate sludge scoop mechanism		-10	1-mk2	6.27	0.16	1.05					1.05
Clean centrate tank inside and outside		-40	1-mk2	6.27	0.67	4.18					4.18
Replace impeller and shaft seal in centrate pump		-20	1-mk4	7.42	0.33	2.47	Impeller and shaft seal	1	20.00m	20.00	22.47

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2 year overhaul interval is assumed for all subsystems/

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD Grumman

	LABOR						PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs)	No. Maintainers/Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Clean interior of ozone reactor		1-	1-mk4	7.42	1.0	7.42					7.42
Clean reactor column packing		1-	1-mk4	7.42	1.0	7.42					7.42
Clean ozone reactor foam overflow line		-15	1-mk2	6.27	0.25	1.57					1.57
Clean effluent tank interior		-40	1-mk2	6.27	0.67	4.18					4.18
Clean and calibrate level sensors in effluent tank		-30	1-mk4	7.42	0.5	3.71					3.71
Replace impeller and shaft seal in effluent pump		-20	1-mk4	7.42	0.33	2.47					2.47
TOTALS	18				10.99	74.83		13		67.00	141.83
Ozone Generator											
Replace cooling water screen		-5	1-mk2	6.27	0.08	0.52	Screen	1	3.00[m]		3.52
Replace inlet air filter		-5	1-mk2	6.27	0.08	0.52	Air filter element	1	13.85[b]		14.37
Replace compressed air filter element		-5	1-mk2	6.27	0.08	0.52	Air filter element	1	10.00[m]		10.52
Calibrate compressed air relief valve		-10	1-mk5	8.13	0.17	1.36					1.36
Replace seats in solenoid valves (4)		-45	1-mk4	7.42	0.75	5.57	Valve Seats	4	4.00[m]	16.00	21.57
Replace humidity indicator		-10	1-mk2	6.27	0.17	1.05	Humidity indicator	1	2.00[m]	2.00	3.05
Calibrate air pressure limit switch		-15	1-mk5	8.13	0.25	2.03					2.03
Calibrate temperature limit switch		-15	1-mk5	8.13	0.25	2.03					2.03
Calibrate time delay timer		-10	1-em4	6.50	0.17	1.08					1.08
Clean high voltage wiring		-15	1-em4	6.50	0.25	1.63					1.63

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2 year overhaul interval is assumed for all subsystems.

MSD Grumman

LABOR							PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Replace molecular sieve in air dryers		~45	1-mk4	7.42	0.75	5.57	Molecular sieve	25 lb[m]	6.00/lb[m]	150.00	155.57
Replace hoses (5) and clamps (or connector)		1-	1-mk2	6.27	1.0	6.27	Hoses and clamps	5	12.76[d] (ave)	63.80	70.07
TOTALS	12				4.0	23.15		14		231.80-	286.80
Ozone Detector											
Clean all parts in contact with analysis solution		~30	1-mk5	8.13	0.5	4.07					4.07
Replace internal elastomeric parts in solution metering pump, eg bellows, diaphragm, gasket		1-	1-mk5	8.13	1.0	8.13	Pump parts	1 kit	20.00/kit[m]	20.00	28.13
Clean and lubricate drive mechanism in metering pump		~20	1-mk5	8.13	0.33	2.71					2.71
Clean and calibrate sensor		~30	1-mk5	8.13	0.5	4.07					4.07
TOTALS	5				2.33	18.98		1		20.00	38.98
INCINERATOR											
Clean interior of sludge feed tank		~40	1-mk2	6.27	0.67	4.18					4.18
Replace all internal parts of M/T pump except motor stator, armature and shaft		1-30	1-mk6	11.16	1.5	16.74	M/T pump parts	1	348.77/set[d]	348.77	365.51
Replace seats and stem seals on all valves		1-	1-mk3	6.84	1.0	6.84	Seats and Seals	5	4.00[m]	20.00	26.84
Replace fuel oil pump		~20	1-mk5	8.13	0.33	2.71	Fuel pump	1	15.00[m]	15.00	17.71
Replace blower inlet screen		~5	1-mk3	6.84	0.08	0.57	Screen	1	3.00[m]	3.00	3.57

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2 year overhaul interval is assumed for all subsystems.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD Grumman

LABOR							PARTS CONSUMED				TOTAL
Overhaul Requirement	Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	Major Overhaul Cost ($)
Replace blower lobes, gears and bearings		1-	1-mk5	8.13	1.0	8.13	Blower internals	1 set	200.00 m	200.00	208.13
Replace fuel oil nozzle		-10	1-mk3	6.84	0.17	1.14	Oil nozzle	1	2.00 m	2.00	3.14
Replace sludge nozzle		-10	20mk3	6.84	0.17	1.14	Sludge nozzle	1	6.00 m	6.00	7.14
Replace incinerator chamber lining		3-	1.mk5	8.13	3.0	24.39	Incinerator lining	1 kit	800.00 m	800.00	824.39
Replace temperature sensors (3)		-40	1-em5	7.22	0.67	4.81	Temp. Sensors	3	35.00 m	105.00	109.81
Replace flame detector element		-15 c	1-em5	7.22	0.25	1.81	Flame detector element	1	10.00 m	10.00	11.81
TOTALS					8.84	72.46		16		1509.77	1582.23

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2 year overhaul interval is assumed for all subsystems.

COLLECTION, HOLDING, TRANSFER (CHT) SYSTEM

PRINICPLES OF OPERATION

A Collection, Holding, Transfer (CHT) System provides storage volume to receive and hold wastewaters, deferring discharge from the vessel until an appropriate time. It is a "no discharge" system. It is the simplest of the MSD's considered for this study from a processing point of view. Various arrangements of wastewaters and storage tanks are possible and have been considered by others for different applications. These are:

- One tank to hold:
  - Black* water only, gray* water not retained
  - Black water, with gray water while in port
  - Black water, with gray water while transiting between open seas and port
- Two tanks: One tank for black water and one tank for gray water as follows:
  - Separate and distinct pump-out facilities
  - Common pump-out facilities
  - Serial pump-out, i.e., gray water is pumped into black water tank, from which both wastewaters are discharged.

CHT systems are usually thought of in connection with standard flush volumes of sea water. Supply limitations on board vessels preclude the use of fresh water with standard flush commodes and urinals. However, a CHT tank can be used with fresh or sea water flush medium in a system containing

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* Black water is synonymous with sewage and soil wastes. It is comprised of human wastes, flush water and, if collected separately, wastewater from a garbage grinder (Coast Guard policy). Gray water is comprised of wastewater from lavatories, sinks, showers, laundry, galley, scullery and inside deck drains.

reduced volume flush commodes and urinals. One reduced volume flush system, using vacuum transport (Jered), requires a separate vacuum tank for collection, in addition to the vented holding tank. Alternately, the CHT tank can be designed as a vacuum tank which may be practical where the total retention volume is small.

A functional block diagram of a Collection, Holding, and Transfer (CHT) System is presented in Figure 11.

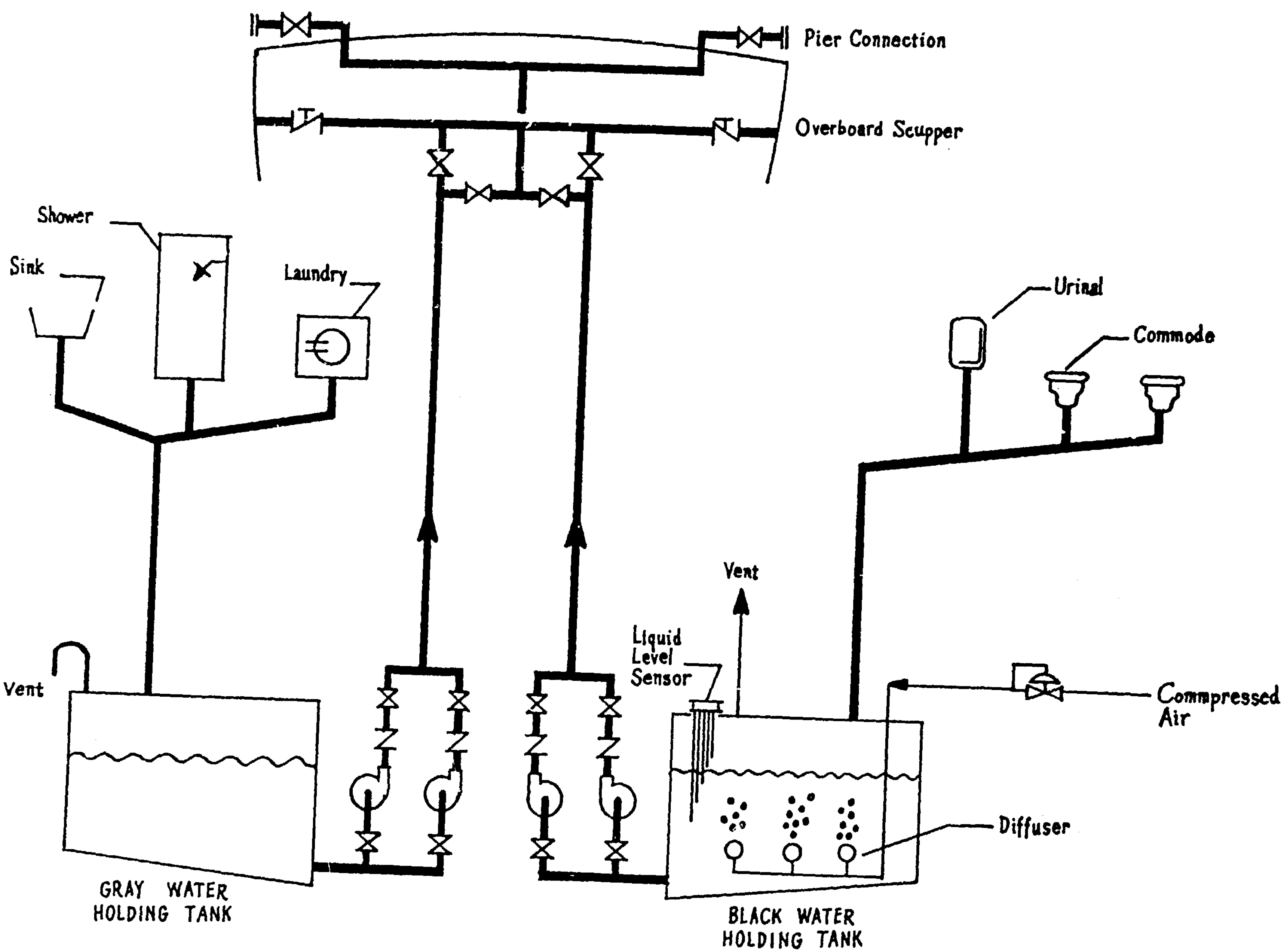

Figure 11

COLLECTION, HOLDING, TRANSFER (CHT) SYSTEM

SYSTEM DESCRIPTION

The black water tank is aerated by bubbling air through the liquid, in order to keep septic odors from being generated. Compressed air is furnished from the vessel's service air supply system or by a specially installed compressor or high pressure blower. For purposes of this study, it will be assumed that compressed air is taken from the vessel's compressed air supply system (if the vessel is so equipped).

The black water tank is sized to retain a specified number of hours worth of wastewater flow. The Navy design goal is 12 hours. Coast Guard vessels, having different mission profiles from Navy vessels, will have design goals related to the maximum number of hours spent away from home port while in restricted waters. The tank is generally free of internal structural members in order to permit effective washdown. A washdown nozzle inside the tank is supplied with water from the firemain. The tank bottom is sloped toward a sump basin at the pump suction. Maintenance access openings are provided. The tank is non-pressurized, has a vent to the atmosphere and an overflow line. Multiple liquid level sensors are set to various heights (tank volumes). Below are the set points prescribed in a preliminary Naval Ships technical manual:

- At 10% of maximum level, shut off discharge pump(s)
- At 30% of maximum level, actuate one discharge pump
- At 60% of maximum level, actuate standby discharge pump
- At 85% of maximum level, actuate alarm(s)

Gray water tanks are similar in design to black water tanks, except that no aeration of the liquid is necessary. There is no compressed air requirement, no diffusers, and the vent line need not extend to the weatherdeck. Gray water may be diverted overboard from the manifold external to the tank, whenever regulations (or Coast Guard policy) allow it, and the manifold is above the waterline. Such a bypass is not allowed for black water drainage. If the manifold is below the waterline, the gray water must enter the holding tank before being pumped off the vessel.

Each tank, black and gray, is connected to two, non-clog, marine sewage pumps connected in parallel, which discharge to shore or barge through a valved deck connection. There may be a total of two or four pumps for both black and gray water tanks, depending upon the installation. The pump(s) can alternately discharge to overboard through a gag scupper valve. The vessel design may allow discharge to one or both sides for either deck or overboard lines.

Retention of wastewaters, black and/or gray, may be effected in one or more tanks, with a practical limit of no more than a total of three tanks (Coast Guard guideline). Every effort is taken in both design, equipment selection and operating procedure to prevent black water tank, whereupon it becomes black water.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD CHT Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data: Collect./Transp. Subsystem	Treat./Disposal Subsystem
12	MSD materials disallowed or not recommended.(1) (a) No disallowed or not recommended materials present(2) in MSD subsystem. (b) Some disallowed or not recommended materials present in MSD subsystem, but resultant problems can be solved or compensated for. (c) Presence of disallowed or not recommended materials in MSD subsystem presents problems with no feasible solutions.	a	a
13	Extent of additional support systems or equipment required to accommodate MSD(3) Identification of support system requirements for MSD subsystem.		(7)
21	Extent of fixture modifications required for MSD installation. (a) MSD uses standard commodes and urinals. (b) MSD uses non-standard commodes and special equipment is associated with the urinals. (c) MSD uses non-standard commodes, special equipment is associated with the urinals and each fixture has additional hook-up requirements.	a	N/A
22	Extent of flush medium supply modifications required for MSD installation. (a) MSD uses sea water for flushing fixtures. (b) MSD uses fresh water for flushing fixtures. (c) MSD uses a non-aqueous for flushing fixtures.	a	N/A
231	Hookup requirements(4) for MSD Collection/Transport subsystem installation. (a) MSD uses standard Collection/Transport subsystem. (b) MSD uses recirculating Collection/Transport subsystem.(5) (c) MSD uses non-standard and centralized Collection/Transport subsystem. (d) MSD uses non-standard and non-centralized Collection/Transport subsystem.(6)	a	N/A

(1) As specified in subchapters J&F of Merchant Marine Code and C.G. MSD regulations.
(2) For purposes of this study, C.G. directs choice (a) for all MSDs.
(3) Examples:
- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(4) Drain piping; electric cables for connecting commodes, M/T pump and control panel, compressed air, etc.
(5) In existing gravity drain system.
(6) Includes conversion from reduced flush vacuum collection to a standard gravity drain system with or without recirculation.

(7) Bilge alarm if required.

MSD EFFECTIVENESS ATTRIBUTE DATA

I - ADAPTABILITY FOR

M/E SHIPBOARD INSTALLATION

MSD CHT

Sheet 2 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
232	Routing flexibility for drain piping modifications(1) associated with MSD Collection/Transport subsystem installation(2) (a) Routing of MSD Collection/Transport piping is highly flexible. (b) Routing of MSD Collection/Transport piping is moderately flexible with some restrictions. (c) Routing of MSD Collection/Transport piping is highly inflexible.	(3) c	N/A
233	Space requirements for MSD Collection/Transport subsystem installation (a) Space required for MSD Collection/Transport subsystem is little or no greater than that required for standard Collection/Transport subsystem. (b) Space required for MSD Collection/Transport subsystem is moderately increased over that required for standard Collection/Transport subsystem. (c) Space required for MSD Collection/Transport subsystem is much greater than that required for standard Collection/Transport subsystem.	a	N/A
234	Modularity of MSD Collection/Transport subsystem (as it affects installation). (a) Collection/Transport subsystem is highly modular. (b) There is an option for some decentralization of the MSD Collection/Transport subsystem. (c) The MSD Collection/Transport subsystem is highly centralized.	a	N/A
235	Vent requirements for MSD Collection/Transport subsystem installation. (a) MSD Collection/Transport subsystem requires no vents. (b) MSD Collection/Transport subsystem requires few vents. (c) MSD Collection/Transport subsystem requires many vents.	(4) c	N/A

(1) Of the three relevant categories of routing lines (piping, ventilation, electrical), piping is the most important for assessing ease of MSD installation.

(2) Notes:

- With gravity drainage, lines must always slope downward and require venting.
- Smaller size lines are inherently more flexible.
- With pump or vacuum Collection/Transport subsystem, sharp bends, risers and long runs can be accommodated in piping.

(3) Gravity drainage through standard drain lines. Answer applies to new installation only; if standard drain lines already installed in vessel, then (a) applies

(4) As for standard drain lines (i.e., all traps must be vented). Answer applies to new installation only; if standard drain lines already installed in vessel, then (a) applies.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD CHT

Sheet 3 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	Attribute Data Collect./Transp. Subsystem	Attribute Data Treat./Disposal Subsystem
242	Hookup requirements(1) for MSD waste Treatment/Disposal subsystem installation (a) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are minimal. (b) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are moderate. (c) Pipe, ducts and/or cable requirements for the MSD Treatment/Disposal subsystem are extensive.	N/A	(5) a
243	Degree of modularity of MSD waste Treatment/Disposal subsystems (as it affects installation)(2) (a) MSD Treatment/Disposal subsystem is highly modular. (b) There is an option for some decentralization of the MSD Treatment/Disposal subsystem. (c) MSD Treatment/Disposal subsystem is highly centralized.	N/A	c
244	Vent requirements for MSD waste Treatment/Disposal subsystem installation(3) (a) No vents are required for MSD Treatment/Disposal subsystem. (b) Vents are required for MSD Treatment/Disposal subsystem.	N/A	(6) b
245	Exhaust stack requirements for MSD waste Treatment/Disposal subsystem installation.(4) (a) Exhaust stack not required for MSD Treatment/Disposal subsystem. (b) Small exhaust stack required for MSD Treatment/Disposal subsystem. (c) Large exhaust stack required for MSD Treatment/Disposal subsystem.	N/A	a

(1) Piping for fuel oil, fresh water, cooling water, compressed air, interconnecting remotely located equipment, overboard discharge line, etc.; electric cables for power supply, remote panels, etc.; ducting for ventilation, etc.
(2) Decentralization of components may require additional hookups and piping runs.
(3) Vents that are only internal to the compartment in which subsystem is located are not considered here.
(4) Notes:
- Electric incinerator requires small (2") exhaust.
- Fuel incinerator requires large (10") exhaust.

(5) Minimal hook-up requirements.

Overboard discharge piping for gray water
Compressed air for black water system
Electricity for pumps

(6) . Gray water requires local vent.

. Black water vent to atmosphere, e.g., to weather deck.

MSD EFFECTIVENESS ATTRIBUTE DATA
I - ADAPTABILITY FOR
M/E SHIPBOARD INSTALLATION

MSD CHT — Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	INSTALLATION Characteristics	INSTALLATION Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
25	Ease of installing MSD support equipment[1] Extent of additional support equipment required to accommodate MSD (a) No additional support equipment required for MSD subsystem. (b) Some additional support equipment required for MSD subsystem. (c) Much additional support equipment required for MSD subsystem.	a	[2] b

(1) Examples:

- Firefighting system must be installed with incinerator.
- Bilge alarm required if large tank is installed above bilge.
- Compressor required on vessels that do not already have one.
- Detectors of toxic or noxious gases should be installed with any system that, as an inherent design feature, uses such gases in processing wastes.

(2) Bilge alarm if required.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHT Sheet 1 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem
311	Effect of peak hydraulic loads in black[1] water stream on MSD performance[2] (a) No significant effect of black water peaks on MSD subsystem performance. (b) Effect of black water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water peaks, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water peaks.	a	(4) a
312	Effect of peak hydraulic loads in gray[1] water stream on MSD performance (2) (a) No significant effect of gray water peaks on MSD subsystem performance. (b) Effect of gray water peaks is of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water peaks, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water peaks.	N/A C/T for black water only	(4) a
321	Effect of low flow conditions/long idle times in black water stream on MSD performance[3] (a) No significant effect of black water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of black water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of black water low flow conditions/long idle times, difficult to overcome, with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle black water low flow conditions/ long idle times.	a	(5) a

(1) Includes instantaneous, hourly and daily loads.
(2) Peak load handling ability depends on C/T subsystem. The ability of an MSD which employs an influent surge tank to handle peaks usually depends almost entirely on the sizing of this tank.
(3) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(4) Ability to handle peaks, if not full.
(5) If black water tank is aerated, low flow and/or long idle times is not a problem.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHT Sheet 2 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
322	Effect of low flow conditions/long idle times in gray water stream on MSD performance(1) (a) No significant effect of gray water low flow conditions/long idle times on MSD subsystem performance. (b) Effect of gray water low flow conditions/long idle times of short duration, with temporary implications for MSD subsystem performance, easy to overcome. (c) Long-term effect of gray water low flow conditions/long idle times, difficult to overcome with long-term implications for MSD subsystem performance. (d) No ability of MSD subsystem to handle gray water low flow conditions/long idle times.	N/A C/T for black water only	a
331	Ability of black water portion of MSD to handle additional personnel (on a long-term basis)(2) (a) MSD black water subsystem will handle additional personnel with little or no degradation in performance. (b) MSD black water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance. (c) MSD black water subsystem will not handle additional personnel	a	(4) b
332	Ability of gray water portion of MSD to handle additional personnel (on a long-term basis)(3) (a) MSD gray water subsystem will handle additional personnel with little or no degradation in performance. (b) MSD gray water subsystem will handle additional personnel with moderately degraded (but still barely acceptable) performance. (c) MSD gray water subsystem will not handle additional personnel.	N/A C/T for black water only	(4) b

(1) An example of low flow condition is when 75% of the crew is not on board vessel for a week and usage rate by remaining 25% of crew is normal. Long idle times are on the order of several weeks of virtually no usage of MSD.

(2) Resulting in long-term increase in average black water stream hydraulic loading. The ability of an MSD which employs a black water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(3) Resulting in long-term increase in average gray water stream hydraulic loading. The ability of an MSD which employs a gray water (or sludge) holding tank to handle additional personnel may be determined by the size of that tank.

(4) . Cannot handle additional personnel and meet maximum holding time requirements.
. May take additional personnel for short time (tank sized in man days) if required tank capacity is accommodated by installation.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHT

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
41	Ability of black water handling portion of MSD to operate for sustained time periods (a) MSD black water subsystem can operate for indefinite period of time if no components fail.[1] (b) MSD black water subsystem can operate for only limited period of time, even if no components fail.[2]	a	b
42	Ability of gray water handling portion of MSD to operate for sustained time period (a) MSD gray water subsystem can operate for indefinite period of time if no components fail.[1] (b) MSD gray water subsystem can operate for only limited period of time, even if no components fail.[2]	N/A C/T for black water only	b
51	Ability of MSD to handle ground garbage in black water stream (a) MSD black water subsystem will handle ground garbage in black water stream on a long-term basis. (b) MSD black water subsystem will handle ground garbage in black water stream on at least a short-term basis. (c) MSD black water subsystem will not handle ground garbage in black water stream.	a	a
52	Ability of MSD to handle foreign materials/objects[3] in black water stream (a) MSD subsystem will handle foreign materials/objects in black water stream on a long-term basis. (b) MSD subsystem will handle foreign materials/objects in black water stream on at least a short-term basis. (c) MSD subsystem will not handle foreign materials/objects in black water stream.	a	(4) a

(1) Applies to a T/D subsystem with an incinerator.
(2) Applies to a T/D subsystem without an incinerator.
(3) Examples:
- Long, narrow objects (pens, pencils, toothpicks, etc.)
- Small hard objects (nut shells, pull tab from a flip top can, bottle caps, paper clips, coins, nuts/bolts/screws/nails, cuff links, etc.)
- Large soft objects (paper towels, newspaper page, stiff and shiny magazine page, strings from a floor mop, rag, tampons and sanitary napkins, etc.)

(4) A rag could plug up pumps.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E II - PERFORMANCE

MSD CHT

Sheet 4 of 4

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
53	Ability of MSD to handle detergents/surfactants in black water stream on a long-term basis.		(1)
	(a) MSD subsystem will handle detergents/surfactants in black water stream on a long-term basis. (b) MSD subsystem will handle detergents/surfactants in black water stream on at least a short-term basis. (c) MSD subsystem will not handle detergents/surfactants in black water stream.	a	a
54	Ability of MSD to handle toxic materials in black water stream		
	(a) MSD subsystem will handle toxic materials in black water stream on a long-term basis. (b) MSD subsystem will handle toxic materials in black water stream on at least a short-term basis. (c) MSD subsystem will handle toxic materials in black water stream.	a	a
61	Ability of MSD secondary emissions to meet applicable standards for the discharge of air pollutants		(2)
	(a) No possibility of discharge of significant air pollution from MSD subsystem. (b) MSD subsystem will meet standards for air pollutants under normal operating conditions. (c) MSD subsystem will meet standards for air pollutants under normal operating conditions and there is a strong possibility of non-conformance to standards under unusual operating conditions.	a	a
62	Ability of MSD secondary emissions to meet applicable standards for disposal of oil-contaminated residues at sea		(3)
	(a) MSD subsystem has no potential for producing oil-contaminated residues at sea. (b) MSD subsystem has a potential for producing oil-contaminated residues at sea.	a	b
71	Performance risk for black water handling portion of MSD		
	(a) MSD black water subsystem has a history of fair or better test results. (b) MSD black water subsystem has a history of poor test results. (c) No test results are available for the MSD black water subsystem.	a	a
72	Performance risk for gray water water handling portion of MSD		
	(a) MSD gray water subsystem has a history of fair or better test results. (b) MSD gray water subsystem has a history of poor test results. (c) No test results are available for the MSD gray water subsystem.	N/A C/T for black water only	a

(1) Lots of detergents will cause foaming; in an extreme case, some foam may excape through vent.
(2) Remote possibility of venting bacteria; no standards prohibit this, however.
(3) May discharge kitchen grease in gray water.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E - III - OPERABILITY

MSD CHT Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
11	Degree of automation for MSD operation (1) (a) MSD subsystem is almost fully automatic. (b) MSD subsystem is semi-automatic: requires infrequent operator attention. (c) MSD subsystem is semi-automatic: requires a moderate degree of operator attention. (d) MSD subsystem is semi-automatic: requires frequent operator attention. (e) MSD subsystem is operated manually.	a	(4) b
12	Ease of disposal of MSD residue(s) (1)(2) (a) MSD subsystem has no residues, or disposal of residues from MSD subsystem is very convenient. (b) Disposal of residues from MSD subsystem is moderately convenient. (c) Disposal of residues from MSD subsystem is inconvenient.	a	(5) b
14	Likelihood of violating effuent standards because of procedural errors in MSD operation. (3) (a) There is virtually no chance of violating effluent standards because of procedural errors in MSD operation. (b) There is a low likelihood of violating effluent standards because of procedural errors in MSD operation. (c) There is a fair to moderate chance of violating effluent standards because of procedural errors in MSD operation. (d) There is a high likelihood of violating effluent standards because of procedural errors in MSD operation.	a	(6) b
23	Skill level requirements for operator of MSD MSD subsystem complexity ranking from 1 to 5	1	1
24	Training requirements for operator of MSD MSD subsystem complexity ranking from 1 to 5	1	1

(1) Residue is any by-product of normal MSD operation, disposal of which is regular operating task. Examples are ash produced by an incinerator, seal water used by vacuum pumps, wastewater or sludge held in a tank, evaporator residue, etc.

(2) Length of time required for disposal is the main factor considered; other factors are ease of access of area of MSD containing the residue, amount of residue to be disposed of, and ease of storing residue on board or taking it off vessel, as appropriate.

(3) By dumping overboard effluent which doesn't meet standards, flush oil, evaporator residue, air pollutants from incinerator, etc.

(4) Discharge requires operator attention.

(5) . Wash down of tank required.
. Navy has installed rinse nozzles in tank.

(6) Start discharge pump at wrong time.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E III - OPERABILITY

MSD CHT

Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	OPERABILITY Characteristics	OPERABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
25	Effect of MSD operation on vessel work routines/schedules (a) MSD operation has minimal or no effect on work routines/schedules. (1) (b) Effect of MSD operation on work routines/schedules is more than minimal (i.e., is moderate or extensive).	a	a
32	Availability of specialized or unique consumables/expendables required for MSD operation (a) No specialized or unique consumables or expendables required for MSD subsystem operation. (b) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from ship's inventory. (c) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from Federal Stock System. (d) Any specialized or unique consumables or expendables required for MSD subsystem operation are available from a commercial source.	a	a
33	Operating requirements for special or unique MSD support equipment (a) No special or unique support equipment required by MSD subsystem. (b) Some special or unique support equipment required by MSD subsystem; equipment requires only minimal and infrequent attention(2) to keep operational.(3) (c) Some special or unique support equipment required by MSD subsystem; requires more than infrequent attention to keep operational.(4)	a	(5) a

(1) By C.G. direction, (a) applies to all MSDs considered in this study.
(2) No more frequently than weekly with a duration not greater than 10 minutes; or more frequently than semi-annually with a duration of 2 hours.
(3) E.g., firefighting equipment, special transformers, ozone detector, bilge alarm.
(4) E.g., compressor installed to support MSD operation.

(5) . Might want combustible vapor detector for black water system (hot wire filament type with temperature sensor).
. Bilge alarm may be required.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHT

Sheet 1 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem
11	Hazard of contact with/spillage of toxic/dangerous substances(1) due to MSD inherent design	(2)	
	L - Likelihood of hazard		
	(a) No chance		a
	(b) Highly unlikely	b	
	(c) Fair to even chance		
	(d) Highly likely		
	S - Severity of hazard		
	(a) No resultant injury.		a
	(b) Results in injury of low to moderate severity requiring first aid or limited medical treatment.	b	
	(c) Results in severe injury or death.		
	C - Hazard correction		
	(a) Hazardous situation can be easily corrected.	a	a
	(b) Hazardous situation is difficult to correct.		
	(c) Hazardous situation cannot be corrected.		

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
    - Typhoid (bacteria)
    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - .. Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (form hands).

(2) Only by contact with sewage in commodes.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHT   Sheet 2 of 6

M/E Factor/ Subfactor Ident. No.	Characteristics	Attribute Data: Collect./Transp. Subsystem	Attribute Data: Treat./Disposal Subsystem
12	Hazard of contact due with/spillage of toxic/dangerous substances[(1)] due to procedural error/equipment failures of MSD	(2)	(3)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	b	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	b	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a

(1) Examples:

- Leakage of fumes from incinerator into adjacent berthing and working spaces.
- Hydrogen sulfide (a toxicant) may be generated in sewage holding tanks.
- Fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply with toxic/dangerous substances.
- Sewage contamination.
  - The following pathogens may be transmitted through sewage.
    - Tetanus (bacteria)
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    - Dysentery (bacteria)
    - Cholera (bacteria)
    - Hepatitis (virus)
    - Polio (virus)
  - Possible methods of infection (a healthy person may be a carrier; infection hazard depends on a person's resistance).
    - Oral (from hands while smoking or eating) - the most common method of transmitting enteric (intestinal) diseases.
    - Through breaks in skin (cuts, abrasions, sores).
    - Eyes and nose (from hands).

(2) If commode breaks

(3) . Overfilling tank may result in backup of sewage
. Hydrogen sulfide may be generated in sewage holding tank.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHT

Sheet 3 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem
21	Hazard of explosive potential for operator/maintainer due to inherent MSD design		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a
22	Hazard of explosive potential for operator/maintainer due to procedural errors/ equipment failures of MSD		(1)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	b
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	b

(1) . If aeration fails, black water tank may go septic and produce explosive gases.
. Might install air sensor
. If diffusers are clogged, they can readily be pulled up out of tank for cleaning.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHT Sheet 4 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data: Collect./Transp. Subsystem	SAFETY Attribute Data: Treat./Disposal Subsystem
31	Hazard of fire ignition potential(1) due to inherent MSD design		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a
32	Hazard of fire ignition potential(1) due to procedural errors/equipment failure of MSD		(2)
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited (c) Results in severe injury or death.	a	b
	C - Hazard correction (a) Hazardous situtation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	b

(1) Oil used for flushing is not flammable under ordinary conditions. However, at high temperatures, e.g., in the presence of a fire, it will support combustion.

(2) . If aeration fails, black water tank may go septic and produce explosive gases.
. Might install air sensor.
. If diffusers are clogged, they can readily be pulled up out of tank for cleaning.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHT

Sheet 5 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data Collect./Transp. Subsystem	SAFETY Attribute Data Treat./Disposal Subsystem
4	Hazard of electrical shock potential(1) for operator/maintainer of MSD		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	b
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a
51	Physical hazards associated with MSD due to sharp edges(2)		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first air or limited medical treatment. (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a

(1) Electric shock may result in severe burns and/or death; in addition, reaction to electric shock may casue affected individual to be thrown aside, possibly subjecting him to severe impact injuries and/or contact with sharge edges/hot surfaces.

(2) Combined effect of injury due to sharp edges/points and sewage contamination may introduce harmful pathogens into the bloodstream of an affected individual.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E IV - PERSONNEL SAFETY

MSD CHT

Sheet 6 of 6

M/E Factor/ Subfactor Ident. No.	SAFETY Characteristics	SAFETY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
52	Physical hazards associated with MSD due to hot surfaces		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	a
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment. (c) Results in severe injury or death.	a	a
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a
53	Physical hazard for maintainer of MSD due to rotating machinery		
	L - Likelihood of hazard (a) No chance (b) Highly unlikely (c) Fair to even chance (d) Highly likely	a	b
	S - Severity of hazard (a) No resultant injury. (b) Results in injury of low to moderate severity requiring first aid or limited medical treatment (c) Results in severe injury or death.	a	b
	C - Hazard correction (a) Hazardous situation can be easily corrected. (b) Hazardous situation is difficult to correct. (c) Hazardous situation cannot be corrected.	a	a

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD CHT Sheet 1 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
11	Habitability problems(1) associated with bacterial contamination due to MSD inherent design (a) There is no bacterial contamination habitability problem due to MSD subsystem inherent design features. (b) There is a bacterial contamination habitability problem due to MSD subsystem inherent design features.	a	a
12	Habitability problems(1) associated with bacterial contamination due to procedural errors/equipment failures of MSD(2) (a) A bacterial contamination problem due to procedural errors/equipment failures of MSD subsystem is highly unlikely. (b) Procedural errors/equipment failures of MSD subsystem are likely to cause a bacterial contamination problem	a	a
21	MSD fixture comfort (a) Commodes and urinals are comfortable and easy to use even under ship's motion. (b) Commodes and urinals are not comfortable and easy to use under ship's motion.	a	N/A
22	Flushing procedure requirements for MSD fixture (a) There are no "non-standard" requirements for flushing. (b) There are "non-standard" requirements for flushing.	a	N/A
23	Waste retention in MSD commode bowl (a) The amount of waste that remains in the bowl after flushing is less than that remaining after flushing a standard full water flushed fixture. (b) The amount of waste that remains in the bowl after flushing is the same as that remaining after flushing a standard full water flushed fixture. (c) The amount of waste that remains in the bowl after flushing is more than that remaining after flushing a standard full water flushed fixture.	b	N/A

(1) As distinguished from problems of health and safety; likely psychological reactions of users are a matter for consideration.

(2) A vacuum waste collection subsystem is less likely to expose personnel to sewage in case of a line break than a pressurized waste collection subsystem; fresh water connections to MSD subsystems have a potential for contaminating the vessel's potable water supply.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V - HABITABILITY

MSD CHT

Sheet 2 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
24	Likelihood of user contact[1] with MSD fixture flushing medium (a) User is unlikely to come into contact with flushing medium. (b) User is more likely to come into contact with flushing medium than with standard water flushed fixture.	a	N/A
25	Appearance of MSD fixture flushing medium (a) The color and general appearance of the flushing medium is as acceptable as clear water. (b) The color and general appearance of the flushing medium are acceptable, but clear water is preferable. (c) The color and general appearance of the flushing medium are not acceptable.	a	N/A
26	Noise produced in flushing MSD fixtures (a) The noise produced in flushing fixtures is less than that of a standard commode/urinal. (b) The noise produced in flushing fixtures is the same as that of a standard commode/urinal. (c) The noise produced in flushing fixtures is greater than that of a standard commode/urinal.	b	N/A
31	Odors produced as a result of inherent MSD design (a) The MSD subsystem produces no odor as a result of inherent design. (b) The MSD subsystem produces a noticeable odor as a result of inherent design.	a	(3) b
32	Odors produced as a result of procedural errors/equipment failures of MSD (a) The MSD subsystem produces no odor as a result of procedural errors/equipment failures. (b) The MSD subsystem produces a noticeable odor as a result of procedural errors/equipment failures.	(4) b	(3) b
41	Heat generation for nearby personnel[2] due to inherent MSD design (a) As a result of inherent design features, the MSD subsystem does not generate enough heat to render its vicinity hotter than most shipboard areas containing machinery. (b) As a result of inherent design features, the MSD subsystem does generate enough heat to render its vicinity hotter than most shipboard areas containing machinery.	a	a

(1) Due to flushing medium composition, fixture design, motion of vessel (which may cause splatter splashing, or spillage of flushing medium).
(2) For operator/maintainer/adjacent berthing and working areas.

(3) Low intensity odor for tanks: "not a bad odor".
(4) In the event leakage occurs.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E V- HABITABILITY

MSD CHT

Sheet 3 of 3

M/E Factor/ Subfactor Ident. No.	HABITABILITY Characteristics	HABITABILITY Attribute Data Collect./Transp. Subsystem	 Treat./Disposal Subsystem
42	Heat generation for nearby personnel[1] due to procedural errors/equipment failures of MSD. (a) The MSD subsystem does not generate enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery. (b) The MSD subsystem does generation enough heat as a result of procedural errors/equipment failures to render its vicinity hotter than most shipboard areas containing machinery.	a	a
5	Noise level for personnel in vicinity of MSD[1] NI - Noise Index (a) The MSD subsystem is silent or nearly silent. (b) Noise level of MSD subsystem is approximately equal to background noise level of vessel. (c) The MSD subsystem is very loud, produces constant noise, drowns out vessel background noise in immediate area of the system; must shout to be heard.	a	a
6	Vibration levels for nearby personnel[1] produced by MSD machinery VI - Vibration Index (a) MSD subsystem produces little or no perceptible vibration in addition to background level on vessel. (b) MSD subsystem produces perceptible vibration, but similar to vessel background. (c) MSD subsystem produces abnormal or disturbing intensity and/or frequency of vibration.	a	a
7	Effect of MSD on user housekeeping routines (restrictions on user imposed by subsystem[2]). (a) Subsystem characteristics do not impose restrictions on user. (b) Subsystem characteristics impose restrictions on user.	a	a

(1) For operator/maintainer/adjacent berth and working areas.

(2) E.g. . Must use water-soluble toilet paper which is not as comfortable as usual toilet paper.
. Must use special bowl cleaner which is less effective than usual cleaner
. Cannot dump detergents down galley sink; must store and off-load at shore.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VI - RELIABILITY

MSD CHT

Sheet 1 of 1

M/E Factor/ Subfactor Ident. No.	RELIABILITY Characteristics	RELIABILITY Attribute Data Collect./Transp. Subsystem	Treat./Disposal Subsystem
21	MSD complexity Complexity index of MSD subsystem based on a complexity ranking from 1 to 5.	1	1
23	Extent of MSD equipment/component redundancy(1) (a) There is some significant redundancy in the MSD subsystem's major components. (b) There is no significant redundancy in the MSD subsystem's major components.	(6) a	(7) a
24	Degree of equipment failure independence(2) (a) There is a high degree of equipment failure independence in MSD subsystem. (b) There is a moderate degree of MSD equipment failure independence in MSD subsystem. (c) There is a low degree of equipment failure independence in MSD subsystem.	a	(8) b
25	Adequacy of MSD equipment ratings (a) Most MSD subsystem equipments are overrated. (b) Some MSD subsystem equipment ratings are nominal, some are overrated. (c) Some MSD subsystem equipments are underrated, some are nominally rated. (d) Most MSD subsystem equipments are underrated.	b	b
26	Provisions for fault actuated cut-off mechanisms(3) for MSD protection (a) There are many fault actuated mechanisms in MSD subsystem, or they are not required.(4) (b) There are some fault actuated mechanisms in MSD subsystem. (c) There are no or almost no fault actuated mechanisms in MSD subsystem.	a	(9) b
3	Reliability risk for MSD(5) (a) MSD subsystem has a history of fair or better test results. (b) MSD subsystem has a history of poor test results. (c) No test results are available for MSD subsystem.	a	a

(1) Any redundancy in electronic circuitry is not considered.
(2) I.e., failure of one item will not result in failure of major component or subsystem.
(3) Includes mechanisms to: (i) alert operator/maintainer to high stress or abnormal conditions that will result in failure, and/or (ii) to correct those conditions or turn off equipment.
(4) E.g., standard commodes and urinals in a gravity drain sewage collection subsystem do not require fault actuated cut-off mechanisms.
(5) E.g., innovative design, experience.

(6) Fixtures, if more than one.
(7) Pumps.
(8) If compressed air goes off, diffuser could get coated and air will not flow again until diffuser is repaired.
(9) High level liquid sensor; extra high level alarm.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD CHT Sheet 1 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data: Collect./Transp. Subsystem	MAINTAINABILITY Attribute Data: Treat./Disposal Subsystem (5)
131	Accessibility of replaceable MSD components (a) High degree of accessibility in MSD subsystem components. (b) Moderate degree of accessibility in MSD subsystem components. (c) Low degree of accessibility in MSD subsystem components.	a	b
132	Extent of MSD modularization for ease of repair/replacement (a) High degree of MSD subsystem modularization. (b) Moderate degree of MSD subsystem modularization. (c) Low degree of MSD subsystem modularization.	a	b
133	Degree of MSD repairability on board vessel.(1) (a) All MSD subsystem items are repairable on vessel. (b) Some MSD subsystem items are repairable on vessel; some must be replaced. (c) All MSD subsystem items must be replaced.	a	a
134	Availability of manufacturer field support and training programs for MSD (a) Manufacturer field support and a training program is available. (b) Manufacturer field support(2) is available but no training program is available. (c) Manufacturer training program is available but field support is not available. (d) Neither field support nor training program are available from manufacturer.	a	a
142	Special/proprietary(3) item requirements for MSD equipment repair (a) No special items required for any MSD subsystem repairs. (b) Some special items required for some MSD subsystem repairs. (c) All items required for MSD subsystem repairs are special items.	a	a
23	Effect of MSD preventive maintenance on watchstander routines (a) No effect on watchstander routines.(4) (b) There is some effect on watchstander routines.	a	a
33	Special docking requirements for MSD overhauls (a) There are no special docking requirements for the MSD.(4) (b) There are special docking requirements for the MSD.	a	a

(1) Versus necessity for replacement of failed equipment.
(2) May include some limited training support during initial MSD installation.
(3) E.g., Incinerator pots, filters versus standard supply parts.
(4) By C.G. direction, this applies to all MSDs considered in this study.

(5) . Diffuser not very accessible.
. Level sensor pulls out easily.

MSD EFFECTIVENESS ATTRIBUTE DATA

M/E VII - MAINTAINABILITY

MSD CHT

Sheet 2 of 2

M/E Factor/ Subfactor Ident. No.	MAINTAINABILITY Characteristics	MAINTAINABILITY Attribute Data	
		Collect./Transp. Subsystem	Treat./Disposal Subsystem
4	Logistic requirements for MSD (a) No special parts are required for the MSD subsystem. (b) Few different categories of special parts are required for the MSD subsystem and there are few parts in each category. (c) Few different categories of special parts are required for the MSD subsystem but many parts of each type are required, or many different categories of special parts are required but there are few parts in each category. (d) Many different categories of parts are required for the MSD subsystem and there is a large number of parts in each category.	a	a

MSD OPERATING CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD CHT

Operational Requirement	LABOR: Scheduled Interval for Operational Activity (Hrs)	Time Required (Hrs - Min)	Number Operators/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	VESSEL RESOURCES USED — Resource Usage Rate: Electric Power (kwh/day)	Fuel Oil (gpd)	Fresh Water (gpd)	Power for Flushing water (kwh/day)	Compressed Air (SCF/day @ P)**	Annual Cost of Resource Consumed: Electric Power (@ ¢/kwh)	Fuel Oil (@ 39¢/gal)	Fresh Water (@2¢ & 0.07¢/gal)*	Power for Flushing Water (@ 1.24¢/1000 gal)	Compressed Air ***	MATERIALS CONSUMED: Materials Required	Rate of Usage	Cost of Material	Annual Cost of Consumed Materials	TOTAL: Annual Operating Cost ($)
C/T SUBSYSTEM																					
COLLECTION SUBSYSTEM (For Black Water only)																					
Flush Commode (by user)										0.0025^k/c				4.0^k/c							43.54/c 1.57/c
Flush Urinal (by user)										0.001^k/c				1.6^k/c							18.27/c 0.66/c
T/D SUBSYSTEM																					
HOLDING AND DISPOSAL SUBSYSTEM																					
Mode changeover cycle*****																					
. Primary - overboard	-	-10	1-MK2	6.27	0.17/cy	1.05/cy															1.05/cy
. Pierside - Primary	-	-10	2-MK2	6.27	0.33/cy	2.09 cy	(required for hose handling) ****														2.09/cy
Tank pumpout (automatic)																					
Monitor liquid level in holding tank	24	-10	1-MK3	6.84	60.83	416.10															416.10
Aerate black water holding tank											to be calc., see below					to be calc., see below					to be calc.
																					515.64

* 2¢/gal. for vessel generated fresh water and 0.07¢/gal for stored fresh water.

** Compressed Air Flow: Minimum SCF/day = 23.47 (gal.) at p = 0.434D.

*** Compressed Air Cost in ¢/year = $[143.699\ (14.7 + 0.434D)^{0.1429} - 210.99\ (gal)]$

SCF = standard cubic feet @ 14.7 psi and 70^0F
D = maximum liquid depth in feet
gal = maximum liquid volume in gallons
P is in psig

**** Electric Power = 0.0006095 Q
Where Q = waste generation rate (gal/day)

***** These values are applicable only to a CHT system. Mode changeover values for a system which uses a holding tank is to be determined by its collection/transport subsystem.

/c = per capita
/cy = per cycle

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MSD PREVENTIVE (SCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD CHT

Page 1 of 1

LABOR							PARTS CONSUMED				TOTAL
Preventive Maintenance Requirement	Scheduled Interval for Maintenance Action (Hrs)	Estimated Time Required (Hrs.Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Annual Labor Required (Man-Hrs)	Annual Cost of Labor ($)	Spare Part Required	No. of Parts Used/Year	Cost of Each Part ($)	Annual Cost of Parts ($)	Annual Preventive Maintenance Cost ($)
C/T SUBSYSTEM											
COLLECTION SUBSYSTEM (for Black Water only)											
None											
T/D SUBSYSTEM											
HOLDING AND DISPOSAL SUBSYSTEM											
Clean aeration diffusers in black water holding tank*	2190	1-30	2-MK2	6.27	12.0	75.24					75.24
Clean compressed air filter element*	168	-15	1-MK2	6.27	13.0	81.51					81.51
Clean and calibrate liquid level sensor	2190	-30	1-MK3	6.84	2.0	13.68					13.68
Lubricate discharge pump motor bearings	2190	-15	1-MK2	6.27	1.0	6.27					6.27
Adjust pump packing glands	2190	-20	1-MK2	6.27	1.33	8.36	Packing ring	8	0.50	4.00	12.36
Clean fan, fan shield and body fins of pump motors	4380	-30	1-MK2	6.27	1.0	6.27					6.27
TOTALS					30.33	191.33		8		4.00	195.33

* Not applicable to gray water holding tank.

MSD CORRECTIVE (UNSCHEDULED) MAINTENANCE CHARACTERISTICS AND COST ESTIMATES
(Based on 100% Utilization Factor)

MSD CHT

Corrective Maintenance Requirement	LABOR: Estimated Time Between Failures (Hrs)	LABOR: Estimated Time Required (Hrs-Min)	LABOR: No. Maintainers/ Skill Level	LABOR: Assumed Labor Rate ($/Hr)	LABOR: Annual Labor Required (Man-Hrs)	LABOR: Annual Cost of Labor ($)	PARTS CONSUMED: Spare Part Required	PARTS CONSUMED: Estimated No. of Parts Used/Year	PARTS CONSUMED: Cost of Each Part ($)	PARTS CONSUMED: Annual Cost of Parts ($)	TOTAL: Annual Corrective Maintenance Cost ($)
C/T SUBSYSTEM											
COLLECTION SUBSYSTEM (for Black Water only)											
Replace flushometer internals	17520	-6/unit n	1-MK2 n	6.27	0.05/unit	0.31/unit	Flushometer internals	0.5/unit	7.00/unit m	3.50/unit	3.81/unit
Clean out salt cake deposit in drain piping	2190	-1-	1-MK4	7.42	4.0	28.80					28.80
T/D SUBSYSTEM											
HOLDING AND DISPOSAL SUBSYSTEM											
* Replace aeration diffuser in black water tank (6)	4380	-40	2-MK2	6.27	2.67	16.72	Diffuser	2	20.00 m	40.00	56.72
* Replace compressed air filter element	2190	-10	1-MK2	6.27	0.67	4.18	Air filter element	4	10.00 m	40.00	44.18
Replace liquid level sensor (2)	4380	-15	1-MK3	6.84	0.5	3.42	Level Sensor	2	60.00 m	120.00	123.42
Repair discharge pump/motor - (4) - replace:											
. impeller	4380	-20	1-MK4	7.42	0.67	4.95	Impeller	2	20.00 m	40.00	44.95
. gland packing	2190	-20	1-MK4	7.42	1.33	9.89	Packing and gland	4 sets	5.00 m	20.00	29.89
. motor bearings	6570	1-	1-MK5	8.13	1.33	10.84	Motor bearing	1.5	8.00 m	12.00	22.84
Replace motor starter (4)	6570	-10	1-EM4	6.50	0.22	1.44	Motor Starter	1.5	30.00	45.00	46.44
TOTALS	11 17				4.05 7.39	30.54 51.44		11 17		237.00 317.00	368.44

* Not applicable to Gray Water.

MSD MAJOR OVERHAUL CHARACTERISTICS AND COST ESTIMATES

MSD CHT

Overhaul Requirement	LABOR: Time Between Overhauls (Yrs)*	Estimated Time Required (Hrs-Min)	No. Maintainers/ Skill Level	Assumed Labor Rate ($/Hr)	Total Labor Required (Man-Hrs)	Total Cost of Labor ($)	PARTS CONSUMED: Part Required	No. of Parts Required for Overhaul	Cost of Each Part ($)	Cost of Parts for Overhaul ($)	TOTAL: Major Overhaul Cost ($)
C/T SUBSYSTEM											
COLLECTION SUBSYSTEM (for Black Water only)	2										
Replace flushometer internals		[a]-6 /unit	1-MK2[a]	6.27	0.10/unit	0.63/unit	Flushometer internals	1/unit	7.00/unit	7.00/unit	7.63/unit
Clean out salt cake deposit in drain piping		16-	2-MK4	7.42	32.0	237.44					237.44
T/D SUBSYSTEM											
HOLDING AND DISPOSAL SUBSYSTEM	2										
Clean inside of holding tank including aeration diffuse.. in black water holding tank		{ 8- 16-	1-MK2 1-MK3	6.27 6.84	8.0 16.0	50.16 109.44					50.16 109.44
Repack pump glands		1-	1-MK4	7.42	1.0	7.42					7.42
Lubricate pump motors		-20	1-MK2	6.27	0.33	2.09					2.09
Clean fan, fan shield and body fins of pump motor		1-	1-MK2	6.27	1.0	6.27					6.27
Clean liquid level sensors		1-	1-MK2	6.27	1.0	6.27					6.27
TOTALS					27.33	181.65					181.65

** Same figures used for black and gray water tanks.

* Since overhaul information was not available from manufacturer for all subsystems and capacities, a 2 year overhaul interval is assumed for all subsystems.

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APPENDIX A

DEFINITIONS OF OPERATING/MAINTENANCE ACTIVITIES

The definitions of operating and maintenance activities given below will help provide objectivity in selecting the category into which a personnel action fits. There are some actions however, that require subjective judgment, for which guidelines are given.

Operation (OP)

There are two groups of activities in this category. The first group is necessary for system operations; such as:

- Manual actuation of a switch or valve
- Sequencing of subsystems or component processes, e.g., servicing of evaporator when full
- Obtaining readouts to assure safety, performance or sequencing
- Addition of a critical expendable or making a critical adjustment, without which action some function does not take place.

The second group is necessary to have the system perform according to minimum criteria. Without these actions the quantity or quality of the system process is degraded, e.g. throughput decreases or the effluent is not purified sufficiently. The criteria for these activities is that failure to do them will cause performance degradation, in quantity or quality, but will not cause a greatly accelerated wear out or failure of a component. The same type of activities listed for the first group would apply to the second group except that the activity is not critical, i.e., the system will function, but in a degraded mode. One example is the removal of ashes from an incinerator. Failure to remove them can cause air pollution, decreased combustion efficiency and a rise in ash accumulation rate.

Preventive Maintenance (MP)

Preventive maintenance is a scheduled or conditionally scheduled action that is designed to prevent early component failure or unduly rapid wear out. Failure to take the action does not generally affect system performance, e.g. "Lubricate motor bearings". The motor will continue to maintain system performance for some period of time even without lubricant. Early bearing failure would be expected because of the omitted PM action. Preventive maintenance for multiple items, e.g., commodes, directs the action to all of the items.

A conditional action is a two step procedure, whether stated as such or not, where the second step depends upon the condition found in step one. Example: "Add lubricating oil to raise level up to scratch mark, once a week." Step one is implied, i.e. once a week, check level of lubricating oil and step two is the oil addition. This is different from the single step example above since no examination is required before lubrication of the bearings. Conditional action statements often use the phrase "if necessary", but should not be confused with combined preventive/corrective maintenance statements discussed below.

Corrective Maintenance (CM)

Corrective maintenance is the repair or replacement of a defective or failed component. It is a random occurrence and is therefore unscheduled. It includes diagnostic time to locate a fault and the check out after repair. Where a CM action addresses multiple units, e.g., commodes, the action is concerned only with the one failed item. The failure interval will depend on the number of multiple units.

The definition of failure can be subjective, arbitrary, continously variable,functional and/or logical based upon the effects of degraded performance. Whether a failure is critical or of minor consequence to the overall system may help determine the failure criteria and establish the priority for the corrective action but once the criteria is set, it alone determines if the action is corrective. Example: A nickel-cadmium battery in an alarm circuit has failed when the open circuit voltage drops below 1.1 volts. This is the criteria, however arbitrary or logical. Even though the battery could still actuate the alarm buzzer at 1.05 volts, it is still considered failed below 1.1 volts.

Confusion often arises out of combined preventive-corrective maintenance statements which should be kept separate. For example: "Check battery voltage quarterly and replace with recharged battery when open circuit voltage is below 1.1 volts." Quarterly battery checks are preventive maintenance actions. Replacement of the battery is the corrective maintenance action.

An often encountered dilemma that requires a subjective decision for classification is the impending failure that causes performance degradation during a short time interval before component failure. Examples are: a slipping V-belt causing decreased pump output, an unoiled rotary vane vacuum pump pulling a diminished vacuum. In a short time the belt will break and the vanes will freeze up; both are failures. The difficulty in classifying these situations is anticipating when the discovery will take place. This is a problem for the analyst doing a cost estimate. For the on-site personnel, the time of discovery determines the type of action; i.e., if the belt is still slipping at the time for scheduled belt adjustment, he performs PM. If it has already failed, it becomes a CM action. If discovery is not at a scheduled time, belt adjustment could be considered an OP action.

Overhaul (OH)

Overhaul is a general cleaning and refurbishment of a system. It has elements of both preventive and corrective maintenance in it. It is scheduled, usually at intervals much longer than any preventive maintenance actions. It permits low priority corrective actions to be carried out. The criteria for replacements are often different or have different values than for corrective maintenance. An obvious additional criterion is the question of a part lasting until the next overhaul. Overhaul often includes diagnostic examinations that are too involved or require too much equipment to be performed more frequently. It also includes upgrading components or performance capability by substitution of improved parts or modification kits. It is difficult to anticipate the development of improvements to a system and therefore none is included in the estimates.

Reclassification/Subjective Classification of PM and OP

Frequency of an action may be sufficient reason for reclassification. Daily preventive maintenance (PM) actions could reasonably be called operational (OP) activities. One example is the daily lubrication of a plastic cam and follower in the Grumman system ozone detector. Failure to do so will cause accelerated wear out which ordinarily would be a PM action.

An example of the reverse situation is the low frequency of adjustment (e.g., semi-annual) of the temperature control set point for an incinerator. Too low a temperature would degrade system performance, an OP action. Because the frequency is so low, the action could reasonably be classified as PM. Classification of activities with intermediate frequencies will require subjective decisions.

Another reason for changing PM to OP is that the action is dependent upon component operational status e.g. the incinerator must be off and cool or the evaporator must have just been emptied. The action is not critical enough to shut down the incinerator or empty the evaporator but can await a suitable operational status.

APPENDIX B

COST OF VESSEL RESOURCES

The resources of a vessel are those supplies that are stored or generated for general use. Of all resources that are or might be available on board, this analysis is concerned only with those that are required by the MSDs, namely:

- Fuel oil
- Electric power
- Fresh water
- Compressed air
- Ventilation air
- Cooling water

The costs that were assigned to these resources by the Coast Guard are:

- Fuel oil - 30¢ per gallon
- Electric power - 3¢ per kilowatt-hour. This is derived from a fuel consumption rate of 0.075 gals/kw-hr for electric power generation. This rate is based on data for diesel driven generator sets with rated output of 200-400 kilowatts, at 1800 RPM, direct-connected, 450 volt, 3 phase, 60 cycle A.C. generators.[1] This does not include the cost of acquisition, installation, maintenance, labor, depreciation, etc.

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[1] "Marine Engineering," edited by Roy L. Harrington, Society of Naval Architects and Marine Engineers, 1971, pg. 611, figure 2.

- Fresh water
  - .. 70¢/1000 gallons when using stored water supplied by shore facilities.[1]
  - .. $20/1000 gallons (2¢/gallon) when generated on board by an evaporator.[2]
- Power consumed in pumping of water - $P = 0.0007314\ pq$, where

  P is power in kilowatts

  p is pressure in psig and is to be assumed as 50 psig for flushing commodes

  q is flow in gpm

- Power consumed in compression of air - $P = 0.492592\ (r^{0.1429} - 1)$, where

  P is power in kilowatts

  V_1 is inlet flow in CFM

  r is the compression ratio

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[1] Following data obtained from LCDR Wilkinson, Public Works Officer at 3rd Coast Guard District, and City of New York. Based on water rate charged by City of New York for commercial customers (i.e., Governors Island).

$$\$0.525/100\ ft^3 \times \frac{1\ ft^3}{7.48\ gal} = \$0.0007018/gal$$

[2] Based on data obtained from Mr. Warren Dietz, Naval Engineering at CG Headquarters.

Power Consumption and Associated Cost of Pumping Flush Fluid

The power and cost of pumping flush medium is derived in the following manner. The power required for pumping water is:[1]

$$P = \left[\frac{pq}{1714\ Ep}\right]\left[\frac{0.746}{Em}\right]$$

where: P = power in kilowatts
p = head in psi
q = volume flow rate in gpm
0.746 = conversion factor from hp to kw
1714 = conversion factor for units
Ep = pump efficiency in decimal
Em = motor efficiency in decimal

Assuming Ep = 0.70
Em = 0.85

$$P = 0.0007314 \frac{kw}{psi \times gpm} \quad (p\ q)$$

This equation is converted for convenience in calculation to:

$$P = 0.0007314 \times 50(psi) \quad (q) \quad \frac{hr}{60\ min}$$

$$E = 0.0006095 \frac{kwh}{gal} \times Q$$ where E = energy in kilowatt hours per day

Q = flow in gallons per day =

$$q \times 1440 \frac{min}{day}$$

The cost to pump flush water is:

$$E = 0.0006095 \frac{kwh}{gal} \times \frac{3¢}{kwh} \times \frac{1000}{thousand} \times Q'$$

C = 1.83¢ (/1000 gal) x Q' where C = cost in ¢

Q' = flow in thousands of gallons

The cost of three cents (3¢) per kilowatt hour is assumed by the USCG for both vessel generated and shore supplied electricity.

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[1] "Marine Engineering," edited by Roy L. Harrington, Society of Naval Architects and Marine Engineers, 1971, pg. 408, equation #17.

Power Consumption and Associated Cost of Compressed Air

The power and cost of generating compressed air is derived in the following manner. The equation for adiabatic compression in a multi-stage compressor with perfect intercooling is:[1]

$$P = \frac{144}{33,000} (n) \left(\frac{k}{k-1}\right) p_1 V_1 \left[r^{\left(\frac{k-1}{nk}\right)} - 1 \right] \left[\frac{0.746}{Ec\ Em} \right]$$

where:

where:	P	= power in kilowatts
	n	= # of stages
	k	= exponent for adiabatic compression = 1.4 for air
	p_1	= initial pressure in psia
	r	= compression ratio = P2/p1
	p_2	= discharge pressure in psia
	V_1	= actual volume flow rate at p_1 in cfm
	0.746	= conversion factor from hp to kw
	Ec	= compressor efficiency in decimal
	Em	= motor efficiency in decimal

Assuming:

n	= 2 stages
k	= 1.4
p_1	= 14.7 psi (standard atmosphere pressure)
Ec	= 0.80
Em	= 0.85

$$P = 0.492592\, V_1 [r^{0.1429} - 1]$$

This equation is converted into more convenient forms by using the two relationships:

$$V_1 = \frac{V}{1440 \frac{\text{min}}{\text{day}}}$$ where V = standard cubic feet per day (SCF/day)

$$r = \left(\frac{P_2}{P_1}\right)_{\text{absolute}} = \frac{P + 14.7}{14.7}$$ where p = gage pressure (psig)

$$\left(r^{0.1429} - 1\right) = \left[\left(\frac{p + 14.7}{14.7}\right)^{0.1429} - 1\right] = \left[\frac{(p + 14.7)^{0.1429} - 1.46828}{1.46828}\right]$$

[1] "Marine Engineering," edited by Roy L. Harrington, Society of Naval Architects and Marine Engineers, 1971, pg. 440-444.

By substitution:

$$P = 0.492592 \frac{V}{1440} \left[\frac{(p + 14.7)^{0.1429} - 1.46828}{1.46828} \right]$$

$$P = \left[2.329786 \times 10^{-4} (p + 14.7)^{0.1429} - 3.420778 \times 10^{-4} \right] \left[V \right]$$

Using the assumed cost of electricity as 3¢/kwh, the annual cost of compressed air is derived.

$$C = P\ (kw) \times \frac{3¢}{kwh} \times 365 \frac{day}{year} \times 24 \frac{hr}{day} = P\ (kw) \times 2.6280 \times 10^{4}$$

$$C = \left[6.12268\ (14.7 + p)^{0.1429} - 8.9898 \right] \left[V \right]$$

where C = cost in ¢/year
V = flow in SCF/day
p = pressure in psig

For compressed air costs in aerating a black water holding tank, the gage pressure in psig is taken as 0.434D where D is the maximum vertical depth of the liquid in feet, and the flow is 16.3 SCFM (23,472 SCF/day) per 1000 gallons measured when the holding tank is full.

* U.S.G.P.O. 727-100/1302-1664