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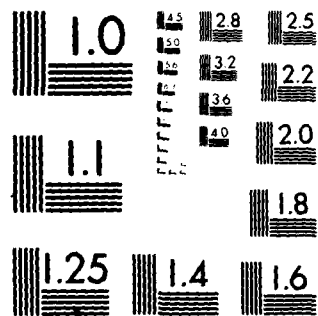
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NAVAL ARCHITECTURAL RESEARCH FOR WOMEN ABOARD SHIP

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A N A C T I V I T Y O F T H E N A V A L M A T E R I A L C O M M A N D

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proportion of the women assigned aboard Navy ships may experience problems due to working in an environment sized for males. *This*

The present report describes the approaches taken to establish the extent of the problems female personnel have aboard ship. *Initial emphasis focused*

The initial emphasis has been to focus on areas of potential hazard which may create unsafe operating conditions by jeopardizing the safety and well-being of either the female crew member or the vessel itself.

The results to date have identified problem areas of ship fittings and ship systems equipment (damage control) which, when used by female and smaller male personnel, cause seriously degraded performance at critical periods. Factors which contribute to these difficulties include differences in grip strength, upper torso strength and reach envelope.

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OBJECTIVE

Identify the extent of problems faced by women serving aboard ships, brought about by their working in an environment sized for males.

RESULTS

The greatest problems have been identified in the areas of shipfittings and ship system equipment (damage control) which, when used by female and smaller male personnel, cause seriously degraded performance at critical periods. Factors which contribute to these difficulties include differences in grip strength, upper torso strength and reach envelope.

RECOMMENDATIONS

1. Develop a more substantial qualitative data base through continuation of the problem identification effort.
2. Make critical assessments of equipment fit, as well as performance measures derived from samples of males and females during simulated damage control and firefighting exercises.
3. Prepare a data base management system for the storage and retrieval of male-female anthropometric, biomechanical and ergonomic difference literature.
4. Expand the literature search to include an evaluation of cognitive differences in performance which impact Navy performance.
5. Conduct an analysis of the significance of these differences with respect to potential C³ applications and design an experimental paradigm to evaluate the utility of the differences in a relevant shipboard C³ mission.

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INTRODUCTION

Following World War II, Congress passed legislation which provided guidelines for the assignment of women in the military (Women's Armed Services Integration Act, 1948). This act limited shipboard assignment of women to hospital and transport vessels.

In 1972, an increased awareness of the practical utilization of females aboard ship was compelled by Z-GRAM 116 from the office of CNO. This awareness ultimately resulted in the USS SANCTUARY study, a pilot program in which the performance of 145 (120 enlisted, 25 officer) female personnel was assessed aboard a hospital ship.

A final report on the project concluded that females were a decided asset aboard ship. Enlisted females generally performed at higher levels than their male counterparts and committed fewer disciplinary acts. It should be noted that these conclusions were based upon an analysis of the CO's reports, rather than upon data derived from actual job performance measures.

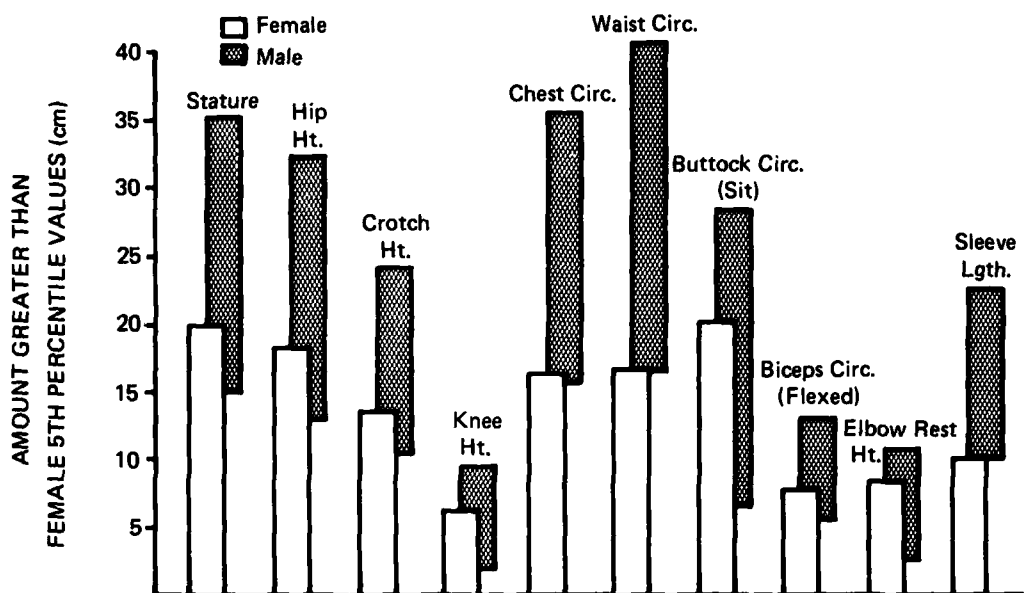
Subsequently, Federal Code Section 6015 was modified to permit women to serve on a broader range of Naval vessels (tenders, auxiliaries, support vessels). In the spring of 1979 (SECNAV INST 1300.12, April 1979), new female enlistees were no longer given the option of serving aboard ship; e.g., sea duty became mandatory for all Naval personnel, regardless of sex.

With the increased opportunities for a wider range of assignments aboard ship for female personnel, CNO tasked NAVSEA to prepare selected Naval ships to accommodate them. (The U.S. Coast Guard had already integrated their WHEC-class cutters with 10 enlisted women and 2 officers by mid-1977).

NAVSEA 3211 became the responsible agent to develop the appropriate ship alterations required to accommodate future female sailors. Ship alteration plans were developed to provide living/privacy spaces aboard 55 selected vessels. To date, 26 ships have been altered, and over 1,000 females are currently serving onboard these altered vessels.

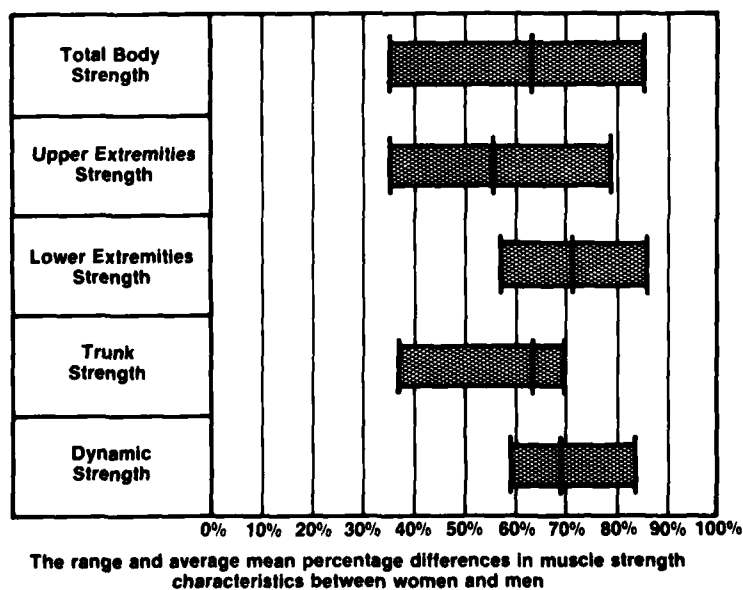
While the presence of women aboard ships is not expected to alter normal shipboard functioning, there are critical functions in emergency situations (e.g., general quarters, damage control, personnel survival) which are totally dependent on personnel performance. Until now, ship systems and equipment were designed for the 5th to 95th percentile male with respect to size and physical strength. Approximately 25 percent of the female population is smaller, lighter and weaker physically than the 5th percentile male. The size differences are depicted in figure 1, and overall strength differences are depicted in figure 2. Therefore, the introduction of women officers and enlisted aboard ships in FY 1979 has precipitated a need to examine existing shipboard systems, equipment and operations to determine the impact on mission requirements, system/equipment performance and personnel safety when used or operated by women.

In several preliminary NAVSEA-funded studies (Palla, et al, 1980; Advanced Marine Enterprises, 1980) it was determined that the lower percentile woman, with respect to size and strength, may have significant problems in operating/using emergency escape scuttles, oxygen breathing apparatus and personnel safety harnesses aboard ship. This can result in serious safety hazards for the female individual and for others who rely on the actions of the individual.



A comparison of 5th - 95th percentile male and female values for selected dimensions showing the range of differences and overlap between the two groups

Figure 1. Size comparison of male and female personnel.



The range and average mean percentage differences in muscle strength characteristics between women and men

Figure 2. The range and average mean percentage differences in muscle strength characteristics between women and men.

These previous reports were limited by the fact that they were based on a theoretical approach, relying on previously published data, etc. Missing was an empirical approach oriented toward determining what kinds of problems were evident based upon the experience women had aboard ship. In short, there was no systematic analysis of how well women were functioning aboard ship.

In the fall of 1979, NOSC Code 533 was tasked to develop a five-year, exploratory development (6.2) program to support the existing NAVSEA ONM Women Aboard Ships program. The objective of this research plan was to provide an analysis of the human engineering technology base necessary to insure the safe and cost effective utilization of women aboard ships (refer to Pepper, 1980).

OBJECTIVE

In the spring of 1980, NOSC was tasked by NAVSEA with the responsibility to determine the nature and extent of problems women may have as a result of working on-board ships which were designed to accommodate male size and strength dimensions. In particular, the emphasis on the first year's problem analysis was directed toward issues of personnel safety and survivability. This general plan is presented graphically in figure 3.

GENERAL PROGRAM PLAN

It can be seen that this plan is comprehensive in scope and the elements are interactive. The three main thrusts are:

- (1) Provide a data base which will support appropriate design guidance recommendations. This data base will include a comprehensive review of the literature and a comprehensive analysis of fleet operating problems. Initial data will be subjective, based upon questionnaires, interviews and on-site observations. As specific problem areas are identified, objective measures of performance will be obtained in critical tests designed to validate the subjectively determined problem areas.
- (2) Identify design features of shipboard equipment which pose problems when used by women. When sufficient information is available, prepare design recommendations and determine needs for human engineering design guidance. A preliminary assessment of these needs can be developed with existing knowledge about available size-strength differences and environmental factors aboard ship.
- (3) Develop design standards oriented toward shipboard equipment (at-sea environmental influences included). Determine male-female differences which influence equipment design.

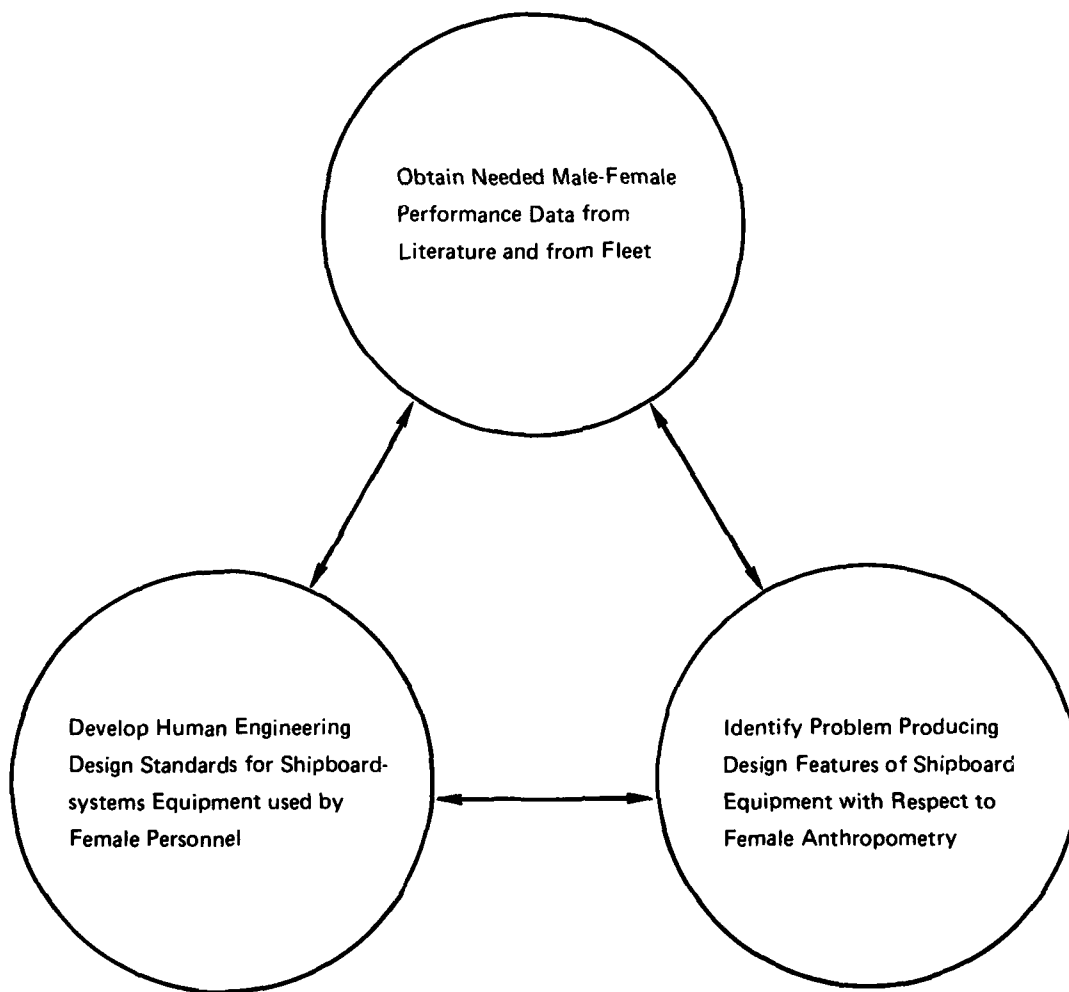


Figure 3. General program plan for Women Aboard Ships.

APPROACH

A specific course of action was developed by NOSC and is presented schematically in figure 4. It can be seen that this is a problem-centered approach which has both theoretical and empirical thrusts.

The first line of action is concerned with establishing a data flow from ships which currently utilize women as part of the ship's crew. As can be seen in figure 4, several methods to obtain data have been developed.

The first method is the development of a set of questions which has been appended to the Navy in Transition (N.I.T.) survey (Thomas, 1978) being conducted by NPRDC. The N.I.T. survey is concerned with the psycho-social factors involved in the integration of women in the shipboard environment. The questions developed for the Women Aboard Ship project are oriented toward hardware, equipment and environmental factors associated with work performance by women.

A second method employed to obtain information was to hold informal discussions with personnel from the Naval Training Command. Female personnel are required to attend both Firefighting and Damage Control school. Thus, an analysis of equipment and tasks employed in this context provided important additional information.

The third method involved the use of structured interviews and on-site observations conducted aboard ship, at the above-mentioned Navy training center, and at selected shore sites. Interview and questionnaire data are limited in that they provide subjective assessments (opinions) rather than objective measures of performance. Observational techniques can measure behavioral performance but are limited in both accuracy and reliability due to the necessarily limited sample sizes and observation periods involved. These techniques have the advantage of identifying and assimilating large amounts of data. Since our preliminary objective sought descriptive rather than cause-effect information, these methods were chosen as useful systems-oriented problem identification tools.

In order to supplement the problem identification efforts described above, a similar approach was initiated with the cooperation of the U.S. Coast Guard. This organization currently has four Hamilton Class WHEC 378-ft cutters with mixed male/female crews. Typically, two officers and 10 enlisted women serve among the ship's company of 130 personnel. In addition to being a combatant vessel (in time of national emergency), these frigate-sized cutters spend a significant portion of time on active patrol, often under difficult conditions (rough weather, temperature extremes, etc.) that are only infrequently experienced by U.S. Naval vessels. Also, SAR missions and fisheries inspection boardings require task evolutions which employ damage control equipment, deck operations in launching and recovery of small boats, and utilization of protective clothing and equipment. To complement the survey data, structured interviews were designed which directed the assessment to items of architectural design.

As described above, three methods were developed to acquire empirical information related to problems female personnel experience aboard ship (questionnaire, shipboard visits for observation and interview, actual observation during exercises and on patrol while at sea, NTC visits, etc.).

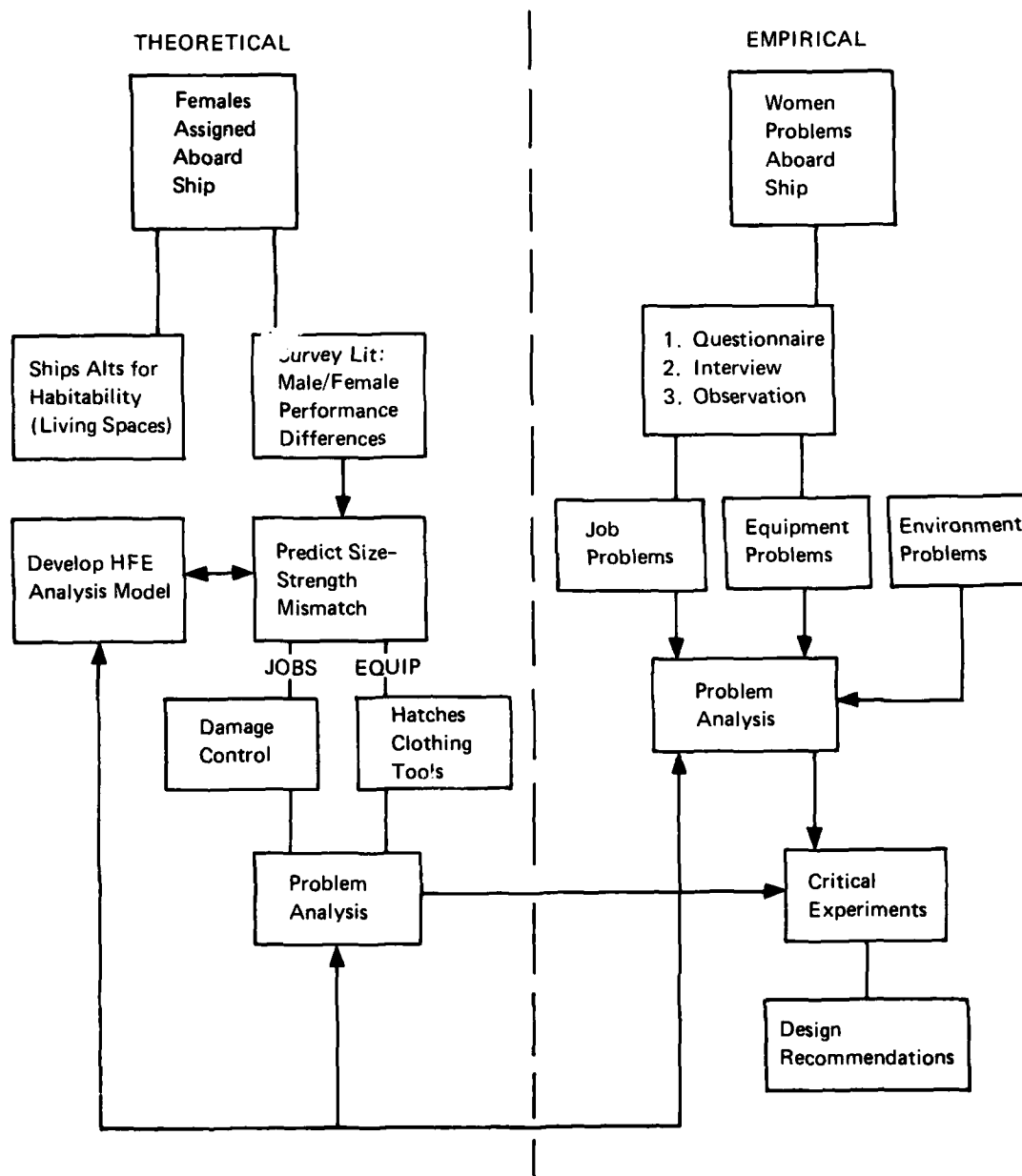


Figure 4. Flow chart for Women Aboard Ships tasks.

The theoretical thrust includes the development and application of a model to evaluate the empirical data. This model is task and equipment centered and will permit a comprehensive evaluation of selected problem areas, as identified by the data obtained from the Fleet, as well as from an analysis of current design guidelines with respect to female anthropometry.

In order to evaluate whether the concern about assigning females to ships that were designed with male-based standards had merit, it became necessary to evaluate the significance of these differences. A survey of the literature, with specific regard to performance differences resulting from psychomotor, physiological, psychophysical, cognitive motor/physical and social psychological factors, was initiated in FY 1980. See figure 5 for a graphic illustration of the literature review process.

The objectives of this literature review are: (1) to collect, review, critique, assemble and integrate pertinent literature regarding sex differences; and (2) to organize this literature relevant to the application of these sex differences to performance in shipboard situations. Therefore, this review sought to: (1) identify sex differences, (2) illustrate the potential effect of these differences in relation to outcomes in terms of performance levels, (3) determine the effect of these differences on the significant equipment/job design related impacts on performance aboard ship, and (4) identify priority areas for future research to resolve as yet unanswered questions.

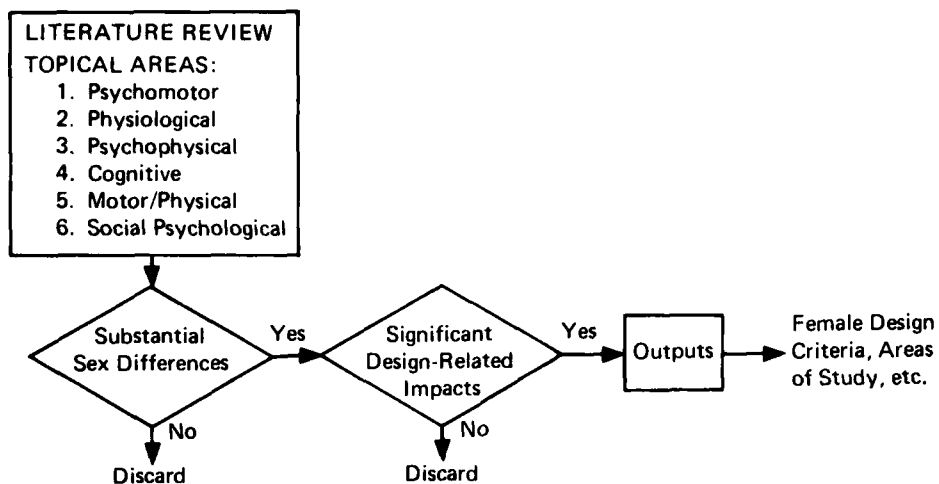
First, following in the wake of the work previously supported by NAVSEA, the forecasting or prediction of potential size-strength mismatches due to equipment design continues, with a focus on equipment and activities which potentially present the greatest hazard; i.e., damage control and firefighting.

A further course of action involved studying the state of literature concerning what is currently available to the naval architect with special regard for women. Thus, a task was identified to determine the needs to update a human engineering guide by surveying all human engineering standards and documents, evaluating the scope, and determining the gaps in knowledge for application to women populations.

PROGRESS

The tasks described generally in the Approach section are listed below, along with the progress made during the first year.

- (1) Develop methods to identify and obtain information about problems aboard ship. A report of the problem identification efforts has been completed and is described in detail in the following section. Much of the data analysis was developed by Mark D. Phillips of ISC and prepared in a progress report (see Phillips and Schneider, 1980).
- (2) Develop a Human Factors Engineering (HFE) model to evaluate shipboard tools, jobs and equipment. This task has been completed and is described in detail in appendix A, titled "Task Description and Analysis Methods for Women Aboard Ships Program" by R. H. Schneider and M. D. Phillips. This is a straightforward application of traditional human factors engineering techniques to shipboard gender-related performance problems.



MAJOR SUBTOPIC AREAS

Psychomotor	Physiological	Psychophysical	Cognitive	Motor/ Physical	Social/ Psychological
Reaction Time	Heart Rate	Vision	Verbal	Dexterity	Motivation
Temporal Judgment	Blood Pressure	Audition	Spatial	Anthropometry	Role Perception
Tracking Skills	Environmental	Olfaction	Arithmetic	Strength	Experience
Monitoring Skills	Sensitivity	Tactile/Cutaneous	Multi-channel	Endurance	Learning
Vigilance	Radiation	Temperature and Pressure Senses	Problem Solving	Explosive Coordination	
	Acceleration	Isolation	General Reasoning	Lifting	
	Low Freq. Radiation	Speech		Vibration	
	High Freq. Radiation			Age	
	Toxic Substances			Clothing	
	Drugs				
	Nutrition				
	Motion Effects				
	Altitude				
	Thermal				
	Energy Management				
	Stress				

Figure 5. Filtration process used in analysis of the literature.

- (3) Identify HFE guide needs related to female personnel. This task has been completed and the results of the effort are described in detail in appendix B in a report titled "Equipment Design Guidance Needs Related to the Assignment of Women Aboard Ships" (Phillips and Schneider, 1980). A human engineering guidance manual, tailored to the special needs of shipboard equipment designers, is outlined in this report. The unique combination of ship motion, temperature, precipitation and noise in the shipboard environment is discussed in terms of the impact on work output. The performance of physically-based tasks by female personnel is a major area of concern due to anthropometric and biomechanical differences. This combination of factors emphasizes the need for specialized human engineering and naval architectural guidance for future shipboard systems and ship acquisition.
- (4) A survey of the literature regarding male-female differences in performance was conducted. A decision was made early on to limit the initial effort to differences in anthropometrics, biomechanics and ergonomics. Relevant articles were abstracted and these abstracts then organized into a matrix relating the basic sex differences to performance characteristics. Each abstract was marked in the matrix to show whether there were no sex differences, whether sex differences were unproven by the study, or whether sex differences are unknown or inadequately tested. Previous work of Ayoub and his colleagues surveyed this area of the literature exhaustively up to 1978 (Ayoub, Grasely, and Bethea, 1978). The current review amplified and extended this work using a similar methodology.

PROBLEM IDENTIFICATION

The balance of this report is a detailed description of the problems currently experienced by female personnel when assigned shipboard duty. The emphasis is on the impact of male-female anthropometric differences as they appear to impact job performance. Rather than try to attempt to predict potential human engineering difficulties, this approach concentrated on identifying the problems which actually occur on-board. As described above, the techniques employed to obtain these "real world" data included questionnaires, observations, and interviews, both dockside and underway.

Methods of Data Gathering

Questionnaires. Questionnaires were administered aboard a sample of Naval and Coast Guard ships (appendix C contains a copy of the questionnaire). Additional data were extracted from questionnaires administered during the Occupational Physical Standards (OPS) project conducted by NPRDC personnel (Robertson and Trent, 1980). An analysis of the human engineering and human performance relevant data was conducted on a subset of the OPS generated data. This subset included only noncombatant vessels, since these are the only ships (except for special TAD assignments) in which women are currently assigned. Personnel in the occupational fields of general seamanship, marine engineering, ship maintenance, and their related apprenticeships were included in this subset.

Observations. Task observations were conducted aboard the USS DIXON (AS 37), the USS GRAY (FF 1054) and the USS O'CALLAHAN (FF 1051). The purpose of the visits is described in detail in a memo sent to each ship prior to the actual visit. This memo is attached as appendix D. All ships were in port for routine maintenance during observation times. Hull technicians (HT), boatswains mates (BM), machinist mates (MM) and mess management specialists (MMS) were observed performing a variety of tasks in their ratings. Observations also were conducted at Naval Damage Control (DC) school. At DC school, class A (solid substance), B (flammable liquid) and C (electrical) fires were simulated. Personnel were observed fighting these fires using the same equipment and protective gear issued aboard ship. Additional observations were made aboard the USCG Cutter MELLON (WHEC 717) and the USCG Cutter MUNRO (WHEC 722) while the vessels were underway. On the latter vessel, the observation period occurred during a nine-day patrol transit from Kodiak, Alaska to Honolulu, Hawaii. On the former vessel, observations were made while sonar tests were conducted in local Hawaiian waters.

Interviews. Formal and informal interviews were conducted with personnel at the observation sites listed under the Observations section (above). The people selected for interview included officers and enlisted male and female personnel. Officers in charge of deck, engineering, fabrications and supply division, executive officers and commanding officers were interviewed. Second class and third class BM's, HT's, MM's and MMS's as well as nonrated personnel also were interviewed. Informal interviews were conducted with selected personnel at the U.S. Navy Waterfront Operations Command located on the Kaneohe Marine Corps Air Station. This group operates small boats (LCM-6, WPB41) in support of the crash boat requirements for the air station. The command employs nine female engineers out of a complement of 20 enlisted and 1 officer. Additional interviews were conducted with the CO and XO of the USCG Cutter MORGENTHAU (WHEC 724). The interviews were informal. However, specific topics were identified prior to the interview session itself. Appendix E is provided to describe the interview procedures in detail.

Questionnaire Results

Questionnaire data were derived from three different sources. A survey was given on the USS SPERRY (AS 12) and the Coast Guard Cutter MELLON (WHEC 717). These data have been compiled and are presented in the first analysis. A similar survey was given on the USS DIXON (AS 37). The information contained in this questionnaire, while similar in content to the Sperry and Mellon survey, was different in format and emphasis. For this reason, a separate analysis was performed on these data. This is presented in the second analysis. The third and final analysis was derived from the Occupational Physical Standards data set. While these data were compiled for a different project, many of the questions had direct bearing on human performance criteria for the Women Aboard Ships program. Responses to selected questions were compiled and tabulated to gain additional information regarding size and sex characteristics and their relationship to human engineering design problems in the shipboard work environment.

Analysis 1

WHEC MELLON. Data from the WHEC MELLON indicate that mean height and weight for males was 5'10" and 169 lbs, respectively, while for the females, it was 5'6" and 137 lbs. These figures are comparable to other military samples (Churchill and Churchill,

1977). Self-reports of fitness and strength were similar to those reported in subsequent surveys. In these questions, 75 percent of the males and 81 percent of the females rated themselves either 3 or 4 on a scale of 1 (weak) to 5 (strong).

USS SPERRY and WHEC MELLON, pooled data. The relevant data from the USS SPERRY and WHEC MELLON were pooled to yield a sample size of 553 males and 57 females. Table 1 shows the items of shipboard equipment, fittings and clothing which were listed in this questionnaire. Subjects were asked if their job performance would suffer when using these items. Responses were from 1 (definitely yes) to 5 (definitely no) and 6 (no experience). A response of 1 or 2 was considered to indicate difficulty in using a listed item (%D).

The percentage of those who reported problems with the use of any listed item was adjusted for those who either had no experience or did not respond to the question. This adjustment was performed as follows:

$$\text{percent with difficulty (\%D)} = \frac{f_d}{N - (f_i + f_r)}$$

where

f_d = frequency of responses of 1 or 2

N = total sample size

f_i = frequency of inexperience (response 6)

f_r = frequency of no response

The rightmost columns of table 1 give the percentage of those who answered 6 (no experience) plus those who did not respond.

$$\% N/A = \frac{f_i + f_r}{N}$$

Unfortunately, the nature of the raw data compilation did not allow a separation of these two responses (f_i , f_r). The "no experience" data must therefore be interpreted somewhat speculatively.

As can be seen in table 1, no consistent differences are evident in %D responses in the equipment category for males and females. Most reports of difficulty average about 20 percent. The female %N/A equipment responses, however, are all higher than male %N/A equipment responses. The greatest differences were found in the use of fire extinguishers, portable oxyacetylene apparatus and escape scuttles. Females seemed to have far less experience than males using these items.

Table 1. Analysis 1: problems with equipment and clothing compiled by sex.

Equipment		% D*		% N/A	
		Male	Female	Male	Female
Watertight Doors	E Q U I P M E N T	20%	21%	11%	25%
Escape Scuttle		20%	26%	10%	39%
Ladders		22%	20%	9%	12%
Footholds		15%	4%	11%	18%
Fire Extinguishers		13%	19%	11%	46%
Portable Oxyacetylene apparatus		20%	13%	40%	72%
OBA	G E A R / C L O T H I N G	36%	50%	23%	51%
MKV Mask		24%	20%	21%	56%
Safety Harness		25%	50%	26%	51%
Wet Weather Suit		24%	48%	31%	60%
Foul Weather Gear		20%	53%	21%	56%
Fire Fighting Suit		32%	53%	43%	74%
NBC Suit		34%	45%	44%	81%
Liquid Fuel Handles Exit		16%	60%	21%	91%
Air-Fed Steam Suit		29%	33%	60%	89%

*Percentage adjusted to exclude those who reported no experience and those who did not respond.

Male N = 553

Female N = 57

An examination of the gear/clothing section shows that women generally report more difficulties than men with their use. Items with the highest female %D responses include OBA, safety harness, wet weather suit and fire-fighting suit. Even higher percentages are seen in the female %N/A column. All female percentages are higher than the male entries. This implies an overall lack of experience with the items listed.

The data in table 1 indicate that, of the items listed, females have the greatest difficulty using protective gear and clothing. This is not surprising, since the gear that is currently available was designed to male anthropometric data. It is interesting to note that without exception, women indicate less experience using all of the items listed than men. This difference is of particular note considering the large difference in sample size (male N = 533, female N = 57).

Some questions revealed similar responses between males and females. Approximately 20 percent of each group reported that escape scuttle lighting was inadequate. Workplace design reported to be inadequate by 30 percent of each group.

Contrasting responses were found in questions regarding tool design. Here, 9 percent of the males reported difficulty with tool usage, while 29 percent of the females reported these difficulties. Life preservers also showed sex differences, with 18 percent of the males and 50 percent of the females reporting problems with life preserver use.

Analysis 2. The format of data from the USS DIXON allowed non-response to a question to be distinguished from a "no experience" response. This provides a more accurate picture of the amount of exposure females have had to various ship fittings and equipment. Categories were set up in this questionnaire to reveal the type of problems which occur, rather than the problem/no problem format of the above data. The percentages reported in this analysis also were adjusted for missing data and "no experience" responses, as described above.

The height and weight ranges of males and females reported in the USS DIXON sample are listed in table 2. These dimensions are similar to those reported in the WHEC MELLON survey discussed earlier.

The types of problems associated with the use of selected special clothing and gear are reported in table 3. The foul weather suit employed by the USCG is essentially a diving wetsuit. The upper portion is always too large for the females, so a typical solution is for a female to use two suits, a small upper and a large lower. The boots pose problems that can be solved only by individually fitted equipment. Since rope ladders are often employed in small boat embarkation/debarcation, the poor fit of the boots (too large) pose a safety hazard to female personnel.

Female respondents primarily reported difficulty with the fit of these items; foul weather gear, OBA and fire fighting suits all had high female "poor fit" ratings. Male difficulties centered on mobility restrictions. The safety harness, life preserver and OBA had the highest response rates in this category. Figure 6 illustrates the poor fit of the safety harness due to the lack of adequate adjustment for narrow shoulders. Figure 7 shows the poor seal on the OBA experienced by female personnel due to the narrowness of the face.

Female "no experience" responses were all considerably higher than male "no experience" responses. Female "no experience" responses for the fire fighting suit, life preserver and OBA were 71, 69 and 45 percent, respectively, compared to 50, 41 and 22 percent for the males.

Problems with ship fittings are summarized in table 4.

The difference between the male and female responses in most of these categories is slight. The weight of watertight doors was a problem for 24 percent of the females and 16 percent of the males. A greater proportion of males reported difficulty with the size of watertight doors (30 percent) and scuttles (42 percent) than females. (See figure 8 for an illustration of these difficulties.) This seems to indicate that for the males, these fittings are too small (e.g., head clearance, body clearance problems), rather than too large. Twenty-four percent of the females reported no experience with the escape scuttle. The after steering hatch aboard the Coast Guard cutters posed a problem for all females and most smaller sized males. Lifting forces in excess of 90 pounds above shoulder level are required for access (figure 9).

Table 2. Height and weight distribution of the USS DIXON sample.

		Lowest	Highest	Mean	S.D.
Height*	Male	63	77	69.80	2.94
	Female	59	71	64.78	2.90
Weight**	Male	118	260	169.12	26.27
	Female	96	160	130.53	16.61

*Height given in inches

**Weight given in pounds

Male N = 100

Female N = 38

Table 3. Problems with special clothing and gear*.

	Fit		Weight		Mobility	
	Male	Female	Male	Female	Male	Female
Safety Harness	26%	25%	4%	12%	50%	25%
Foul Weather Gear	20%	60%	5%	4%	35%	22%
OBA	26%	42%	22%	16%	38%	26%
Life Preserver	22%	36%	0%	9%	45%	36%
Fire Fighting Suit	30%	40%	20%	20%	30%	20%

*Percentages adjusted for missing data and no experience.

N = 100 Males

N = 38 Females



Figure 6. Safety harness shoulder straps are poorly designed for female, and cannot be adjusted.



Figure 7. Oxygen Breathing Apparatus (OBA). Note the poor seal due to narrow facial features of female.

Table 4. Problems with ship fittings*.

	Position		Size/Shape		Weight	
	Male	Female	Male	Female	Male	Female
Ladders	40%	30%	22%	24%	4%	3%
Watertight Doors	22%	15%	30%	18%	16%	24%
Escape Scuttles	26%	15%	42%	27%	13%	8%

*Percentages adjusted for mission data and no experience.

N = 100 Males

N = 38 Females

Approximately one-third of the male and female respondents reported that ship motion interfered with the performance of their jobs. In order to see the effects of size of personnel on this variable, the sample was divided into three weight categories. The weight categories were chosen to approximate a normalized distribution around the mean values for this sample. Male categories were:

- Group 1 Males = 118 - 156
- Group 2 Males = 156.5 - 182
- Group 3 Males = 182.5 - 260

Female categories were:

- Group 1 Females = 96 - 126
- Group 2 Females = 126.5 - 140
- Group 3 Females = 140.5 - 160

For both the male and female samples, the larger the personnel, the greater were the reports of motion-related difficulties. The percentage reporting motion problems by group is as follows:

	<u>Male</u>	<u>Female</u>
• Group 1	16%	25%
• Group 2	40%	35%
• Group 3	48%	43%



Figure 8. Escape scuttle aboard cutter MUNRO.



Figure 9. After steering hatch aboard cutter MUNRO.

No direct conclusions can be drawn about the cause of the apparently strong linear trend in these data. It may be inferred that larger personnel are subject to more tripping and bumping hazards in a confined, moving platform. If this is the case, the smaller females seem to have an advantage (at least subjectively) with reduced motion-related task interference.

Males and females reported similar amounts of motion sickness incidence during deployment. Five to six percent reported that emesis occurred often, 23 percent responded "sometimes," and 59 percent responded "never." The males had more experience at sea, though, with only 4 percent of the females reporting no sea experience. However, in interviews and observations aboard the cutter MUNRO, motion sickness was infrequently reported, despite the experience of two Alaskan patrols by all nine respondents. The only reported incident occurred during the first trimester of pregnancy for one of the females.

Questions regarding difficulty reaching controls and equipment indicated that 17 percent of the females and 8 percent of the males reported problems. A closer examination of the data revealed that 34 percent of the smaller women (Group 1) had difficulty reaching objects.

Problems in reaching the stowage compartment of their berth were reported by 5 percent of the males and 12 percent of the females. In this case, 18 percent of the Group 1 females reported reach problems. When considering this figure, it must be remembered that only 1/3 of the female population have the upper berth in a three-tiered rack. Obviously, reach problems would be considerably reduced for those with the middle or lower berths. Other complaints about berthing centered on ventilation and amount of storage space. Approximately 50 percent of males and females reported problems in these areas.

Analysis 3. The data set from the Occupational Physical Standards (OPS) sample included 107 males and 32 females. This sample was similar in weight to the prior two samples. Male weights ranged from 120 - 275 lbs., with a mean of 173 lbs. Female weights ranged from 96 - 180 lbs., with a mean of 131 lbs.

The OPS questionnaire asked subjects to choose one of their most physically-demanding tasks and describe some of the factors which contributed to the difficulty in performing the task. Some examples of tasks that were repeatedly reported to be physically demanding are listed below:

- Moving relief valves
- Moving stores up and down stairs
- Carrying ammo boxes
- Removing/replacing pumps
- Carrying P-250 pump
- Handling mooring lines
- Moving red devil blower
- Casting molten metal

- Moving gas bottles
- Handling nylon rope.

Figure 10 illustrates a typical line-handling task at sea.

Tools that were noted to be difficult to use included:

- Sledge hammer
- Chipping hammer
- Combination wrench.

Respondents were asked what type of body effort (e.g., lift, carry, push) was most closely associated with the task they listed. Fifty percent of the males and forty-four percent of the females answered "carrying" to this question. More females (22 percent) than males



Figure 10. Handling nylon rope during rescue mission at sea.

(11 percent) had difficulty pulling objects. This pattern was reversed with 22 percent of the males and 13 percent of the females reporting difficulties with lifting. These data may reflect the fact that with a relatively greater lower extremity strength, and a significantly reduced upper torso strength, women attempt to pull objects, while men tend to lift objects.

Table 5 shows the breakdown of problems associated with grip configuration, restricted work space and reach by sex. Subjects who responded "very difficult" or "fairly difficult" were considered to have problems in these areas.

Table 5. Problems associated with demanding tasks.

	<u>Male</u>	<u>Female</u>
Grip	63%	47%
Restricted Space	66%	34%
Reach	70%	50%

Two things are apparent upon examining Table 5. The first is that all of these factors are strongly associated with task difficulty. Secondly, all of the female responses are lower than the corresponding male responses. It is possible that females are more motivated than males to perform difficult tasks adequately, and so are less inclined to report task-related problems. If this is not the case, the response pattern in table 5 implies that either females do not have the degree of difficulty that males do in these areas, or that females have less exposure to tasks that involve restricted spaces, reach and grip difficulties. However, one must consider the implications of the "demand" characteristics involve in social-judgment settings. The added visibility of the limited numbers of females produces social forces which dictate their response to be biased, which may result in disclaimers to the lack of skills, strength or other less socially acceptable responses.

A combination of the above interpretations might be the most accurate. The greater reach envelope and grip strength of the male suggest that lower female response rates on these factors reflect lowered exposure rates to these types of tasks, rather than less difficulty with grip and reach. The smaller size of the female, however, might give them an advantage in working in tight, restricted spaces. This is supported by the 34 percent response rate for females reporting problems with restricted space, as compared to the 66 percent male response rate on this factor.

A better indication of female exposure to "typical" shipboard tasks is given by questions regarding deployment status. Here, respondents were asked what their deployment status was when the task they listed was most typically performed. Table 6 lists the responses to this question by sex.

The majority of women (63 percent) list their shore station as deployment status during performance of their most demanding task. This compares to a male entry of only 3 percent. This implies that, while many of the women in this sample have been given shipboard billets, they have yet to be exposed to extensive sea duty.

Table 6. Deployment status during task performance.

Status	Male	Female
Shore Station	3%	63%
In Port	60%	13%
Moving or Getting Underway	6%	0%
Underway	15%	0%
In Overhaul	15%	25%

Questions on environmental factors that contributed to task difficulty elicited very similar responses from males and females. High temperature was noted as a problem by 36 percent of the males and 39 percent of the females. In questions regarding physical strain, frequent strain was reported by 12 percent of the males and 17 percent of the females. Fifty percent of the males and 44 percent of the females reporting strain cited the back as the primary location of discomfort. The lower back was cited by 23 percent of the males and 19 percent of the females. Twenty-six percent of the females cited arm strain, compared to only 16 percent of the males. These last figures may reflect the reduced female upper torso strength compared to the males.

Observation and Interview Results

Damage Control Equipment. Damage control (DC) equipment was examined, both aboard ship and at Damage Control school. The latter site provided the opportunity to see much of the fire-fighting equipment in use under simulated emergency conditions. Actual emergency operations may be complicated by increased vessel motion or list. It can be assumed that the human factor problems identified in this section would be aggravated under actual operating conditions. Specific items of DC equipment which were found to be difficult to use are discussed below.

Twinned Agent Light Water and PKP Nozzle. Twinned Agent Units (TAU) are used to shoot a combination of light water and a dry chemical called PKP at large oil and gas fires. TAU's are located in all engine and machinery spaces and were designed to be operated by one person. Operation of the TAU requires the use of both hands to actuate a dual trigger nozzle.

Smaller sized personnel report difficulty in using the TAU. This difficulty is due to the extra large grip span of the trigger assembly. In addition to this wide grip, the breakaway force required to activate the nozzle exceeds the grip strength of many of the smaller/weaker personnel. Since both hands are required to operate the TAU, the operator cannot compensate for a poor grip by using two hands on one nozzle. Failure to activate either of the triggers can be extremely hazardous when the operator is close to the fire. The use of protective gloves during fire-fighting makes the application of sustained grip forces even more difficult. Additionally, the hose pressures make maneuvering the TAU nozzle very difficult for smaller personnel.

Portable Extinguishers. The two types of portable extinguishers that are used by the Navy are the PKP dry chemical and the CO₂ extinguisher (shown in figure 11). Both were designed to be carried by one person to the scene of the fire. Activation of either of these extinguishers requires pulling a locking pin and squeezing a lever, as shown in figure 12.

Smaller personnel report difficulties both carrying and activating these extinguishers. Carrying them is difficult due to weight and bulk. The weight of a fully-charged extinguisher is 50-60 pounds. Only one handle is provided on the top of the extinguisher for carrying. However, smaller personnel may require the use of both hands, especially when carrying extinguishers up or down ladders. Activation is difficult due to the lever configuration. Lever breadth was reported to be too wide for personnel with small hands. Breakaway force for activation also was reported to be a problem.

All-Purpose Nozzle. The Navy's all-purpose nozzle is used with both 1-1/2 and 2-1/2 inch hoses. By placing the handle in the various positions shown in figure 13, the nozzle will produce a straight stream of water, high velocity fog, or the water can be shut off.

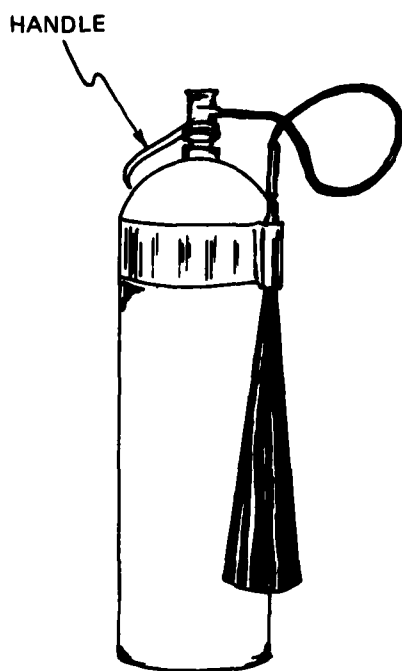
Smaller personnel reported difficulty controlling and directing this nozzle under full pressure. This was especially true for females when using the nozzle in the overhead stance. Difficulty also was observed in manipulating the control handle.

P-250 Pump. The P-250 is a portable, gasoline-powered pump for dewatering flooded compartments and fire fighting. The pump is contained in a steel frame which measures approximately 30" x 36" x 36" (see figure 14). The weight of the pump without the gas tank is 147 pounds. Use of P-250 may entail moving it from a stowage compartment and up or down several ladders to the damage site. Two P-250's were employed to salvage the distressed sailing vessel shown in figure 15. The crew member in the bow of the small boat is a female BM2.

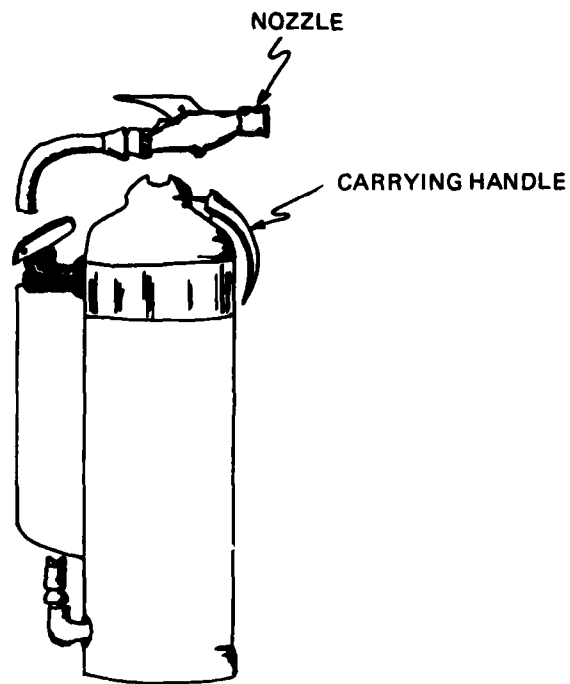
Personnel have difficulty moving the P-250 due to weight and inadequate grip surface. The only grip surface available is the steel frame. While this frame is accessible, it is occasionally covered with oil and does not provide adequate friction for maximum transfer of force. Damp weather will make the frame even more slippery, increasing grip difficulties. Moving the P-250 up or down ladders is reported to require the efforts of two to four persons, depending on the sea state and strength of personnel.

Starting the P-250 is also a problem for smaller personnel. The pump is started by firmly pulling an outboard-type cord to turn the engine over. The pumps are typically hard-starting, especially in foul weather. Personnel with weaker upper torso strength cannot pull the starter cord with enough force to turn the engine over rapidly.

Tools. Comments from female personnel on tools predictably centered on grip configuration. Grips were noted to be too large on paint scrapers, sanders and grinders. Senior personnel noted a general lack of familiarity with tool use and care in many of the male and female operators. See figure 16 for an example of tool use aboard the cutter MUNRO.



PORTABLE CO₂ EXTINGUISHER



DRY CHEMICAL EXTINGUISHER

Figure 11. Two types of extinguishers.

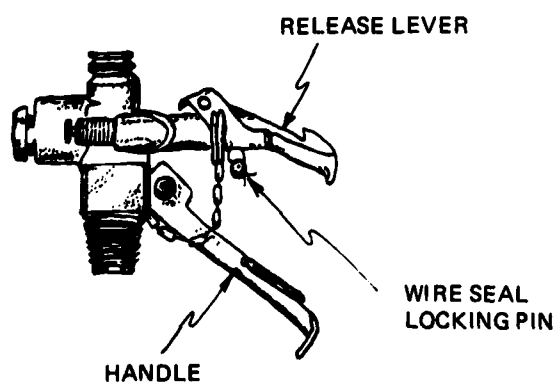


Figure 12. Extinguisher handle, lever, and locking pin.

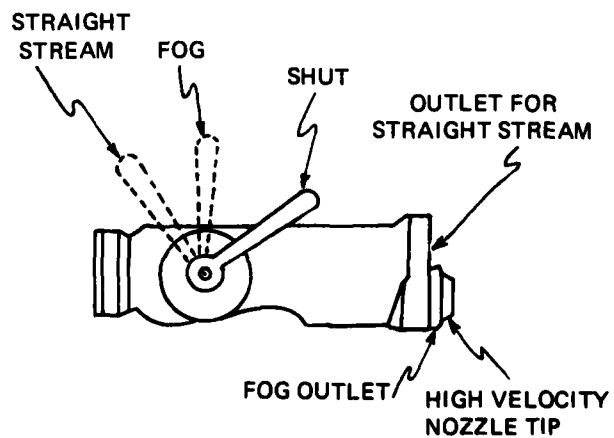


Figure 13. All-purpose nozzle.

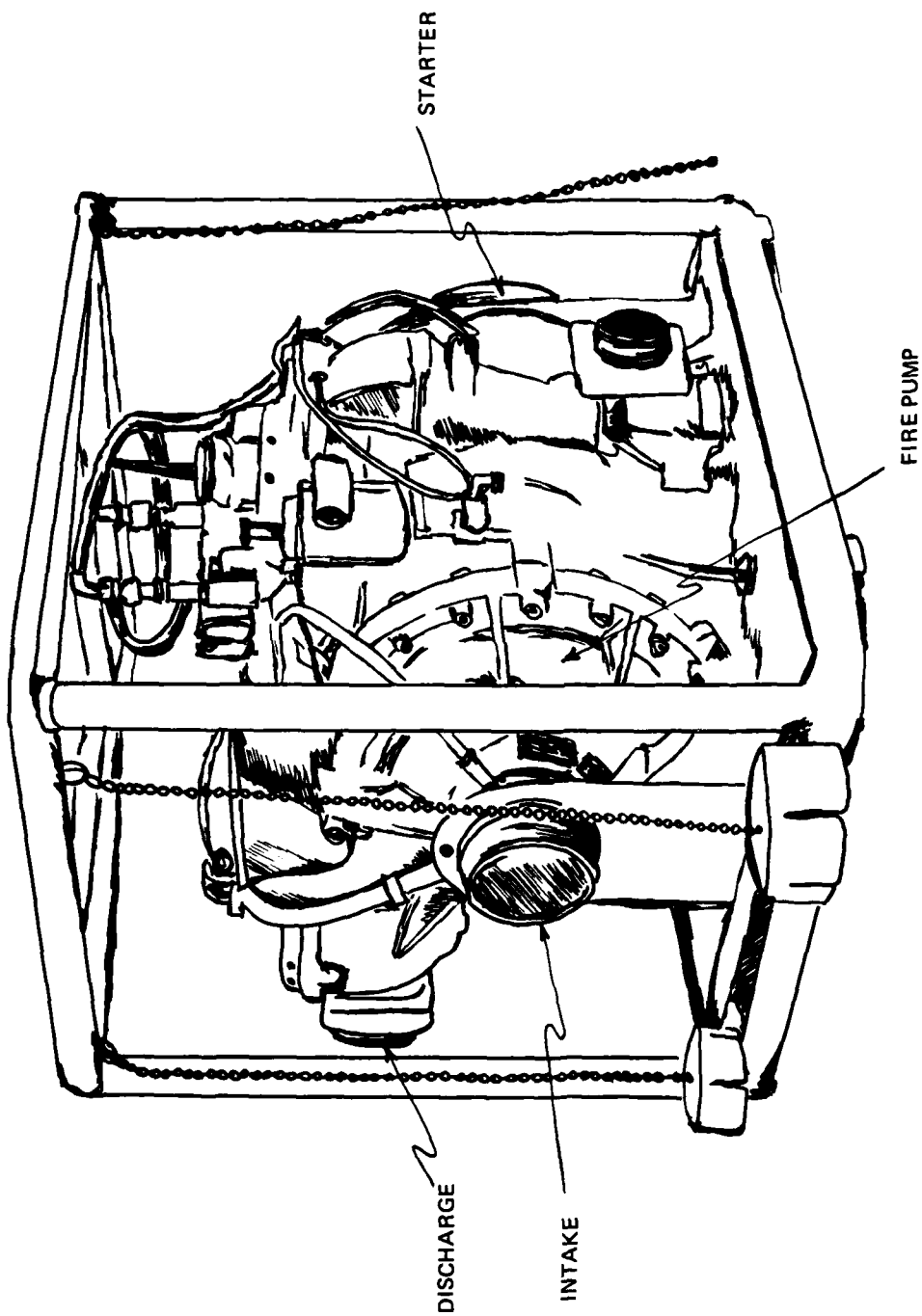


Figure 14. P-250 portable pump.



Figure 15. Attempted rescue mission by U.S. Coast Guard crew. Employed P-250 pump to dewater stricken vessel. Note female boatswains mate in the bow of the small boat.



Figure 16. Common example of tool use for general deck maintenance.

Equipment and Materials. Difficulties with the use of the shipboard equipment and materials concerned either weight, bulk or reach problems. Tasks that were noted to be difficult for women and smaller personnel due to the weight and bulk of objects which had to be moved include:

- Anchoring
- Chain handling
- Moving small boat covers
- Moving 5-foot argon bottles to weld site
- Removing/replacing deck plates
- Handling 5" - 54 shells
- Carrying ammo from helo pad to hold.

The handling of some stores was mentioned as being difficult due to weight. Another problem noted was that the conveyor belt used for the transfer of stores was too narrow for the pallets that held them. This necessitated manual loading and unloading of the pallets at each end of the conveyor belt.

Reach difficulties were found in stowage and maintenance tasks. Small personnel have trouble reaching some ovens and upper shelves in the mess area. Reaching stowed paint cans was also a problem. Ammunition storage in the hold and 5" - 54 shell storage in the loading area was out of reach for many crew members. A non-fixed step platform was provided in the loading area to aid in accessing the uppermost rows of 5" - 54 ammo. This often was not used, however, since it is not well suited for higher degrees of ship motion. In other areas of the ship, crew members use boxes, garbage cans, and similar support objects to reach inaccessible items. These solutions also lose their utility in higher sea states. It should be noted that women found it especially difficult to load or access heavy items stored above their shoulder height.

Many remove/replace maintenance tasks involved obstructions, cramped work spaces, minimal footing and extended reaching. In machine spaces, this often was compounded by oily, slippery floors. Examples of tasks that involved these factors are:

- Remove/replace relief valve
- Repair condensate pump
- Remove #1 spring bearing.

Ship Fittings. Ship fittings include ladders, scuttles, watertight doors, berthing and the like. Items that were found to be difficult to use are discussed below.

Stairs. Shipboard stairs are fixed at 60°-65°. Handholds are either fixed rails, as on newer ships, or loose chains. Many sailors reported trip/fall incidents, head bumpings, etc. on ship stairs, especially during heavy roll. Stairs with chain handholds are more hazardous than those with fixed handholds. Carrying items up or down these stairs is particularly difficult.

Tripping hazards are often elicited by a 6-inch lip that surrounds the open stairwell (see figure 17). Lack of adequate footing around many of these stairwells added to the problem.

Walkways. Some walkways were found to be wet and slippery. Areas noted included the engine room, mess area and weather deck. Many obstructions and low clearances also were found, presenting tripping and bumping hazards in rough sea states.

Escape Scuttles. Figure 18 shows a typical escape scuttle layout. As is shown, the ladder is set in 6" - 12" from the scuttle opening. The escape scuttle was found to be more difficult to use when ascending the scuttle shaft than descending, especially for female personnel. Opening the scuttle from below requires considerable reaching and stretching due to ladder position. Force must be applied above the shoulder level to open the scuttle. No extra footholds are provided at the top of the ladder to add balance or more body leverage for opening the scuttle. This task often is made more difficult since the locking wheel operates in an opposite direction, depending on whether the operator is above or below the scuttle. This causes many operators to exert their initial opening force in the locking, rather than unlocking, direction. When this sort of error occurs, much more breakaway force is needed in the correct direction to release the lock. The after steering hatch described above in figure 9 cannot be accessed from below by the women aboard the cutter, due to the offset position of the ladder and the 90-pound lifting force required.



Figure 17. Stairwell.

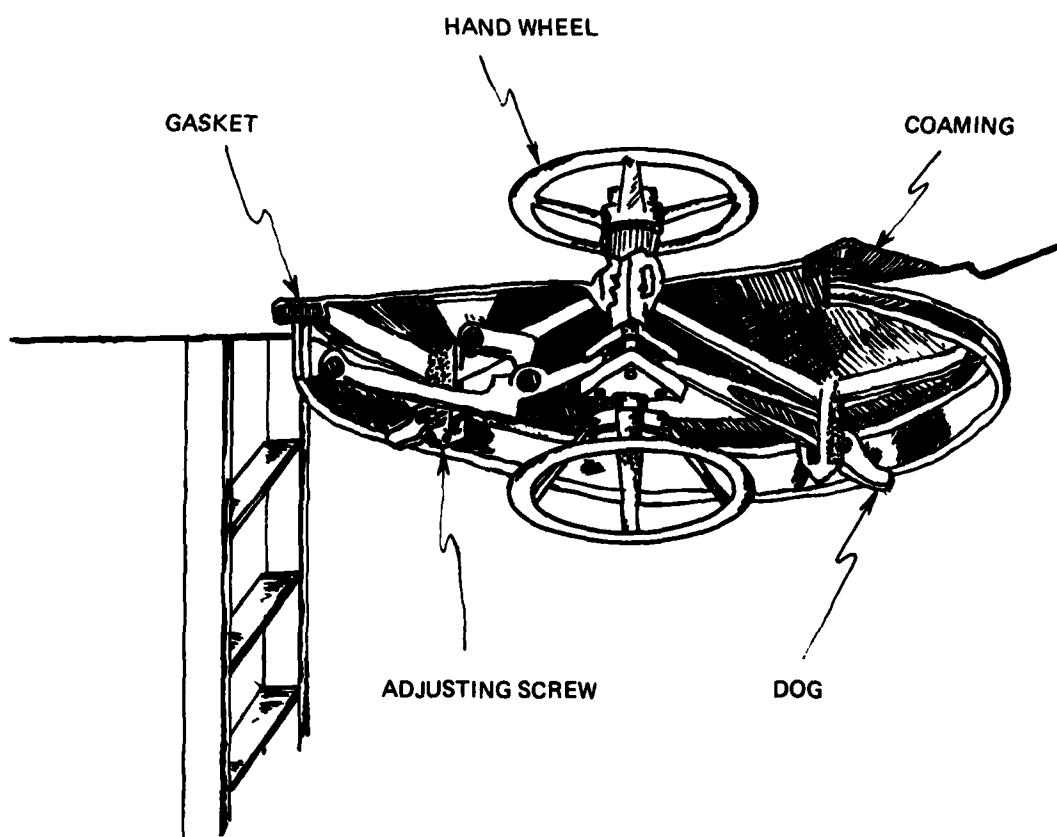


Figure 18. Typical escape scuttle layout.

Watertight Doors. Force required to open watertight doors was found to vary greatly. Some doors were easy enough to activate for all personnel. Others required break-away forces which exceeded the capabilities of many of the female and male crew. The force requirements seemed to be a function of age, lubrication, maintenance and prior locking force. Another problem noted was that some female crew members could not reach the top dogs on individually-dogged doors.

Berthing. Figure 19 shows a typical berthing unit. On board, many low overhead obstructions and bumping hazards are found over the top berth. Women sailors reported difficulty getting into the top berth, especially in rough sea states. Lifting the top rack to access storage also was difficult for some women due to height of the rack and excessive weight. Tricing up the lower berth in the two-tiered racks aboard the WHEC cutters was consistently reported as a problem for both males and females. Other problems reported by women concerned a lack of privacy in the berthing area.

Protective Clothing and Gear. Female sailors reported problems with the fit of some protective clothing. Safety harnesses and life jackets are too large for the narrow shoulder breadth of many women. The arrangement of safety harness straps was reported to interface with the female breast (see figure 6). Foul weather gear and safety shoes also were noted as being too large. Figure 20 illustrates the fact that exposure suits are used in a working environment. The coxswain of the small boat is a female BM2. Female boatswain mates reported that hard hats don't adjust to their size. The OBA also was noted by male and female sailors to be bulky and hard to work with. Poor facial seal was found by some women using the OBA and the Mark V mask (see figure 21).

General Comments

Comments which bear mentioning here were repeatedly made during interviews. Female crew members' superior motivation and higher learning ability were consistently noted by supervisory personnel who had experience working with women. The lesser strength of women often was circumvented by delegating the muscularly-demanding tasks to larger male crew members. This shipboard selection applied to smaller men as well as women. Shortage of man/woman power was cited as a major problem. This shortage caused a concentration on corrective, rather than preventive, maintenance in machine areas. Limited available labor hours also increased the work pace of many of the operators on duty, resulting in increased fatigue and lowered motivation.

CONCLUSIONS AND RECOMMENDATIONS

The data indicate that females lack experience using many items of equipment, ship fittings and protective clothing. Except for the Coast Guard personnel, very few of the women appear to have had sea duty. Additionally, the larger males often are selected to handle some of the more physically-demanding jobs. The resulting lack of exposure of women to many ship system elements may inhibit the reporting of equipment-related problems by female personnel. Also, the high motivational level of the female sailors might tend to mask some equipment problems in the self-report indices, as the social demand characteristics inherent in self-report techniques tend to bias the responses. Another important factor is that the females currently aboard ship are small in number and tend to be exceptional, both emotionally and educationally, i.e., female personnel are required to be high school graduates, while males are not.

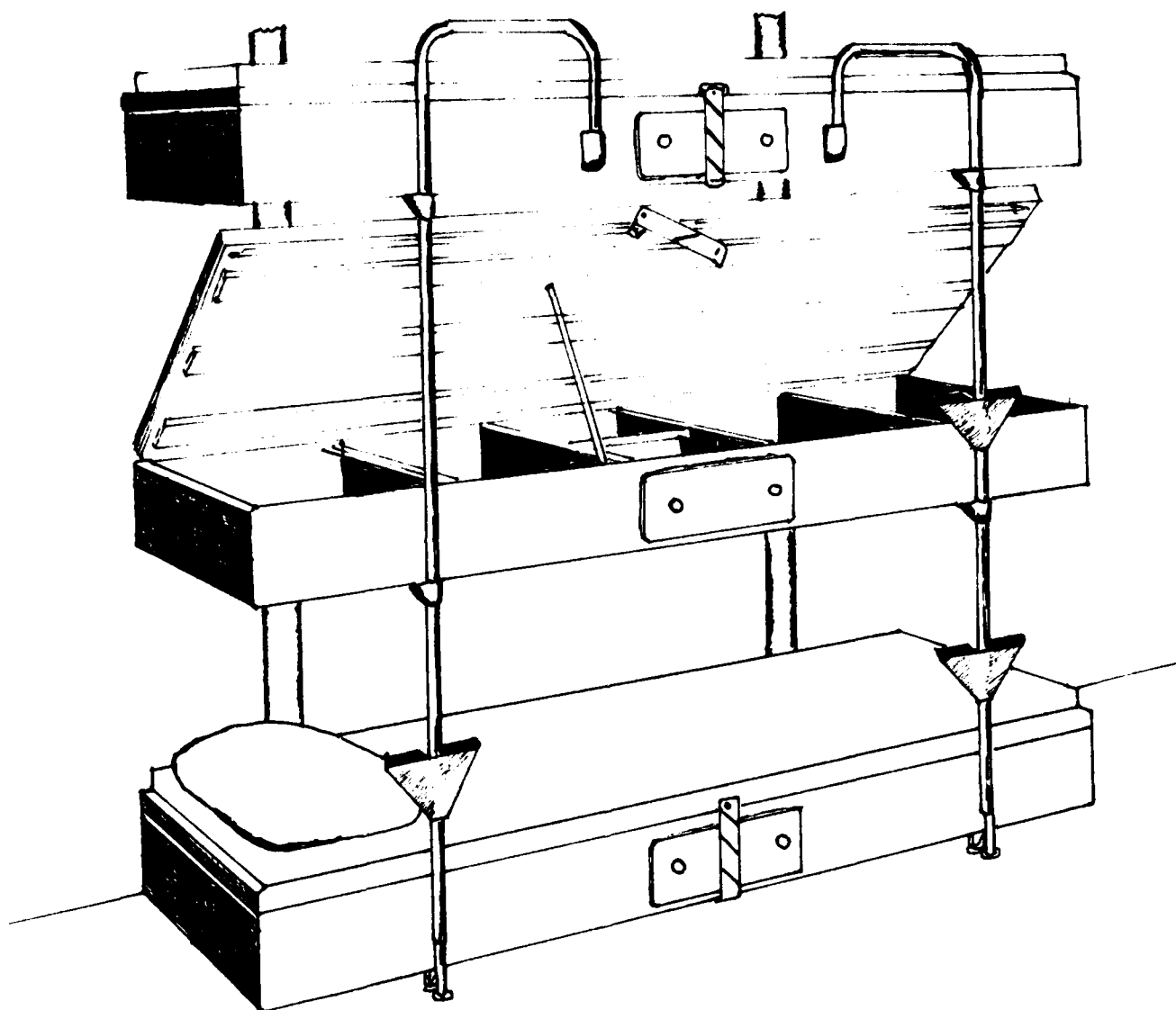


Figure 19. Typical berthing unit.



Figure 20. Exposure suits. Note: These are required during small boat operations in the north Pacific. Coxswain is female BM 2.

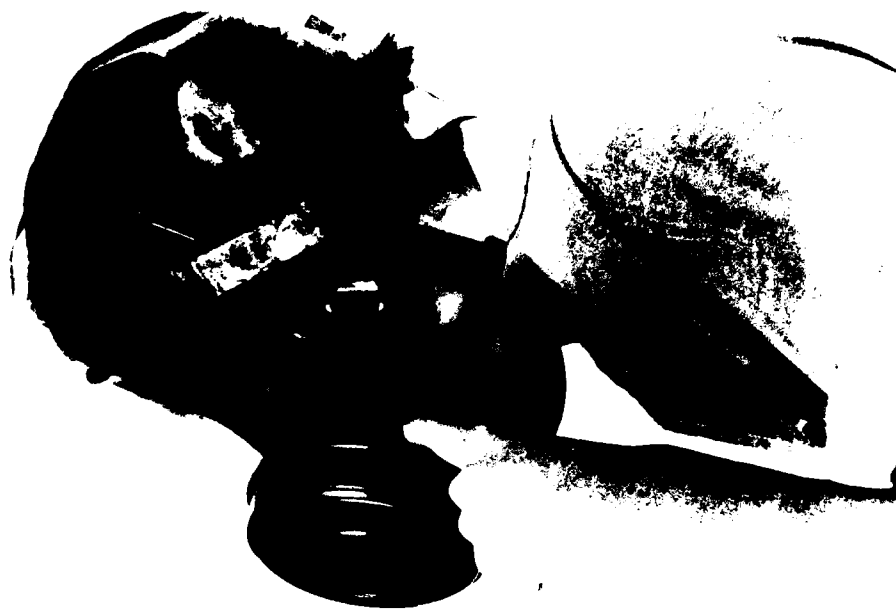


Figure 21. Poor fit of the MKV mask.

Even with the limitations of the above data, several items of ship equipment, clothing and fittings emerged as being especially deficient for use by females. Protective gear such as the OBA, safety harness, life preserver and foul weather gear do not adequately fit the women on board. Hand tools and fire fighting equipment were found to be difficult for a significant proportion of the women to operate. Ship fittings such as escape scuttles and watertight doors also were revealed to produce problems.

Many males and females reported that carrying items (e.g., stores, ammo, pumps, valves) up and down ships' stairs was very difficult. This difficulty can be attributed to the weight and configuration of the items carried and the design of the ships' stairs. The frequency of these carrying tasks (both in calm and rough sea states) and the influx of smaller and lighter personnel suggests that alternate ships' stairway designs be considered in future research.

Several general factors emerged that seemed to account for many of the difficulties that women reported with equipment use. Tasks that involve full extension and reaching (e.g., accessing stowage on the top berth, loading stores on the upper shelves) were difficult for smaller personnel. These difficulties may become more significant in higher sea states. Tools and equipment that required grip activation were more difficult for women than for men. Grip strength and limited upper torso strength added to problems associated with lift and carry tasks. Tasks involving pulling (e.g., line handling) also were more difficult for women due to lesser female upper torso strength.

These results indicate that sexually-based anthropometric differences can affect the use of shipboard fittings, equipment and protective gear. Increasing the number and experience of the female personnel in the future may reveal more human engineering problems since there would be less opportunity for shipboard task selection to occur. This would be especially critical during damage control operations.

Several factors described previously in this section tend to bias the reporting of equipment-related problems by female personnel. As women are assigned in greater numbers to ship billets, that bias may diminish. Therefore, it is recommended that data collection for problem identification and analysis continue. Further research will concentrate on identifying the underlying factors which contribute to specific types of equipment use problems. Measures are needed which assess the effects of current equipment design on the performance of female personnel.

PLANS AND MILESTONES

Task 1, a continuation of the problem identification effort, will enable a more substantial qualitative data base to be developed. The emphasis will be on problems posing safety hazards; i.e., fire fighting, damage control and other emergency procedures. Supplementing the continued questionnaire, interview and observational techniques will be a new effort which will seek to obtain objective measurements. Thus, task 2 will involve critical assessments of equipment fit and performance measures derived from samples of males and females during simulated damage control and firefighting exercises.

The equipment selected for critical evaluation includes:

- OBA
- Fire Nozzles (various)
- Fire extinguishers
- P-250 pump.

Task 3 will involve the preparation of a data base management system for the storage and retrieval of male-female anthropometric, biomechanical and ergonomic difference literature.

Task 4 will expand the literature search to include an evaluation of cognitive differences in performances which impact Navy performance.

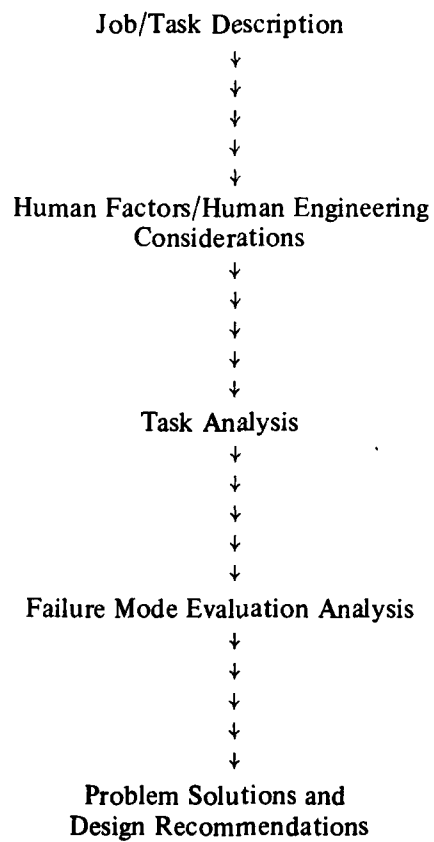
Task 5 will consist of conducting an analysis of the significance of the differences identified in task 4 with respect to potential C³ applications and designing an experimental paradigm to evaluate the utility of the differences in a relevant shipboard C³ mission.

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**APPENDIX A: TASK DESCRIPTION AND ANALYSIS METHODS FOR
WOMEN ABOARD SHIPS PROGRAM**

METHODOLOGY AND APPROACH



1.0 TASK DESCRIPTION PARAMETERS

1.1 JOB NAME

- Indicate generic job name.

1.2 GOALS

- In operational terms, define the desired job outputs within given performance criteria (time, accuracy, amount).

1.3 FUNCTIONS

- Describe the separate processes attendant to goal attainment.

1.4 WORKPLACE ENVIRONMENT

1. Temperature
2. Illumination
3. Ventilation
4. Noise
5. Special factors
 - a. Ship's motion
 - b. Layout of workspace
 - c. Ship fittings encountered during task (descriptions and specifications where applicable).

1.5 MACHINES, TOOLS, EQUIPMENT USED

1. List all items directly relating to job.
2. Include descriptions and specifications where applicable.

1.6 APPAREL

1. List any special protective clothing or gear that is used.
2. Include descriptions and specifications where applicable.

1.7 TASKS

Delineate the individual task requirements within job functions in tabular form as follows:

Function	Task	Indicators (Inputs)	Response Activity (Outputs)	Feedback

2.0 EXAMPLE OF THE TASK DESCRIPTION APPROACH

(Note that the following is a brief hypothetical example which is offered as a method demonstration only. It is not intended to reflect true operative conditions.)

2.1 JOB NAME

Dewatering of compartment Y.

2.2 GOALS

- 2.2.1 Compartment Y dewatered of 10,000 gallons of water within 15 minutes of alarm.
- 2.2.2 Workers unharmed/uninjured during operation.
- 2.2.3 Equipment intact and undamaged at end of operation.

2.3 FUNCTIONS

- 2.3.1 Damage Control (DC) party assembled at area X and clothed in protective gear.
- 2.3.2 DC equipment assembled and carried to compartment Y from area X.
- 2.3.3 Equipment activated, compartment dewatered.
- 2.3.4 Equipment reassembled, returned to area X and stowed.

2.4 WORKPLACE ENVIRONMENT

- 2.4.1 Compartment Y temperature = 90°(F).
- 2.4.2 Compartment Y luminance = 15 ft = candles.
- 2.4.3 Compartment Y ventilation < 1 cu ft/min, high smoke and CO content from prior fire.
- 2.4.4 Ship roll and pitch agitated due to rough sea state.
- 2.4.5 Equipment and DC party must traverse:
 - a) 1 ladder
 - tread spacing = 18"
 - angle = 65°
 - length = 10'
 - b) 1 watertight (WT) door
 - 72 square inches
 - 800 pounds
 - wheel activation requires 50 ft-lbs of force.

2.5 MACHINES, TOOLS, EQUIPMENT USED

2.5.1 P-250 Pump

- Gas driven pump with valves, regulators, and a 6-gal. fuel tank
- Dimensions = 30" x 36" x 36"
- Weight = 147 lbs (without gas tank).

2.5.2 Hosing

- Weight = X lbs/ft
- Length = X feet
- Carried on X-lb roller.

2.6 APPAREL

2.6.1 Firefighting Suit

- Coverall, hood, gloves, boots.
- Acts as body insulator, results in X° /min increase in body temperature during physical stress.
- Good fit provided for the 20- thru 75-percentile man.

2.6.2 OBA

- Oxygen recirculating system worn on face and chest.
- Tight facial fit required for seal.
- Weight = X lbs.
- Adds X amount of clearance space around chest and head area.

2.7 TASKS

Function	Task	Indicators (Inputs)	Response Activity (Outputs)	Feedback
DC Party Assembled	Party Notified	Alarm Sounds	DC crew report to area X from various ship locations within 3 mins. of alarm	
	Clothing Assembled		DC members retrieve suit and OBA from overhead locker	
	Clothing Donned		Suits put on and secured by each worker OBA put on and secured by each worker	Body covered Respiration begins thru OBA Crew readied
Equipment Carried from X to Y	Equipment Assembled	Verbal Instruction	Two workers lift P-250 3' vertically from hold. Gas tank filled Hose coil retrieved from hold	Equipment readied
	Equipment Moved		Workers lift and carry P-250 and hose down 50-ft walkway, up 1 ladder, thru WT door to area Y	Equipment and crew arrive at compartment Y within 8 minutes of alarm
Compartment Dewatered	Hose Coupled P-250 Started	Verbal Instruction	MM or HT attaches 2-1/2" hose coupling, pulls pump starter cord	Pump activated, ambient noise increase 50 dB
	Pump inflow/outflow directed		Crew locates and monitors hose	Compartment dewatered within 15 minutes of alarm

2.7 TASKS (Continued)

Function	Task	Indicators (Inputs)	Response Activity (Outputs)	Feedback
Equipment Returned to Stowage	Equipment Assembled		MM or HT turns off P-250, detaches hose Hose coiled	Ambient noise decreases 50 dB Equipment Assembled
	Equipment Returned		Pump and hose returned thru WT door, down ladder, into area X Equipment replaced in hold	Equipment Returned
			Suit and OBA taken off and returned to locker	Return to normal respiration and body covering
	Crew Dismissed			Apparel returned Crew leaves area X

HUMAN ENGINEERING CONSIDERATIONS FOR WOMEN ABOARD SHIP TASK ELEMENTS

1.0 WORKER/EQUIPMENT INTERFACE PARAMETERS

1.1 BODY POSITION REQUIRED FOR ACCESS TO TASK EQUIPMENT

1. Free access.
2. Some manipulation required for access.
3. Excessive manipulation required for access.
4. Body position constrained.
5. Position constrained with minimal angle of insertion.

1.2 FORCE REQUIRED FOR MANIPULATION/ACTIVATION

1. Minimal effort required.
2. Some effort required.
3. Exceeds functional force range of 5-percentile woman.
4. Exceeds functional force range of 50-percentile woman.
5. Exceeds functional force range of 95-percentile woman.

1.3 DURATION OF FORCE

1. Momentary.
- 2.
3. Intermittent.
- 4.
5. Continuous.

1.4 GRIP OF OBJECT

1. Appropriate grasp location/configuration.
- 2.
3. Inappropriate grasp location/configuration.
- 4.
5. Extremely difficult to grasp or hold.

1.5 REACH/MANUAL ACCESS PARAMETERS

1. Accessible.
2. Some reaching needed for access.
3. Exceeds functional reach of 5-percentile woman.
4. Exceeds functional reach of 50-percentile woman.
5. Exceeds functional reach of 95-percentile woman.

1.6 VISUAL ACCESS PARAMETERS

1. Accessible.
2. Some physical motion required for access.
3. Exceeds functional limits of 5-percentile woman.
4. Exceeds functional limits of 50-percentile woman.
5. Exceeds functional limits of 95-percentile woman.

1.7 OVERALL OBJECT CONFIGURATION

1. No size/shape constraints.
2. Some size/shape constraints.
3. Inappropriate configuration for use by 5-percentile woman.
4. Inappropriate configuration for use by 50-percentile woman.
5. Inappropriate configuration for use by 95-percentile woman.

1.8 PACING OF TASK

1. Self paced.
- 2.
3. Regulated/time limited.
- 4.
5. Force paced.

1.9 FREQUENCY OF TASK

1. Seldom.
2. A few times a month.
3. A few times a week.
4. Daily.
5. Several times a day.

1.10 INDICATOR PARAMETERS

1. Indicators clear and consistent.
- 2.
3. Indicator information somewhat unclear.
- 4.
5. Indicators inconsistent/confusing.

2.0 WORKER/ENVIRONMENT INTERFACE PARAMETERS

2.1 SHIP MOTION

1. No effect on task/not applicable.
- 2.
3. Inhibits some workers in task.
- 4.
5. Greatly impairs task completion.

2.2 TEMPERATURE

1. Within comfort zone.
- 2.
3. Within tolerance limits per exposure duration.
- 4.
5. Exceeds tolerance limits per exposure duration.

2.3 VENTILATION

1. Within comfort zone.
- 2.
3. Within tolerance limits per exposure duration.
- 4.
5. Exceeds tolerance limits per exposure duration.

2.4 ILLUMINATION

1. Appropriate for task functions.
- 2.
3. Adequate for task functions.

- 4.
5. Insufficient/inappropriate for task functions.

2.5 NOISE

1. Ambient noise conditions within comfort zone.
- 2.
3. Within tolerance limits per exposure duration.
- 4.
5. Exceeds tolerance limits per exposure duration.

3.0 WORKER/APPAREL INTERFACE PARAMETERS

3.1 FIT

1. Good fit provided.
- 2.
3. Adequate fit provided for 95% female population.
- 4.
5. Inadequate fit provided for 95% female population.

3.2 WEIGHT OF GEAR

1. Light, evenly distributed.
- 2.
3. Moderately heavy/non-optimally distributed.
- 4.
5. Heavy/poorly distributed.

3.3 MOBILITY

1. Unrestricted.
- 2.
3. Restricted but does not interfere with task functions.
- 4.
5. Gear inhibits completion of task functions.

3.4 THERMOREGULATORY ALTERATIONS

1. No effect.
- 2.
3. Body temperature within tolerance limits while in suit.
- 4.
5. Marked heat potentiation.

3.5 VENTILATION

1. Unrestricted.
- 2.
3. Within tolerance limits while in suit.
- 4.
5. Ventilation restricted beyond tolerance range.

TASK ANALYSIS INVENTORY

TASK _____

EQUIPMENT/ACCESSORIES INVOLVED _____

TOOL(S) INVOLVED _____

APPAREL INVOLVED _____

1.0 WORKER/EQUIPMENT INTERFACE PARAMETERS

	1	2	3	4	5
1.1 Body position in relation to task					
1.2 Force required for manipulation/activation					
1.3 Duration of force					
1.4 Grip of object					
1.5 Reach/manual access parameters					
1.6 Visual access parameters					
1.7 Overall object configuration					
1.8 Pacing of task					
1.9 Frequency of task					
1.10 Indicator parameters					

2.0 WORKER/ENVIRONMENT INTERFACE PARAMETERS

	1	2	3	4	5
2.1 Ship motion					
2.2 Temperature					
2.3 Ventilation					
2.4 Illumination					
2.5 Noise					

3.0 WORKER/APPAREL INTERFACE PARAMETERS

	1	2	3	4	5
3.1 Fit					
3.2 Weight of gear					
3.3 Mobility					
3.4 Thermoregulation alterations					
3.5 Ventilation					

FAILURE MODE EVALUATION INVENTORY

JOB: _____

Sub Task	Equipment Tools/Apparel Involved	Equipment Failure Cause	Environmental Failure Cause	Apparel Related Failure Cause	Consequences of Failure	Solutions/Recommendations
Identify	List ↓	Limits on: Body Position, Force Required, Duration of Force, Grip, Manual Access, Visual Access, Object Configuration, Pacing of Task, Indicator Parameters	Adverse or inappropriate: Motion, Temperature, Ventilation, Illumination, Noise	Inappropriate: Fit, Weight, Mobility Restrictions, Thermoregulatory Restrictions, Ventilation	Criticality Frequency Consequences	List ↓

APPENDIX B: EQUIPMENT DESIGN GUIDANCE NEEDS RELATED TO ASSIGNMENT OF WOMEN ABOARD SHIPS

1.0 INTRODUCTION

1.1 Background

Since the mid 1970's, the number of military-aged males in the United States has been consistently on the decline. Current Pentagon estimates hold that the number of eligible men might drop by as much as 25% by 1992 [ref 1]. This population shift has been accompanied by the abolition of the draft in 1973. These two factors have forced the armed services to re-examine the utilization of women in non-traditional areas.

The role of women in the armed forces has expanded from traditional clerical and nursing positions to include almost all non-combatant military jobs. The Navy has, in turn, expanded its assignment of women to include permanent shipboard duty assignments on non-combatant ships.

In a recent instruction from the Secretary of the Navy [ref 2], it was stated that, "It is the policy of the Department of the Navy that women members, officers and enlisted, will be assigned to billets commensurate with their capabilities to the maximum extent practicable." The only restriction placed on female personnel utilization is that women may not be permanently assigned to a combatant vessel. Women may serve temporary duty on any ship in the Navy, provided that it is not expected to have a combat mission during the period of temporary duty. This expansion of the role of women aboard ship has led to female personnel being assigned to twenty Naval ships to date. Projections indicate that there may be 5000 women aboard 55 ships by 1983.

The introduction of a significant proportion of women into shipboard billets has far reaching implications to the designer of ship systems and equipment. The female population differs from the male population in terms of anthropometry, biomechanics, and work physiology.

Men are larger than women at any given percentile for most body measurements. Men's arms and legs are both absolutely longer than women's, and longer relative to standing height [ref 3]. In terms of overall mechanical capacity, most studies have found women to possess 67% of the strength of men [ref 4].

¹Marcinick, E.J. Sex Differences and their Implications to the United States Navy. Naval Health Research Center, 1980, DRAFT.

²Secretary to the Navy. Assignment of Women in the Department of the Navy. SECNAVINST 1300.12, 18 April 1979.

³White, R.M. The Anthropometry of United States Army Men and Women: 1946-1977. Human Factors, 1979, 21(4), 473-482.

⁴Ayoub, M.M., et al. Classification, Summary, Relevance, and Application of Male/Female Differences in Performance. N36126-77-M-4098, for Pacific Missile Test Center, Point Mugu, California.

These differences have considerable impact on shipboard tasks when performed by women. Preliminary human engineering analyses of several items of hull, damage control, safety equipment, and protective clothing have pointed out some potentially serious problems associated with use by the Navy's female population [ref 5, 6].

The proper human engineering of tools, equipment, and workspace for a heterogeneous shipboard population will enhance both male and female performance in shipboard work settings. This sort of human engineering effort requires a task-oriented approach that concentrates on mechanical equipment and an analysis of the situational aspects of shipboard work.

1.2 Objectives

This document reviews and assesses the current human engineering guidance literature that relates to the design of shipboard equipment. In addition to directing the designer to the references that are most relevant to his/her needs, this review is intended to identify those areas not covered by existing human engineering guidance documents.

An analysis of the special human engineering requirements of ship systems is offered. The synthesis of this requirements analysis and the above cited literature review is used to make recommendations for the additional human engineering guidance that is needed. Special consideration is given to the impact of the introduction of the female population into the shipboard work environment.

These recommendations are given in the form of an annotated outline of the contents of a human engineering guidance document for ship systems and equipment (appendix 1). A section of this guide is included to serve as a representative sample of the information that the final guide will have (appendix 2). Although the guide is currently in the planning and preparation phase, the enclosed sample will provide useful information which is otherwise not readily available to the designer of shipboard equipment and systems.

2.0 SPECIAL CHARACTERISTICS OF SHIPBOARD EQUIPMENT AND OPERATIONS

2.1 Shipboard Work

The work that is done aboard ship can be conceptualized into two categories. The first category would include tasks that are oriented toward information processing and decision making. Shipboard command, control, and communications systems would fall into this generic category. The human factor considerations for these C³ systems have been examined [ref 7]. The second category of shipboard work includes those tasks where the demands are primarily physical. Mooring, underway replenishment, and the handling of stores typify this category of tasks.

⁵Palla, R.L., Jr., et al. Evaluation of Selected Navy Equipment for the Women Aboard Ship Program. NBSIR 79-1949 (Navy). For Commerce Product Technology, National Engineering Laboratory, National Bureau of Standards, Washington D.C. 20234, January 1980.

⁶Advanced Marine Enterprises. Suitability of Hull and Damage Control Equipment and Systems for Women Aboard Ship. Arlington, VA, March 1980.

⁷Coburn, R. and Lowe, T.D. Human Factors Engineering Integration for Ship Systems: FY76 Report on Methodology for Command, Control, and Communications, NELC/TN 3194, 19 July 1976.

It is currently unknown whether there are male/female differences in cognition of a significant enough nature to affect information processing tasks. It is clear, however, that the anthropometric differences of men and women are significant and may have serious impact on the performance of physical tasks. The impact of these differences on physical task performance will be in a large part determined by the human engineering of physical task relevant equipment and systems.

2.2 Non-Routine Operations

Non-routine operations, such as combative engagements or damage control, often require prompt action under conditions of extreme stress and adverse environmental conditions. In fire fighting and damage control situations there may be excessive heat, fumes, and wet equipment and decks. Protective gear which restricts mobility and endurance may have to be worn. Ship motions may be amplified by the nature of the damage (loss of steerage or a list). Many personnel may be called upon to perform tasks that meet or exceed their normal capabilities.

Although these non-routine operations are performed relatively infrequently, there is a very high degree of criticality associated with them. This criticality indicates a need for human operated response systems that are reliable and effective under all possible conditions.

2.3 Environmental Variables

Many environmental factors distinguish shipboard work from traditional industrial work settings. The most obvious of these factors is ship motion. Although the specific effects of ship motion on human performance are somewhat unclear, it can be assumed that tasks involving the operator in a non-fixed position (e.g., standing, walking, carrying) will be adversely affected by ship motion. This will be especially true on smaller ships which are more responsive to rough sea states.

Shipboard personnel are subject to many extremes of temperature. Job performance decrements associated with tropical climates may be particularly severe [ref 8]. Heat can be a constant source of stress for engine room operators [ref 9]. Deck division personnel must cope with such weather factors as precipitation, wind, and cold.

Noise is another source of difficulty in the shipboard environment. Noise from engines and machinery can mask sound signals, warnings, and communications. Studies have shown shipboard noise to affect work output as well as hearing [ref. 8, 9].

Many shipboard tasks involve the use of paints, solvents, oil and gas. Dense concentrations of the fumes of these substances can inhibit work output, as well as be hazardous to the sailor [ref 10].

⁸de Walden-Galuszko, K. A Review of Maritime Occupational Health Research in Poland. Institute of Maritime and Tropical Medicine, Gdynia, Poland, 1977.

⁹Ivergard, T. Occupational Hygiene and Health in the Design of Ships. Ergolab, Stockholm, Sweden, 1977.

¹⁰Svedung, I. Air Quality on Board a Tanker. Swedish Water and Air Pollution Laboratory, Gothenburg, Sweden, 1977.

2.4 Personnel Variables

2.4.1 Introduction of the Female Population into the System. Shipboard equipment and fittings were not designed with the female user in mind. While it is not unknown for males to have difficulty with shipboard items (e.g., opening scuttles, moving pumps), it can be assumed that these items will pose even greater problems for women.

The anthropometric differences mentioned earlier in this report have been cited as the reason for the non-accommodation of women with hand tools [ref 11]. Another study found that 90% of the female population would be poorly fitted into a workplace designed to male dimensions [ref 12]. The designer of shipboard equipment must take measures to provide a work environment that properly accommodates the men as well as the women who are now coming aboard.

2.4.2 Job Incumbent Turnover. The manning of shipboard work stations is a function of the natural cycle of Naval rating advancement and the constant influx of novice job incumbents. Novice operators tend to exhibit great variation in how they use equipment and accomplish tasks. This user variation may cause anything from an increase in the time needed to accomplish a task to equipment damage or on-the-job accidents. Much of this variance in equipment use can be eliminated through human engineering practices that standardize and simplify the operation of shipboard equipment.

2.5 Spatial Constraints

Ships are designed with extreme limits on spatial dimensions and layout. This may result in inaccessible fittings, overhead obstructions, and other compromises to the "optimum" workplace configuration. The behavioral impact of these constraints is manifest in such areas of movement restrictions, body positioned limits, and limited visual and manual access.

3.0 REVIEW AND ASSESSMENT OF SHIPBOARD RELEVANT HUMAN ENGINEERING GUIDANCE DOCUMENTS

3.1 Review

3.1.1 Military Specification, Human Engineering Requirements for Military Systems, Equipment, and Facilities. MIL-H-46855B, 31 January 1979. This document presents implementation criteria concerning contractual compliance with current human engineering standards. Specific tasks are identified for the performance of human engineering projects. Requirements for the inclusion of human engineering in the following areas are discussed:

¹¹Ducharme, R.E. Women Workers Rate "Male" Tools Inadequate. Human Factors Society Bulletin, 1977, 20(4), 1-2.

¹²Ketcham-Weidl, M.A. and Bittner, A.C., Jr. Anthropometric Accommodation of a Female Population in a Workplace Designed to Male Standards. Pacific Missile Test Center, Point Mugu, California, TP-76-3, 31 December 1976.

- Design and development
- Test and evaluation
- Program planning
- Function allocation
- Task analysis
- Equipment detail design
- Applied experiments
- Simulations and mock-ups
- Work environment, crew stations and facilities design.

Other main areas of emphasis include quality assurance and product delivery criteria. The appendix describes selective methods of tailoring MIL-H-46855B to specific project needs.

The focus of this document is on where and when to use human engineering practices in system design. No actual design criteria are established.

3.1.2 Military Standard, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities. MIL-STD-1472B, 31 December 1974. The authoritative human engineering design standards of the Department of Defense are described in this publication. The criteria referenced apply to all military systems, equipment, and facilities. The intent is to standardize human engineering specifications throughout the Army, Navy, and Air Force.

General and detailed requirements and human engineering specifications are defined for such areas as:

- Control/Display integration – position, movement, ratio, layout.
- Visual Displays – location, arrangement, coding, illumination.
- Auditory Displays – warning systems, communications systems, speech reception equipment.
- Anthropometry – male and female measures on selected dimensions, reach envelopes, and workplace design implications. MIL-STD-1472B Notice 2 (10 May 1978) expands this section to include male and female maximum force producing limits.
- Environmental Variables – heating, ventilation, air conditioning, illumination, noise, vibration.
- Maintenance – access, adjustments.
- Small Systems and Equipment – portability, tracking.
- Hazards and Safety.

A recent study was undertaken to improve the adequacy of MIL-STD-1472 in an effort to reduce waiver requests [ref 13]. This study indicated a need to update component specifications to be consistent with items currently on the market. Other major changes that the study recommended concerned conflicts with other human engineering guidance manuals and the need for examination of current man-computer interface systems. These changes have been incorporated into MIL-STD in the form of a proposed version entitled MIL-STD-1472C [ref 14], which is currently in the evaluation phase.

3.1.3 Shipboard Habitability Standards. OPNAVINST 9640.1, 13 October 1979. The policy of the Chief of Naval Operations regarding peacetime shipboard habitability standards are stated in this instruction. Procedures for criterion attainment are also established. These standards are to apply to all commissioned Navy ships greater than 150 feet in length or manned by more than 100 crew members. Standards are divided into three categories to reflect the feasibility constraints of overhauling existing ships. These divisions are as follows:

CATEGORY I. Human Habitability Standards for New Ships. New ships are considered to be those that have not as yet completed the "preliminary design" phase.

CATEGORY II. Minimum Habitability Standards for Existing Ships.

CATEGORY III. Improvement Standards for Existing Ships.

Environmental control standards are established in the following areas:

- Air conditioning and ventilation
- Heating
- Noise abatement
- Illumination
- Materials
- Radiological controls
- Passageway clearances
- Fresh water capacities.

¹³Elke, D.R., et al. Human Engineering Design Criteria for Modern Control/Display Components and Standard Parts. Essex Corp. RS-CR-80-1 for U.S. Army Human Engineering Laboratory Detachment, U.S. Army Missile Command, Redstone Arsenal, Alabama 35809, May 1980.

¹⁴Military Standard, Human Engineering Design Criteria for Military Systems, Equipment and Facilities. MIL-STD-1472C (Proposed) 18 July 1980.

Habitability systems are directly discussed with standards being established in the areas of:

- Berthing
- Stowage
- Sanitary spaces
- Food service spaces
- Recreation
- Personal services.

Rather than offer specific human engineering guidance for equipment designers, this document expresses standards in terms of minimum allowable dimensions of spaces and fittings. Additionally, separate male and female berthing and sanitary facilities are provided for, and the procedure of "hot bunking" (more than one crew member assigned per berth) is disallowed on surface ships.

3.1.4 Human Engineering Guide to Ship System Development. R. Coburn, NELC/TD-278, 3 October 1978. This guide was prepared to assist in the planning and carrying out of human engineering programs for ship systems. The role of human engineering in the ship system development cycle is discussed from requirements determination to fleet operation. This paper is intended to be a guide for personnel responsible for procuring, funding, or monitoring human engineering efforts.

This document focuses on the sequence of human engineering activity. Requirements analysis and man-machine concepts analysis methods such as:

- Functional block diagrams
- Information flow charts
- Operational sequence diagrams
- Link analysis
- Time line charting

are briefly described. The role of human engineering in man-machine design and subsequent design verification also is discussed.

The contracting procedure for human engineering work is covered with emphasis on program planning, project costs, preparation of a Request for Proposal, and contract monitoring responsibilities.

An extensive reference bibliography is given for military and nonmilitary human engineering guides and publications. The appendices also present selected human engineering tools and methods in the area of time line analysis, link analysis, and checklist troubleshooting.

3.2 Assessment

The documents reviewed above fall into two categories. One discusses what types of human engineering effort need to be applied to system development and establishes procedures for procuring and monitoring these human factor services. Military Specification MIL-H-46855B and the Human Engineering Guide to Ship System Development NELC/TD-278 fall into this category. The other category provides design guidance such as in Military Standard MIL-STD-1472B and the Shipboard Habitability Standards, OPNAVINST 9640.1. The emphasis of MIL-STD-1472B, however, is on electronic control and display systems. While these are relevant to certain shipboard systems, the mechanical equipment and operations typically encountered in shipboard tasks are not adequately covered. The Shipboard Habitability Standards, OPNAVINST 9640.1, are limited to habitability systems and concentrate on minimum dimensions (e.g., clearance, sizing) rather than the task relevant areas of human engineering.

The special characteristics of ship systems reviewed in Section 2.0 indicate a need for human engineering guidance in areas that are not adequately covered in the above documents. A guide is needed that focuses on the task oriented aspects of equipment design. Equipment must be assessed in terms of how it is manipulated, by whom, and under what conditions it will be used. More guidance has to be given on the design of mechanical fixtures and equipment. Special attention should be given to equipment used in emergency situations or in adverse environments.

A more in-depth analysis of the user population (especially the female user population) is needed in terms of anthropometry, biomechanics, and work physiology, with emphasis on implications to design. Finally, a user-oriented problem identification methodology is needed that will pinpoint present and future human engineering/human factor problems in shipboard equipment design.

4.0 SHIPBOARD DESIGN GUIDANCE MANUAL DEVELOPMENT

4.1 Areas to be Covered

The shipboard equipment human engineering design guide's main function is to aid the designer in making decisions about the specifications and arrangement of shipboard equipment and fittings. Since it is impossible to cover every piece of task oriented equipment or to predict what future needs will arise, a mixture of background knowledge and application to design will be offered. Within this framework, cross references to other relevant human engineering guidance documents will be given where needed.

The goal is to make all necessary information available to the designer, while avoiding duplication of the existing data base. At times, all that may be needed is an explanation of how to use existing data (e.g., anthropometrics). In this case an explanation and an example of use would be offered, with a reference to the most applicable guidance manual containing the needed data.

4.1.1 Background Knowledge. Since cross referencing will be an integral part of this document, general information will be given to acquaint the reader with the other manuals that relate to the design of shipboard equipment. Special characteristics of ship systems will be discussed to give the designer a broad overview of the kinds of conditions in which shipboard equipment must be used. Sections will be included that give background information in anthropometrics, biomechanics and work physiology. These sections will highlight male/female differences in functional capabilities. This background knowledge in user characteristics is essential for understanding the subsequent human engineering guidelines. It will also enable the designer to generate meaningful alternate design solutions when necessary.

4.1.2 Application to Design. Sections in the guide will be included that discuss the design considerations attendant to the special environmental factors of shipboard work. The use of shipboard equipment and fittings will be covered in terms of generic categories that reflect similar human factor considerations. These categories will contain such divisions as equipment that is moved vs. stationary, routine vs. emergency, etc. Where possible, specific examples will be given that reflect the human factor considerations most relevant to the category under investigation.

A problem identification methodology will also be included. This methodology will aid the designer in pinpointing current human engineering problems aboard ships, as well as predicting the types of problems that a proposed design might have.

4.2 Approach to Preparation

There will be two main efforts in assembling the information needed for this guide. The first consists of a comprehensive literature review of all documents and studies that apply to the performance effects of biomechanics, anthropometrics and work physiology in males and females. This literature review is currently in progress and will be summarized in another report by Integrated Sciences Corporation later this year. The knowledge gained from this current state-of-the-art literature review will be utilized in making design recommendations, as well as identifying the further research needed.

The other source of information will be actual shipboard visitations. Information will be gained from observations, formal and informal interviews with shipboard personnel and questionnaire data. The data gained from these visits will be used to identify problem areas and to develop "real world" examples for various sections in the guidance manual.

The manual itself will be prepared section-by-section. Since it is projected that a great deal of time will be required to finish the guide, each section will be released upon completion.

4.3 Example of Human Engineering Guidance Manual

The appendices of this document include two examples of the proposed human engineering guidance manual for ship systems. Appendix 1 contains an annotated outline of contents. Although these contents are generalized and tentative, they indicate the areas of emphasis that this guide will have. Major section headings are listed with brief introductions that discuss contents of the various chapters. Sectional subheadings provide additional information regarding the emphases of each section.

Appendix 2 is an example of one section of the guide in greater detail. The information included in this section was gained from the methodology described in Section 4.2 of this report. In addition to giving a future indication of the type of guidance that this manual will offer, this appendix is intended to be of immediate use to the designer of shipboard equipment and systems.

5.0 CONCLUSIONS AND RECOMMENDATIONS

During the rest of this decade and continuing through the 1990's, women will be coming aboard Navy ships in greater numbers. As the ships' female complement grows, the opportunity for placing larger and stronger personnel into physically demanding jobs will be lessened. The most efficient utilization of smaller and lighter personnel will require a re-examination and redesign of some equipment and systems board Navy ships.

This report examined the special environmental and situational aspects of ship systems. The performance of physical tasks by the female population is an area of concern due to anthropometric differences. The effects of these differences on critical non-routine operations are especially in need of analysis. The unique combination of ship motion, temperature, precipitation and noise in the shipboard environment was discussed in terms of impact on work output. Personnel variables such as the recent introduction of the female population and job incumbent turnover indicate a need for workspace accommodation and equipment simplification.

This combination of factors emphasizes the need for specialized human engineering guidance for ship systems and equipment. The guidance documents reviewed in this report do not adequately address the special human factor considerations of shipboard equipment design. These documents tend to emphasize more traditional human engineering areas such as electronic control and display systems rather than the mechanical tasks typically found on board.

A human engineering guidance manual which is tailored to the special needs of shipboard equipment designers is outlined in this report. In order to maintain real world validity, the manual's development should include shipboard visitations as well as a human performance literature search. The human engineering guidance developed through this effort will aid designers in creating a shipboard work environment that most efficiently utilizes the capabilities of the current and future heterogeneous crew composition.

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APPENDIX 1 TO APPENDIX B: PRELIMINARY ANNOTATED OUTLINE OF CONTENTS

1.0 Purpose

This document is intended to supplement rather than duplicate existing human engineering reference sources for the design of U.S. Navy shipboard equipment. This guide focuses on the task and situational aspects of human engineering requirements for equipment design. It is felt that equipment must be designed and assessed in terms of how it is employed (use characteristics), by whom (user characteristics), and under what conditions it will be used (environmental and situational characteristics).

An analysis of the user population in terms of anthropometry, biomechanics and work physiology is advanced, which emphasizes implications to equipment design. Finally, a user-oriented problem identification methodology is offered to assist in pinpointing present and future human factor/human engineering problems in shipboard equipment design.

2.0 Related Documents

There are several reference documents that have applications in the human engineering of shipboard equipment.

This section describes these documents in terms of the areas that they cover and their relevance to various shipboard systems.

For the most part, these documents fall into two categories. One discusses what types of human factors effort need to be applied to systems development. The other type provides design guidance. However, there is a heavy emphasis on consoles and controls and displays. More attention needs to be given to shipboard mechanical equipment.

2.1 Military Specification, Human Engineering Requirements for Military Systems, Equipment and Facilities. MIL-H-46855B, 31 January 1979

2.2 Military Standard, Human Engineering Design Criteria for Military Systems, Equipment and Facilities. MIL-STD-1472B, 31 December 1974

2.3 Shipboard Habitability Standards. OPNAVINST 9640.1, 13 October 1979

2.4 Human Engineering Guide to Ship System Development. R. Coburn, NELC/TD-278, 3 October 1978

3.0 Special Characteristics of Ship Systems

The shipboard environment is uniquely different from the "standard" industrial work setting. These differences necessitate different areas of emphasis from those that are usually focused on in standard human engineering guides and references :

Several major variables that are specific to ship systems are outlined in this section.

- 3.1 The Nature of Shipboard Work
- 3.2 Non-Routine Operations
- 3.3 Environmental Variables
- 3.4 Personnel Variables
 - 3.4.1 Introduction of the Female Population
 - 3.4.2 Job Incumbent Turnover
- 3.5 Space Constraints
- 4.0 Crew Characteristics

The optimum match of workers with tools, machines and systems can only be achieved with a proper understanding of certain worker characteristics. Areas that have particular relevance to design are anthropometry, biomechanics and work physiology. Anthropometry is the science of measuring human populations to establish size and proportional characteristics. Biomechanics (also termed "ergonomics") answers questions such as how much force can be exerted in various body positions. Work physiology concentrates on the reactions of body functions to conditions of exertion, thermal stress, etc.

The following sections are limited to areas that have direct implications to shipboard equipment design. No attempt was made to comprehensively cover all aspects of the above cited areas. The reader with further interest in particular areas is directed to the reference list at the end of this section.

4.1 Anthropometry. Anthropometry describes the shape, size and weight of specific populations of people in terms of percentile ranks. This system describes a normalized distribution of body dimensions that usually includes 90% to 95% of the total population. As will be demonstrated later, the actual dimensions vary as a function of which population is being described. There is obviously great variability between the sexes, as well as racial and even occupational differences.

The design caveat is that equipment should be made to accommodate those who will be the users. For this reason, this section will focus on the use of data that are relevant to the current heterogeneous shipboard population.

- 4.1.1 The Difference Between the 50th Percentile and the "Average Man"
- 4.1.2 Factors that Affect Body Size
 - 4.1.2.1 Sex
 - 4.1.2.2 Body Position
 - 4.1.2.3 Clothing

4.1.3 Understanding Anthropometric Data

4.1.4 Anthropometrics of the User Population

4.1.4.1 Examples and Sources for Male and Female Dimensions

4.1.4.2 Examples and Sources for Male and Female Reach Envelopes

4.1.5 Applications of the Data to Design

4.2 Biomechanics. The focus of this section is on the force producing capabilities of people who are required to perform shipboard work. These capabilities are greatly affected by muscle mass, the parts of the body used and the leverage afforded by certain body positions. The difference between male and female capabilities in various body component areas is covered, as well as the effects of constrained or altered body positions.

There is a great deal of difference between total capability or maximal force output and appropriate loadings for repetitive tasks. The specifications given in this section should be used in consideration of what the worker will be doing, how often he/she will be doing it, and what else will be required of the worker either concurrently or in sequence with task performance.

4.2.1 Definitions of Body Movements

4.2.2 Force Producing Capabilities of Men and Women

4.2.3 Positional Limitations

4.2.4 Applications of the Data to Equipment Design

4.3 Work Physiology. Human physiological regulatory processes have a profound impact on the performance capabilities of workers. The capacity for endurance and thermoregulation (adaptation to heat and cold stress) have particular relevance to the design of task related shipboard equipment. This section explores some of the differences between male and female thermoregulatory processes and endurance capacities and their potential impact on work output.

4.3.1 Reactions to Thermal Stress

4.3.2 Endurance

4.3.3 Considerations for Design

5.0 Environmental and Situational Considerations

Tools and equipment are designed with a use or a goal in mind. The goal might be simple and routine, such as turning a screw, or complex and critical, as in dewatering a compartment. The attainment of the goal might involve wearing protective gear and/or clothing. Additionally, the environment in which the task is to be accomplished may contain extremes of motion, temperature and the like.

These environmental and situational variables significantly alter task complexity and demands on the worker. This section explains some of the behavioral effects of special environmental and situational circumstances, and discusses their implications to design.

5.1 Ship Motion

5.1.1 Effects on Psychomotor Performance

5.1.2 Psychological Effects

5.1.3 Motion Sickness

5.1.4 Sex Differences in Motion Effects

5.1.5 General Design Considerations

5.2 Temperature

5.2.1 Male, Female Tolerance Limits

5.2.2 Performance Decrements Under Heat and Cold Stress

5.2.3 Design Implications

5.3 Wind, Precipitation

5.3.1 When and Where Most Affected

5.3.2 General Design and Safety Considerations

5.4 Special Clothing

5.4.1 Types, Where and When Used

5.4.2 Movement Restrictions

5.4.3 Endurance Restrictions

5.4.4 Design Guidance for Equipment Used with Special Clothing and Gear

6.0 Human Factor/Human Engineering Considerations for the Use of Shipboard Equipment, Fittings and Materials

Other sections of this guide have focused on user characteristics and the environmental/situational aspects of shipboard equipment design. This section addresses the human factor considerations directly relevant to the use of shipboard equipment and fittings.

Since there is a large array of different types of equipment, fittings and materials aboard any given ship, no attempt has been made to comprehensively cover specific types or model numbers. The emphasis is rather on general human factor/human engineering principles that are common to shipboard equipment and fittings which fall into similar categories. Where possible, examples are given by examining the design characteristics of typical shipboard items.

6.1 Ship Fittings

6.1.1 Force, Grip, Body Leverage

6.1.2 Visual, Manual Access

6.1.3 Body/Equipment Clearance

6.1.4 Maintenance

6.2 Equipment

6.2.1 Use

6.2.1.1 Force, Grip, Body Leverage

6.2.1.2 Visual/Manual Access

6.2.2 Movement (Carrying, Pushing)

6.2.2.1 Clearance/Number of Workers Involved

6.2.2.2 Grip, Force, Body Leverage

6.2.3 Maintenance

6.3 Materials Handling

6.3.1 Handling and Carrying Materials

6.3.2 Storage

6.4 Accommodations, Habitability

6.4.1 Berthing

6.4.2 Stowage

6.4.3 Sanitary Facilities

6.5 Tools

6.5.1 What is Provided

6.5.2 Configuration/Use Parameters

6.5.2.1 Grip/Force, Body Leverage

6.5.2.2 Portability

6.5.2.3 Use at Work Site

7.0 Problem Identification

Human factor/human engineering problems in equipment design can be identified by pre-design prediction and post-design evaluation. The prior sections in this guide have focused on problem avoidance through understanding the use, user and situational aspects of equipment design. This section presents an evaluation methodology for pinpointing specific human factor/human engineering problem areas in equipment design. This methodology can be applied to problem prediction or to identification of existing problems.

Task description and analysis methods are presented. A checklist inventory is given which, incorporated into the task analysis, specifies and categorizes problem areas for further evaluation. This evaluation is then used to generate equipment modification alternatives that increase the compatibility of the intended users with the equipment they must use.

7.1 Methodology and Approach

7.1.1 Job/Task Description Methods

7.1.2 Human Factor/Human Engineering Inventory

7.1.3 Task Analysis Inventory

7.1.4 Use Scenario

7.1.5 Failure Mode Evaluation and Design Solutions

7.2 Example of Evaluation Methods and Design Solutions

7.2.1 Use Scenario

7.2.2 Task Evaluation

7.2.3 Design Solutions

APPENDIX 2 TO APPENDIX B: 5.1 SHIP MOTION

Information received from visual and auditory stimuli, muscle motion sense and the inner ear's semi-circular canals is largely responsible for human orientation. When messages sent by the above systems are in agreement, we can reliably judge verticality. Conflicting visual feedback and g forces in a moving environment, however, severely compromise this function [ref 1].

Sensory orientation information received in the shipboard environment is influenced by the frequency, amplitude and direction of ship motion. These sensory influences significantly affect psychomotor, physiological and psychological functions. The resultant performance effects range from increased task completion times to debilitating motion sickness.

5.1.1 Effects on Psychomotor Performance

The more obvious effects of ship motion on motor performance involve tasks where mass, balance and acceleration are the key parameters and the operator is in a non-fixed state. Examples of tasks involving these factors are carrying a heavy pump (e.g. P-250), balancing on a narrow platform or traversing a wet slippery deck.

Laboratory findings on the psychomotor effects of motion have been somewhat equivocal. Simulated motion failed to degrade the performance of subjects in combination lock opening tasks, grip strength or ball throwing [ref 2, 3]. A more recent study [ref 4], however, found significant motion-related performance decrements in tasks such as plotting, lock opening and tracking. Subjects in this experiment reported that task difficulty was mainly due to the direct physical and biodynamic effects of motion.

The results of field investigations have been more consistent. Russian investigators have found deleterious motion effects in the "professional proficiency" of crew members [ref 5]. This reduction in proficiency was attributed primarily to large increases in error rates. Other investigators [ref 6, 7] have found decrements in plotting and critical tracking tasks on board due to ship motion.

¹Woodson, W.R. and Conover, D.W. Human Engineering Guide for Equipment Designers. Second ed., University of California Press, Los Angeles, 1964.

²Guedry, G.E., Kennedy, R.S., Harris, C.S., and Graybiel, A. Human performance during 2 weeks in a room rotating at 3 RPM. Aerospace Medicine 35, 1071-1082, 1964.

³Clark, B. and Graybiel, A. Human performance during adaptation to stress in Pensacola SRR. Aerospace Medicine 32, 93-106, 1961.

⁴Jex, H.R., O'Hanlon, J.F. and Ewing, C.L. Simulated rough water operations during long cruises in a 2000-ton surface effect ship, phases 1 and 1A. Systems Technology Inc., Hawthorne, Ca. Tech. Report No. 1057-2, 1976.

⁵Sapov, I.A. and Kuleshov, V.I. Seasickness and efficiency of the crew on a surface vessel. Military Medical Journal (Voenno-Meditsinskiy Zhurnal) 4, 88-91, 1975.

⁶Pepper, R.L. and Wiker, S.F. Repeated assessment of stress, mood and performance changes resulting from exposure to vessel motions at sea. Presented to the Annual Human Factors Society Convention, Boston, Mass., October 1979.

⁷Wiker, S.F. and Pepper, R.L. Changes in crew performance, physiology and affective state due to motions aboard a small monohull vessel: a preliminary study. Prepared for Department of Transportation, Report No. CG-D-85-78, December 1978.

An earlier study conducted aboard the USS GLOVER (AGDEI) [ref 8] correlated degree of roll with motor performance. This study found three different gradients of motor performance decrement as a function of three difference classes of roll severity. It was found that 0° - 4° roll moderately altered motor behavior. At this roll gradient, people needed a steadying hand while traversing walkways, decks, etc. Fine motor tasks such as soldering required extra aids, extra time and a steadier work stance. At the 4° - 10° level, this pattern continued, greatly impairing tasks that required body or equipment movement or the use of hand tools. Maintenance tasks were found to be most severely affected at this level. Specifically, shock hazard, equipment damage and extended task completion times were noted. Roll above 10° was found to seriously compromise all shipboard work involving the movement of men and materials. These effects are summarized in table B-1.

Table B-1. Effects of ship roll on psychomotor tasks (from Warhurst and Cerasani, 1969).

Degree of Roll	Behavioral Impact		
	Locomotion and Material Transport	Gross Motor Tasks	Fine Motor Tasks
0°	Normal	Normal	Normal
0° - 4°	Handholds needed	Handholds needed	Handholds needed
4° - 10°	Handholds needed, traffic impaired, additional personnel, additional time, use of non-skid surfaces	Additional personnel, additional care, additional time, use of restraining devices	Extra care, use of use of steadying devices, tool holders needed, raised table edges needed
>10°	Difficult to impossible depending on weight, delicacy of load, condition of work space and availability of extra personnel	Extreme care to avoid equipment damage and personnel injury	Extreme care to avoid equipment damage and personnel injury

⁸Warhurst F. and Cerasani, A.J. Evaluation of the performance of human operators as a function of ship motion. Naval Ship Research and Development Laboratory, Washington, D.C. Report No. 2828, April 1969.

Critical incidents were also found to be a function of degree of roll. Figure B-1 shows the number of incidents (e.g. falling, spilling, dropping, slipping or incidents of injury or equipment damage) plotted as a function of degree of ship roll. Although there were too few points to justify a significant mathematical function, the results are interpreted as evidence of a causal relationship between ship roll and critical incidents. Some typical incidents reported in this study are listed below :

- People falling off stools when using them to reach inaccessible items.
- Danger to deck personnel increased greatly as a function of roll and proximity to the sea surface.
- During heavy roll, many deck surfaces were wet due to tracking water through doors and spillage of fluids. Some of these surfaces were not skid-proofed and offered poor footage.
- Personnel banging legs or tripping on companionway lights.
- The effects of roll coupled with improper console design caused inadvertent activation of a pushbutton on a sonar control resulting in electrical damage to the equipment.

5.1.2 Psychological Effects

Onboard studies of cognitive processing have found detrimental effects of ship motion in concentration tasks [ref 6], mental arithmetic measures [ref 5] and grammatical reasoning tasks [ref 7]. Affective states are also altered by ship motion. Reports of anxiety increase with motion, as do reports of fatigue [ref 7, 8]. Motivational level has been found to increase as roll approaches 4° . From 4° - 10° , fatigue begins to set in, and above 10° morale is impaired and frustration rises, resulting in a lowered motivational state [ref 8].

5.1.3 Motion Sickness

Incidences of frank motion sickness (emesis) aboard marine craft range from 11% to 70% of the crew, depending on sea state. The widespread impact of this malady is supported by motion sickness questionnaires, which indicate that approximately 90% of populations sampled had experienced motion sickness [ref 9].

A more recent investigation [ref 10] found that not only the incidences of emesis, but the severity of the associated symptomology (e.g. facial palor, sweating, nausea) varied as a function of hull design and ship's attitude toward the primary swell. In this study, no incidences of emesis occurred on a 378-foot Coast Guard White High Endurance Cutter, while all but one sailor (N=18) experienced emesis aboard a 95-foot Coast Guard White Patrol Boat.

⁹Reason, J.T. An investigation of some factors contributing to individual variation in motion sickness susceptibility. Flying Personnel Res. Comm. Rep. No. 1277. London Ministry of Defense, 1967.

¹⁰Wiker, S.F., Kennedy, R.S., McCauley, M.E. and Pepper, R.L. Susceptibility to seasickness: Influence of hull design and steaming direction. Aviation, Space, and Environmental Medicine, 50(10) 1046-1051, 1979.

The influence of swell direction on motion sickness can be seen in figure B-2. In this study [ref 10] three vessels teamed an octagonal pattern in a sea state of 2 for two days. Each leg of the octagon was 30 minutes in length. As is shown in figure B-2, motion sickness symptoms were greater in legs that had a head sea component than in legs with following seas (note that there was a lag between the influence of swell direction and the onset of symptoms).

There are direct and indirect performance effects of motion sickness on the sailor. The direct effects of emesis are obvious. The worker in this state cannot be expected to perform any given task adequately. Indirect effects are less clear, but are no less critical. An operator who is afflicted with a lesser degree of motion sickness will most likely continue to perform his/her billet. In addition to lessened psychomotor capability, this operator will possess impaired cognitive processing, fatigue and a lowered motivational state. This situation greatly increases the probability of accidents and equipment damage due to misuse or neglect. This is an area of special concern to the designer of smaller monohull vessels of the type examined by Wiker et al. (1979) [ref 10].

5.1.4 Sex Differences in Motion Effects

At this time, there are no shipboard or field studies reported in the literature that have addressed themselves to the effects of sex on motion related performance decrements. It would be prudent to assume that the decreases in cognitive and psychological functioning and incidences of motion sickness found in studies on male populations would be at least as prevalent if these studies were done with female participants.

Tasks requiring biodynamic responses might affect the sexes differently under motion stress. Due to shorter height and a greater concentration of weight mid-body, the female center of gravity is lower in the vertical plane than the male's center of gravity. Females therefore have a physiological advantage over men in tasks requiring balance (e.g. using life lines or traversing a moving deck) [ref 11]. However, when a physically demanding component is added, such as carrying a heavy pump, the female might be disadvantaged.

The overall mechanical capacity of women is approximately 55% of that of men [ref 12]. In terms of performance, this means that a task that requires two-thirds of a man's mechanical capacity will require all of a woman's. In this case there will be no "reserve capacity" for the extra demands on strength and balance that ship motion causes.

The effects of reach envelope also change in a moving environment. When an operator is in a free or non-fixed state, he/she is able to compensate for inadequate reach capacity by adjusting body position. A moving environment will require anything from

¹¹ Palla, R.L., Jones, C.E., Lovett, C.D., Porter, L.G. Evaluation of selected navy equipment for the women aboard ship program. National Engineering Laboratory, National Bureau of Standards, Washington, D.C. NBSIR-79-1949 (Navy), December 1979.

¹² Ayoub, M.M., Grasely, C.C., and Bethea, N.J. Classification, summary, relevance and application of male-female differences in performance. Institute for Biotechnology, Texas Tech University, Lubbock, Texas, December 1978.

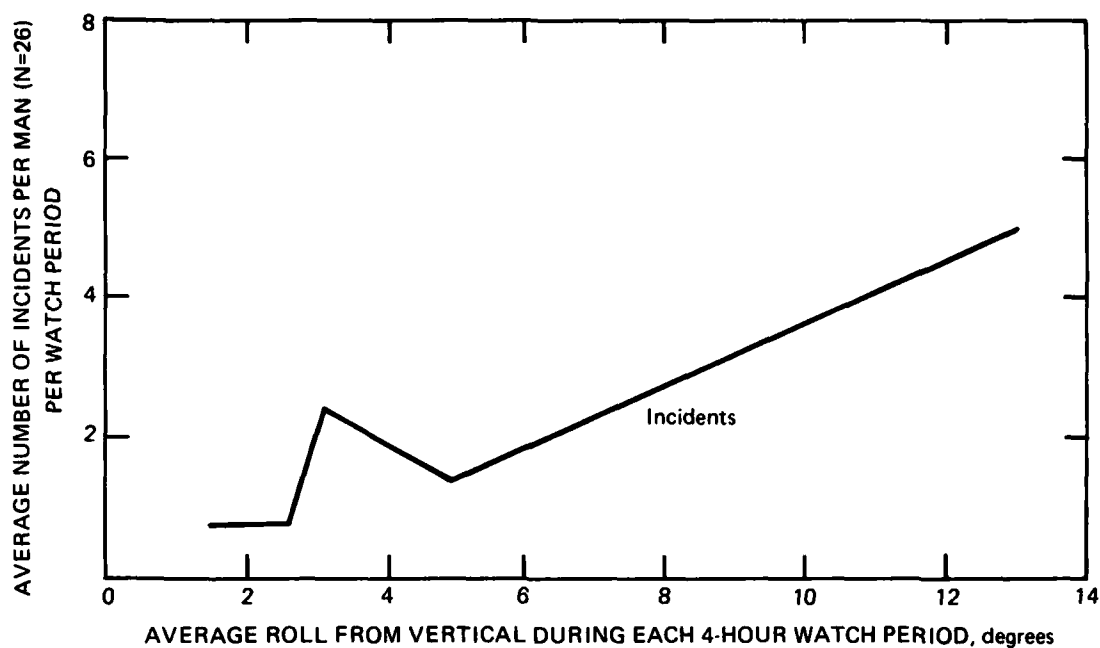


Figure B-1. Roll-caused incidents as a function of ship's roll (from Warhurst and Cerasani, 1969).

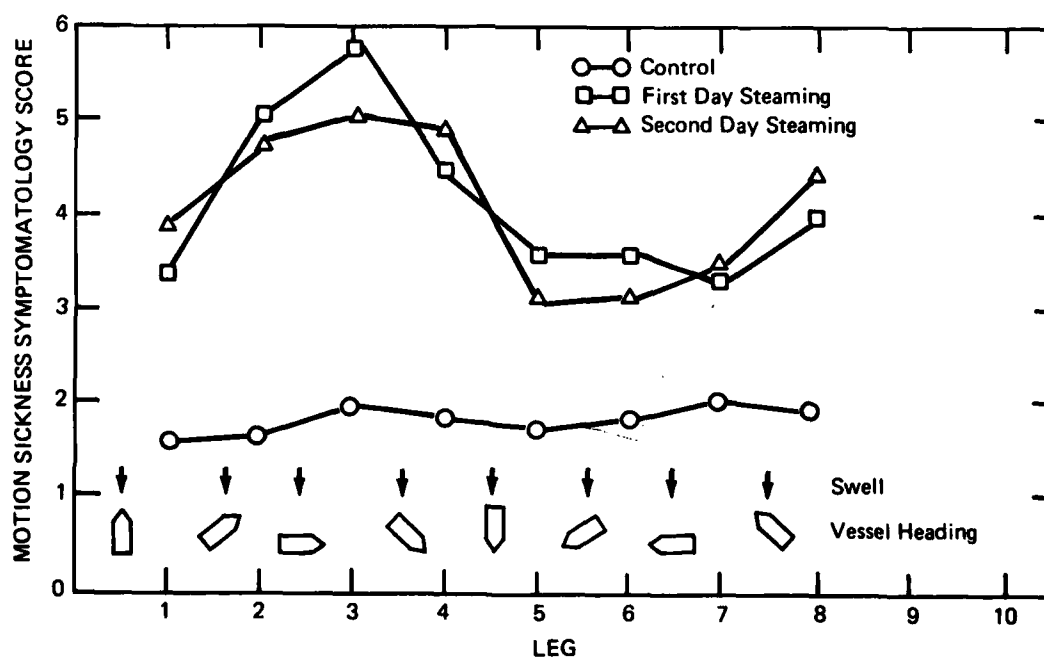


Figure B-2. Motion sickness symptomatology severity as a function of ship's attitude towards swell (from Wiker et. al., 1979).

a steadying hand to external restraining devices, depending on roll severity. This restricts the amount of body adjustment possible to facilitate reaching. While this problem will affect both sexes, it will have more impact with women due to their significantly smaller reach envelope [ref 13].

5.1.5 General Design Considerations

Traditional design solutions to the problem of ship motion include handholds, non-skid surfaces, guardrails and raised table edges. While these alterations are helpful, their impact must be assessed from the user's viewpoint. For instance, handholds that are placed in high traffic areas or in overhead locations often cause tripping, bumping, etc. In this case, recessed handholds should be considered where possible. Another example concerns non-skid surfacing. All traffic areas of the ship should be considered when placing non-skid surfacing. Ship motion can cause wet decks inside the ship due to spillage (especially in the galley) as well as on the weather decks. Non-skid surfacing is especially important on walkways and ladders that will be used for the manual transport of stores.

The design of work areas should consider the full spectrum of reach envelopes in the population. Personnel attempting to reach objects that are out of their grasp in a moving environment pose a significant safety hazard to themselves and others.

Other general recommendations related to ship motion problems include :

- Equipment should be designed to minimize the need for tools for use or maintenance.
- Moving parts must be protected from falling objects. Design features (shields, etc.) should be employed to keep hands from slipping into moving parts.
- Shielding and insulation should be used on wiring and electrical parts of electrical equipment, as well as adjacent metal surfaces and floors, to prevent electric shock.
- If low overheads or equipment cannot be avoided, these should be well marked, padded and illuminated.
- Projecting corners or edges should be eliminated from equipment located in traffic areas. If projections cannot be removed or rounded, they should be sufficiently padded.
- Special attention should be given in the design of damage control equipment. Damage control operations by nature might coincide with greatly increased ship motion or list. Additionally, any member of the ship's complement (including the smallest and lightest) might need to operate or move DC equipment.

The information presented in this section should give the designer a good idea of the severity of human psychological and motor performance alterations due to ship motion. The design guidance given here is intended to be broad and generalized. Later sections in this guide will treat specific types of equipment and fittings in a more detailed manner.

¹³Kennedy, K.W. Reach capability of men and women: A three dimensional analysis. AMRL-TR-77-50, July 1978.

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4. Jex, H.R., O'Hanlon, J.F. and Ewing, C.L. Simulated rough water operations during long cruises in a 2000-ton surface effect ship, phases 1 and 1A. Systems Technology Inc., Hawthorne, Ca. Tech. Report No. 1057-2, 1976.
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13. Kennedy, K.W. Reach capability of men and women: A three dimensional analysis. AMRL-TR-77-50, July 1978.

APPENDIX C: QUESTIONNAIRE FORMAT

Problems concerning special gear and clothing usually stem from one or more of the following areas: fit, weight, ventilation, body temperature (while in suit), or body movement restrictions. Please place a check in the column that corresponds to the type of problem(s) that you feel the following gear might create. If you have never used the gear in question, check "no experience."

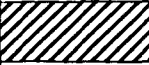
	Fit	Weight	Ventilation	Body Temp	Body Movement Restrictions	No Experience
77. Safety Harness						
78. Foul Weather Gear						
79. OBA						
80. Fire Fighting Suit						
81. Life Preserver						
82. Airline Mask						
83. MKV Mask						

84. Does the use of any special gear or clothing make it difficult to perform shipboard duties? _____

85. If you answered "YES" to #84, please list that gear or clothing and the tasks they interfere with.

Clothing/Gear	Task
_____	_____
_____	_____
_____	_____
_____	_____

Problems with the use of ship fittings usually stem from one or more of the following areas: position, size/shape, or force required for use. Please place a check in the column that corresponds to the type of problem(s) that the following ship fittings might create.

	Position	Size/ Shape	Force
86. Ladders			
87. Footholds			
88. Water Tight Doors			
89. Escape Scuttle			
90. Others (List)			
91.			

Problems with the use of tools, equipment, and supplies usually stem from one or more of the following areas: grip, appropriateness of size/shape, or weight. For questions 90 to 94, please list the tools, equipment, or supplies that you use that have problems in any of these areas. Check the column that corresponds to the type of problem(s) that may occur with their use. If you have no problems with tools, equipment, or supplies to report, leave this section blank.

List Tools/Equipment/Supplies Here	Grip	Size/Shape	Weight
92.			
93.			
94.			
95.			
96.			

97. Do you feel that ship motion or foul weather ever interfere with the conduct of tasks you must perform? _____

98. If you answered "yes" to #97, please list the tasks and associated equipment most affected.

Tasks	Equipment
_____	_____
_____	_____
_____	_____

99. Do you ever have trouble reaching any controls, equipment, or accessories that you need? _____

100. If "yes," please specify.

Problems with living quarters usually stem from one or more of the following areas: lighting, ventilation, difficulty of reaching and handling fittings, difficulty of reaching and amount of storage space, and low overhead clearances. Please place a check in the column that corresponds to the type of problem(s) that the following living quarters and services might have.

	Lighting	Ventilation	Fittings		Storage		Low Clearance
			Reaching	Handling	Reaching	Handling	
101. Berthing							
102. Head/Sanitary Facilities							
103. Stowage							
104. Others (List)							
105.							

106. Please list any other problems that you have with items 101 thru 105.

APPENDIX D: MEMO OUTLINE OF PURPOSE OF SHIPBOARD VISIT BY NOSC SCIENTISTS

This memorandum indicates the kinds of information that project staff hope to gain from shipboard visitation. Information gathering techniques are discussed. Examples of questionnaires and interview formats are attached.

WHAT WE WOULD LIKE TO SEE

The main area of concern for the Women Aboard Ships Project is in tasks that entail reaching and heavy muscular work. For this reason, we would like to observe some deck division manual labor tasks. Of particular interest are the tools, equipment, and ship fittings involved in these jobs. If possible, we would like to observe any machine/equipment maintenance operations or any fabrication work (e.g., sheet metal, pipe cutting, etc.).

We would like to examine and handle ship fittings such as scuttles, watertight doors, ladders, and the like. Habitability fixtures such as berthing, head, and stowage would also be examined.

WHO WE WOULD LIKE TO SEE

Ideally, we would like all available hands to respond to the questionnaire. We are aware of the plethora of questionnaire administrations that shipboard personnel have been subjected to of late. In recognition of this, the questionnaire has been designed to be clear, easy to administer, and above all, brief. An example of this questionnaire is attached with this memorandum.

A structured interview regarding potential person/machine interface problems has been devised by project staff. The people we would be most interested in interviewing would be:

1. Officers in Charge of the deck division and engineering division
2. Boatswains Mate, supervisor of deck division labor tasks
3. Machinist Mate, supervisor of engine room staff
4. Hull Maintenance Technician, supervisor of fabrications and maintenance.

We would also like the opportunity to interview several workers where possible (F2-F3). The people interviewed should be males and females who are experienced in working with a heterogeneous labor force. An outline of the interview format is enclosed with this memorandum.

APPENDIX E: STRUCTURED INTERVIEW FORMAT FOR WOMEN ABOARD SHIPS PROJECT

1.0 General Information

Rate	_____
Rating	_____
Sex	_____
Time Aboard	_____
Time in Navy	_____
Height	_____
Weight	_____
Jobs supervised or performed	_____

2.0 Billet and/or special duties (such as damage control)

2.1 Tools

Are any tools moved to and from your worksite?

List problems associated with tool movement, such as:

- weight
- bulk
- difficulty of movement leading to non-retrieval of tools.

Do you feel that the tool kit which is provided is appropriate for this job?

List problems associated with tool kit appropriateness, such as:

- tools missing
- special tools not provided
- tool kit not updated when equipment is modified or added.

Are any hand tools difficult to use due to a poor grip, weight or size?

Are any power tools difficult to use for these reasons?

Do any power tools give off excessive vibration or noise that bothers you or makes it hard to speak with others?

Where are the tools stored when not in use?

List problems associated with tool storage, such as:

- amount of storage space
- accessibility of storage space
- ability to find things in storage.

2.2 Equipment

Is there equipment that must be moved from one area to another?

List problems associated with equipment movement, such as:

- inadequate grips
- weight
- size
- balance
- difficulties associated with the number of people required to move it (fitting through doors, ladders, etc.).

Are there controls or gauges that are difficult to reach or see on any equipment?

If so, does the position of these controls or gauges force you to twist, stretch or strain in order to reach or see them?

Are there controls that have an inadequate grip or require large amounts of force to operate?

Is there equipment that gives off annoying vibration, noise or large amounts of heat?

2.3 Job Pacing

Are there jobs that are difficult because of the limited time given to accomplish them?

Are there jobs that involve physical endurance due to the amount of repetitions per day?

2.4 Environment

What jobs are most affected by rough sea states?

List problems associated with rough sea states, such as:

- falling
- sickness
- endurance
- movement of people and objects.

What jobs do extreme temperatures affect?

List problems associated with extreme temperatures, such as:

- endurance
- manipulability of tools or controls.

Is there anything in the worksite difficult to see due to poor lighting or obstruction by other ship fittings or machinery?

Does noise in your worksite make it difficult to communicate with your co-workers?

2.5 Clothing/Special Gear

Are there problems with the fit, bulk or weight of special gear or clothing that you use?

Does wearing special gear restrict your endurance on the job due to movement difficulties or body heat buildup?

Is it difficult to operate equipment (e.g., grip objects) or move through passageways and scuttles while wearing any protective clothing or gear?

2.6 Safety

Are there any objects in the worksite that people trip over or bump into, especially in rough sea states?

Are there any lifting tasks that cause muscular twisting or straining?

Are there any exposed moving machinery parts that people can catch their hands or clothing in?

Do people wear their protective masks in areas that have toxic fumes from paint, oil, gas and the like?

(Weather Deck Tasks Only) Do people tend to slip and fall during any tasks performed in rainy weather?

