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INVESTIGATION OF NON-PRODUCTIVE TIME ALLOWANCES FOR SHIPBOARD PERSONNEL

Herman L. Williams, et al

Naval Personnel Research and Development Labaoratory
Washington, D.C.

March 1973

NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY

WTR 73-20 APRIL 1973

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FOR
SHIPBOARD PERSONNEL

H. L. Williams
U. Shvern

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NAVAL PERSONNEL RESEARCH AND DEVELOPMENT LABORATORY
WASHINGTON, D. C. 20374

A LABORATORY OF THE BUREAU OF NAVAL PERSONNEL

FOREWORD

This investigation was performed in response to Advanced Development Objective 43.07X, Manpower Effectiveness.

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13. ABSTRACT

The objective of this research study was to investigate the need for and feasibility of developing and applying more accurate allowances to account for the non-productive time associated with shipboard workloads. Findings of the study indicate that because of the dominance of watch station, NEC requirements and other constraints, the non-productive time allowance has only a minimal impact on billet requirements. It was concluded that primary emphasis needs to be given to the development of second generation improvements in the billet determination process rather than to improvements in the accuracy of the non-productive time allowances. Improvements in the allowance are recommended, however, as a means of better satisfying the needs of shipboard personnel.

The relative importance of non-productive time allowances in the billet determination process was evaluated by means of a sensitivity analysis. In this analysis, the sensitivity of billet requirements to errors in the non-productive time allowance was determined and compared with the sensitivity of these requirements to errors in the workload/manpower determination processes. Appropriate conclusions were drawn on the basis of the findings generated during the study.

Findings

During the course of the study, it was noted that all personnel aboard ship receive a non-productive time allowance, i.e., time off for personal needs, rest, etc., in one form or another. The problem of concern was to determine when it should be taken into account in determining billet requirements. Study of this problem led to the conclusion that the allowance should be taken into account when the time taken off results in a requirement for additional manpower (Section V).

Three categories of billets were considered when examining the impact of the non-productive time allowance: (a) watch stations, (b) service billets, and (c) bulk task billets. Watch station billets are those generated in response to the ROC (Required Operational Capability). The occupants perform assigned functions during scheduled time periods.

The concept of a service billet is new and was developed for the purpose of identifying support billets whose occupants also perform assigned functions during scheduled time periods. For example, cooks in the galley usually fall into this category. Service billets are similar to the watch station billets. Like the watch stander, occupants of service billets normally "guard" or occupy a position.

The concept of a bulk task billet is also new. This type of billet was defined for the purposes of identifying work such as facility maintenance, etc., where the presence of the occupant is required only when actual work must be performed. The primary difference between the service and bulk task billets is that the latter does not involve a guarded position (Section V).

Findings of the study indicate that as a general rule only the allowance granted to occupants of bulk task billets must be compensated by additional manpower. Time off granted to watch standers and occupants of service billets usually does not result in a requirement for additional personnel. The opposite is true in the case of the bulk task billet. Work not accomplished as a result of time taken off remains to be done and usually requires additional personnel to perform it (Section V).

An analysis, based on a sample of 12 ships, indicates that the non-productive time allowance has a relatively minor impact on billet requirements, even though it is now granted to occupants of service billets (Section V). An analysis of the DD 938 which took the service billet into account shows that only 4 out of 295 enlisted billets could be saved by completely eliminating the present 20% allowance. This finding stems from the fact that billet requirements are dominated by watch stations, NEC requirements and other constraints (Section VII).

Billet requirements were found to be approximately six times more sensitive to errors in that portion of the billet determination process dealing with workload/manpower requirements than to errors in the non-productive time allowance. This led to the conclusion that improved methods need to be developed for determining workload and manpower requirements before an extensive effort is devoted to increasing the accuracy of the allowance (Section V).

The non-productive time allowance consists of three primary elements, i.e., personal, fatigue and delay components. Industrial experience indicates that a 5% personal allowance is adequate (Section IV). It was concluded that further research to improve the accuracy of this component is not warranted. In contrast, the present values of both the fatigue and delay allowance components are open to question (Section VII and Appendix B). The application of the experimental methodology for determining fatigue allowances to the DD 938 showed the distribution of fatigue allowance requirements to be bimodal. A constant fatigue allowance, such as that presently used, provides some personnel with more time off than needed. Others are granted too little. Completion of the development of the experimental methodology is warranted by the need for its use as a management tool to improve the efficiency of personnel utilization aboard ship (Section VI).

Because of the severe motion environment, the present 5% delay allowance component may be too small. This finding is based on an analysis which indicates that severe sea state conditions occur with a frequency greater than 5% (Appendix B). Numerous naval personnel when questioned about the problem agreed that a point is reached with increasing sea state where all non-essential work aboard the smaller ships ceases. Such work stoppage constitutes an unavoidable delay and should be taken into account in determining allowance requirements.

The use of the term "productive allowance" to describe the allowance granted to compensate for non-productive time associated with the shipboard workload is a misnomer. It is actually a non-productive time allowance (NPTA) and should be so designated (Appendix E).

Conclusions

1. Because of the dominant influence of watch station, service billet, NEC and other requirements, non-productive time allowances have little impact on billet requirements. Complete elimination of the allowance would result in only a minor reduction in billet requirements (Sections V and VII).

2. Primary emphasis needs to be given to the development of second generation improvements in the billet determination process. There is an immediate need to modify the process so that it will discriminate between support billets that should receive an allowance and those that should not.

Longer term efforts should emphasize improvements in the workload/manpower requirements portion of the billet determination process (Sections V, VII, VIII).

3. A 5% personal allowance is adequate. Further study of this component is not required (Section IV).

4. Application of the experimental methodology for determining fatigue allowance requirements for ships indicates that the present constant allowance is inadequate. Improvements are required to satisfy the needs of shipboard personnel. Further development of the experimental methodology should be undertaken to provide the tools needed to determine fatigue allowance requirements (Sections VI and VII).

5. The delay allowance component may be inadequate, particularly in the case of the smaller ships. Further study should be conducted to fix its value (Appendix B).

6. The allowance granted for non-productive time associated with shipboard workloads should be designated by the term non-productive time allowance (Appendix E).

<u>Recommendations</u>

1. Research programs are recommended to accomplish the following objectives:

(a) Development of second generation improvements to the billet determination process (Sections V, VII, VIII)

(b) Development and validation of the experimental methodology for determining fatigue allowances (Section VI)

(c) Development of required values for the delay allowance (Appendix B)

2. It is recommended that the allowances granted for non-productive time associated with shipboard workloads be designated as a non-productive time allowance, i.e., as an NPTA (Appendix E).

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I. INTRODUCTION

This study was undertaken to determine the need for and feasibility of developing and applying more accurate allowances to account for the non-productive time associated with shipboard workloads. The concern is with the time lost in satisfying personal needs, recovering from fatigue and encountering unavoidable delays. At present the allowance consists of a constant 20% assessment which is applied to support functions of the ship without regard for the nature of the work assignment or degree of task difficulty.

The constant 20% allowance is used only for the purpose of accounting for non-productive periods in the workday and is not a time allowance granted to shipboard personnel. Rather, it serves as an indication that non-productive time does occur and must be accounted for as part of the billet determination process.

To demonstrate <u>the need</u> for more accurate allowances for non-productive time, one must show that the present allowance leads to an excess or shortage of manpower aboard ship or to an improper distribution of manpower. To establish <u>the feasibility</u> of developing and applying more accurate allowances, one must show that the cost of developing and applying the new allowances is reasonable in light of the benefits to be obtained.

The objective of the program of study was accomplished by means of a combination of analytical and empirical investigations. A survey of the more recent literature in the field was conducted. Visits were made to a number of industrial plants and agencies which have been active in the field. The manpower impact of the present 20% allowance was evaluated. An experimental method of establishing fatigue allowances was then employed to estimate allowance requirements for a selected ship. A comparison was made between the manpower impact of the new versus that of the existing methodology. The results of this comparison are employed in developing the final conclusions to this report.

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II. BACKGROUND

As employed in the development of ship manning documents, the "productive" allowance factor consists of a constant 20% applied to what has been termed basic productive hours. Such hours are defined to be those devoted to equipment and facility maintenance, administrative support, utility tasks and certain evolutions. Time spent at watch stations is not included under basic productive hours. Work performed by watch personnel in the support areas (outside of watch standing hours), however, is included.

The logic used in arriving at the 20% allowance, according to reference (a), proceeds as follows: Allowances granted by industry for personal needs and rest to recover from fatigue generally vary from 10% for light tasks to 20% for more difficult tasks. An intermediate value of 15% was selected as the most appropriate rate to apply across-the-board to ships. An allowance of 5% was added to account for time lost due to unavoidable interruptions.

In preparing the SMD, the minimum watches or stations are determined on the basis of the required operational capability, ship configuration and operating procedures. Preventive maintenance (PM) requirements are obtained from MIP's (maintenance index pages) for shipboard equipment. A make ready/put away allowance of 30 percent is added to the MIP requirements. Corrective maintenance (CM) requirements are computed as a ratio of the PM requirements. The ratio is either 1:1 or 1:2, PM to CM, depending upon the type of equipment involved.

A number of different procedures are used in determining the requirement for other types of work. The most frequently used procedure is activity sampling. However, activity sampling covers only actual work being accomplished during the sampling period. Other essential wo[rk] must be taken into account. Therefore, activity sampli[ng is] normally supplemented by records checks, and personal interviews.

The procedures of primary interest are those used in determining the minimum qualitative and quantitative billet requirements for work centers or divisions. As a first step, reference (l), all rate/NEC requirements are listed in order of seniority. Work requirements by category, i.e.

watch stations, PM, CM, etc., are then listed in hours for each rate/NEC. Since watch station requirements are dominant, billets corresponding to rate and NEC are allocated first to the watch stations. Essential or minimum condition I stations are next added. Additional hours are then assigned to these billets from other work categories as necessary to fill out the work week. Work remaining after the assignment of functions to watch station billets is assigned to non-watch billets.

The normal workweek of the watch stander is 74 hours. It consists of 56 hours of watch, 11.25 hours of productive work in one or more of the support areas*, a "productive" allowance of 2.25 hours and a service diversion and training allowance of 4.5 hours. In the case of the non-watch stander, the workweek is 66 hours and consists of 50 hours of productive work, a "productive" allowance of 10 hours and a service diversion and training allowance of 6 hours.

* Note: Occasionally the number of hours spent on watch is increased in lieu of an assignment to a support task.

III. APPROACH

In developing the approach to be followed in conducting the present study and in answering questions posed in reference (b), certain fundamental requirements had to be taken into account. First of all, the question of a proper designation or name for the allowance had to be addressed. The term "productive" allowance is a misnomer, since the function of the allowance is to account for non-productive time. Therefore, in the present report it is referred to as a non-productive time allowance. The problem of a name for the allowance is discussed further in Appendix E.

Next, the need for more accurate allowances had to be investigated. This involved making an attempt to determine: (1) The amount of savings or increases in billet requirements that could be expected to result from employing more accurate allowances, (2) the extent to which imbalances occur in the distribution of manpower aboard ship as a result of the present constant allowance, and (3) the possibility that the present constant allowance contributes to poor retention and morale aboard ship as a result of inadequacies in the allowance. If a need for more accurate allowances were demonstrated, one had to determine if the benefits obtained justify the cost of developing and applying the new allowances.

Steps taken in meeting these requirements included:

1. A survey of recent literature in the field (identified by means of bibliographies included as a part of recent significant publications) to determine how industry treats the problem of allowances (Appendix C and Section IV).

2. Visits to key industries and age[illegible]o discuss the problem of allowances with th[illegible]xperts (Section IV and Appendix F).

3. A critical examination of the billet determination process to determine the validity of the present method of generating billet requirements (Section V).

4. An analysis of a representative sample of SMD's to determine the manpower impact of the present allowance (Section V).

5. An analysis of the sensitivity of manpower requirements to errors in the billet determination process, including errors in determining the allowance (Section V).

6. Investigation of an experimental methodology to compute allowances (Sections VI and VII).

7. Development of findings and conclusions relative to the need for and feasibility of developing and employing more accurate allowances (Sections VIII and IX).

8. Preparation of a final report.

In addition to the above steps, a number of studies were conducted in order to answer questions posed by OP-01B(Z). These studies are reported in appendices A through E. Significant findings relating to the primary objective of the basic study are reported in the Summary.

IV. NON-PRODUCTIVE TIME ALLOWANCES IN INDUSTRY AND OTHER ORGANIZATIONS

As a part of the effort to improve or develop alternatives to the present constant allowance employed in SMD development, a brief survey of the literature dealing with personal, fatigue and delay allowances in industry and other agencies was undertaken. It was found that techniques in use for establishing such allowances are highly subjective and are by no means standardized. One company may depend upon the observations and judgements of a single expert, using one or two workers as subjects Another may depend upon tables of allowances in general i e for typical tasks. Still others may grant morning and afternoon rest periods of 10 to 15 minutes each.

Although general agreement is lacking as to the best techniques to use in determining allowances, most companies do agree on the factors giving rise to a need for an allowance. These are personal time, fatigue and unavoidable delays. Personal time is that granted to a worker for the satisfaction of his personal needs. According to reference (c) the amount of personal time varies more with the individual than with the type of work. However, the author concedes that more personal time is needed when the work is heavy and done under unfavorable conditions, particularly a hot humid atmosphere. Reference (c) goes on to state that for light work where the operator works 8 hours per day without organized rest periods, 2 to 5 percent per day is all that a worker needs.

It is in the development of the fatigue allowance that most disagreements arise. Much has been done in the well-managed plant in this country to eliminate fatigue. Many engineers believe that fatigue is of such little consequence that no allowance at all is required, except for jobs which involve heavy physical exertion. The problem of setting an allowance for such jobs is complicated by the fact that no easy-to-use and accurate measure of fatigue has been developed for the industrial engineer to use. The problem is perhaps best placed in focus by reference (d) which states that "Many well-known engineers and corporations have acceded to the fact that fatigue is a factor of production. They use a flat percentage on all operations to exonerate themselves in saying that fatigue has been considered."

It was mentioned earlier that some companies employ various approaches to arrive at allowances which they consider to be satisfactory. One such chart from reference (c) is reproduced in Figure 1. The percentages listed in the figure cover both personal and fatigue allowances. This particular company was involved primarily in handling and hand-truck operations.

An attempt is made in industry to compensate for delays which are considered unavoidable. These include delays caused by equipment breakdown, operators or outside forces. Delay allowances normally are determined individually for each type of work by means of a study of the work in question. Such studies had their origin in the work conducted by F. W. Taylor late in the 19th Century. His work was motivated by the realization that before work standards can be accurately set for cost purposes, wage incentives, etc., allowances must be made for delays incidental to the performance of the work.

One method which is frequently used today to determine delay allowances is called the ratio-delay study (Reference e). It is quite similar to work or activity sampling. A large number of observations are taken of a machine operation and a record is kept of whether the machine is operating or not. The percentage number of readings that record the machine as working tends to equal the percentage time it actually is in that state. The cause of delays in each case are determined and recorded. Those that are unavoidable are used in establishing the delay allowance.

Visits and/or contacts were made to a number of industrial plants and agencies to discuss the development and use of non-productive time allowances. The most elaborate program encountered in this area was at the Eastman Kodak plant in Rochester, New York. The approach used in determining allowances and in assessing the physical demands of various jobs is significantly more objective than that encountered to date in the literature. A worker's physical effort is determined by measuring his heart and

30 — HANDLE 70-POUND CONTAINERS FROM SKID WAIST-HIGH TO SHOULDER-HIGH STACK.

29

HANDLE 60-POUND CONTAINERS FROM SKID WAIST-HIGH TO SHOULDER-HIGH STACK.

28 — PULL LOADED 4-WHEEL TRUCK UNDER NORMAL CONDITIONS. (GROSS WEIGHT, 2500 POUNDS, WHEEL DIAMETER, 11 INCHES.)

27

UP-END ROSIN BARREL WEIGHING 500 POUNDS GROSS. (TWO MEN)

26 — SHOVEL SALT FROM OPEN-END TRUCK TO KETTLE 40 INCHES HIGH (SHOVEL WEIGHT, 6 POUNDS SALT WEIGHT, 20 POUNDS.)

25 — WALKING ON LEVEL CARRYING 75 POUNDS ON SHOULDER.
PUSH LOADED WHEELBARROW. (WEIGHT OF MATERIAL, 350 POUNDS.)
PUSH LOADED 4-WHEEL TRUCK. (GROSS WEIGHT, 2000 POUNDS; WHEEL DIAMETER, 11 INCHES.)

24 — HANDLE 65-POUND CONTAINERS FROM SKID WAIST-HIGH TO R.R. CAR KNEE HIGH.

23 — HANDLE 40-POUND CONTAINERS FROM SKID WAIST-HIGH TO SHOULDER-HIGH STACK.
HANDLE 65-POUND CONTAINERS FROM SKID WAIST-HIGH TO KNEE-HIGH STACK.

22 — USE PICK WEIGHING [illegible] POUNDS TO LOOSEN NEW SALT IN R.R. CAR.
PAINT SMOOTH CEILING FROM STEP-LADDER USING A 4-INCH BRUSH.

21 — HANDLE 50-POUND CONTAINERS FROM WAIST-HIGH SLIDE TO SKID.

20 — PULL LOADED 4-WHEEL TRUCK. (GROSS WEIGHT, 1[illegible]00 POUNDS; WHEEL DIAMETER, 11 INCHES.)

19 — WET-MOP ROUGH CONCRETE FLOOR.

DRY-MOP ROUGH CONCRETE FLOOR.

18 — SAW A YELLOW PINE 2" X 4" ACROSS GRAIN.
HANDLE 30-POUND CONTAINERS FROM WAIST-HIGH SLIDE TO SKID.
PULL LOADED 4-WHEEL TRUCK. (GROSS WEIGHT, 1000 POUNDS; WHEEL DIAMETER, 11 [illegible]

17 — WET-MOP WOODEN FLOOR IN GOOD CONDITION.
DRY-MOP WOODEN FLOOR IN GOOD CONDITION.

16 — SCRAPE DIRT FROM WOODEN FLOOR IN GOOD CONDITION. (HANDLE OF SCRAPER 60 INCHES [illegible], BLADE 6½ INCHES WIDE.)
WALKING ON LEVEL CARRYING 25 POUNDS.

15 — SWEEP ROUGH CONCRETE FLOOR.
HANDLE 20-POUND CONTAINERS FROM WAIST-HIGH SLIDE TO SKID.

14 — DRY AND POLISH WINDOW WITH RAG, WORKING FROM INSIDE.
FORM AND STITCH FIBER CONTAINERS.
SWEEP A WOODEN FLOOR IN GOOD CONDITION.

13 — WASH WINDOW WITH WET RAG OF SPONGE, WORKING FROM INSIDE.
PULL EMPTY 4-WHEEL TRUCK. (WEIGHT, 400 POUNDS; WHEEL DIAMETER, 11 INCHES)

12 — OPERATE TYPEWRITER.
WIPE TOP OF DESK OR TABLE TO REMOVE DUST.
CUT STRINGS ON BUNDLES OF CONTAINERS.

11 — WALK DOWN STEPS.
STAMP SAMPLE TAGS.

10 — WALKING ON LEVEL UNOBSTRUCTED.
RECORD DATA.

9

MAKE PHONE CALL

8

Figure 1: Personal and Fatigue Allowance Used in Industry

oxygen consumption rate. These measures are then related to the worker's maximum capacity. If the criterion levels for excessive exertion are exceeded on either of the two measures, a more detailed study of the job is undertaken to determine if (1) specific aspects of the job are particularly taxing, (2) environmental factors are contributing significantly to fatigue, and (3) changes in the work procedures can alleviate the fatigue. Where it is not possible to change the work situation sufficiently to bring the oxygen consumption and heart rate levels within acceptable limits, longer or more frequent rest pauses are introduced to permit sufficient recovery from the work.

A number of interesting conclusions have been reached by Eastman Kodak in the course of their studies, including the following:

1. It is not possible to accurately assess the effort required in the performance of a job by even the most careful observation. Subjective estimates of physical difficulty of jobs can be so erroneous, even when made by highly trained observers, that they have been abandoned in favor of objective methods.

2. High ambient temperatures have a great effect on heart rate; very little activity is required at high temperatures to produce an excessive heart rate.

3. The factors that significantly affect the effort (and fatigue) on a job include the amount of heavy physical work involved, the ambient heat and humidity, the degree of arm motion required, and the static muscle loading necessary.

It is relatively easy according to Eastman Kodak to measure heart rate and oxygen consumption levels without interfering with the worker's normal work activities. Heart rate can be monitored on an FM receiver by strapping a small (about 8 oz.) transmitter to the worker's belt and attaching two electrodes to his chest. Alternately, his heart beats can be stored on a miniaturized tape recorder for later replay. Oxygen consumption is sampled only a few times (when there is a major change in tasks being performed) since it is a more stable physiological measure and because it is permissible to combine the readings taken throughout the day to obtain an average rate. Such manipulation is incorrect for heart rates unless there is very little fluctuation throughout the day.

At the Westinghouse Electric Corporation in Pittsburgh, it was found that a 5 percent personal allowance only is granted for "measured daywork". The assumption is made that fatigue does not exist to any significant extent and that what there is has been incorporated into the time standard. Delays are considered to be the foreman's responsibility and no allowance is provided.

At the IBM production plant at Manassas, Virginia, the allowance consists of a 15 minute break midway in the morning work period and another in the afternoon. Standards have been developed and are employed to determine work output rates, etc.

A visit was also made to the Defense Supply Agency which has approximately 50,000 employees of which 62% are covered by engineering standards. A constant 12% allowance is normally granted for personal needs and rest. This allowance may be varied between the limits of 12 and 15% by lower level management without justification. However, written justification with definitive criteria is required if it is desired to deviate either above or below these limits.

The Air Force includes in its work center manning standards appropriate allowances for personal needs, rest and unavoidable delays (reference (f)). A standard personal and rest (P&R) allowance of 6.96 minutes for each productive hour or 11.6% is used for most work centers. This standard allowance for personal needs and rest cannot be exceeded without full justification and advance approval from HQ USAF.

Delay is entered into the allowance factor only when it is fully justified as unavoidable delay. An inclusion of delay must be accompanied by a detailed explanation showing the basis and computations used in deriving the magnitude of the delay.

As a general rule the Air Force permits allowances to be included for personal needs, rest and unavoidable delay only when the productive time value has been derived in a manner that definitely limits that value to purely productive time.

V. ANALYSIS OF THE APPLICATION AND IMPACT OF THE PRESENT NON-PRODUCTIVE TIME ALLOWANCE

In conducting the analysis reported in this section, the objective was to critically examine the present approach used in applying the "productivity" allowance in order to determine the validity and impact of the process. As was mentioned earlier, the present approach separates shipboard functions into two categories, i.e., watch stations and non-watch or productive work. The constant 20% allowance is applied across-the-board to work falling in the second category.

In making the examination, two requirements were of primary concern. The first was the need to determine if the allowance is being properly applied to shipboard tasks. The second was to establish the impact of the allowance upon billet requirements. Since the allowance is applied only to non-watch tasks, its impact in terms of percent of total manpower, obviously, is only a fraction of the allowance itself.

A. Present Application of the Allowance

In conducting the analysis it was recognized that all shipboard personnel, irrespective of the category into which their billet falls, require time off on occasion for personal needs, rest, etc. The time off granted for the satisfaction of these needs actually constitutes a non-productive time allowance (NPTA). The problem of concern was to determine just when this allowance should be taken into account in determining billet requirements. The writers reached the conclusion after evaluating the situation that the allowance should be taken into account in determining billet requirements, if the time taken off leads to one of the following:

1. A requirement for additional manpower to perform the functions of the billet while the occupant is absent from his workplace.

2. A requirement for additional manpower to perform work not accomplished as a result of the occupant's being given time away from his workplace.

3. A requirement for the occupant to work a significant amount of time beyond his normal work week in order to complete tasks not performed as the result of time taken off.

Further analysis of the problem of determining when the allowance should be taken into account led the writers to conclude that three primary types of billets exist aboard ship. These are watch station, service and bulk task billets. Each of these billets is discussed below.

1. Watch Station Billet

In the case of watch station billets which at present do not receive an allowance, one needs to determine if the time taken off leads to one of the above requirements. The conclusion must be affirmative, i.e., it must be taken into account, if it leads to a requirement for additional relief manpower. A watchstander may be relieved by supervisory personnel, or in certain instances it may be feasible for a watch stander at an adjacent station to time share his attention for a short period between his own station and that of the occupant requiring relief. In this event, additional manpower is not required and the allowance need not be taken into account in determining billet requirements.

In certain situations, e.g., where extreme environmental conditions are encountered, a requirement may arise for relief personnel. The number of relief personnel required is established by the magnitude of the allowance, i.e., the amount of time required away from the station, and by the number of watch standers requiring formal relief. Therefore, if a requirement arises for relief personnel, an evaluation of the watch tasks requiring such personnel to establish the magnitude of the required allowance would be relevant.

2. Service Billet

In examining the non-watch billets, it became apparent that these billets should be classified into two sub-categories. The first has been designated as the service billet; the second as the bulk task billet. The characteristics of the service billet are quite similar to those of the watch station. Such billets require the occupants to perform a function on a continuous basis over specified periods of time. The service billet may be found in any of the support areas. For example, it may be the billet of yeoman who handles administrative matters in one of the ship's offices, answers the telephone and greets visitors. It may be that of cook who works a given schedule, a storekeeper who mans a storeroom or a medical technician who serves in the sick bay. In other words, the occupants of a service billet may be thought of as "guarding" a position.

The requirement for taking the non-productive time allowance into account, in the case of a service billet, arises essentially in the same way as it does for a watch stander. If additional personnel must be employed in order to provide the necessary relief, then the allowance is relevant and should be taken into account. The "productive" allowance is now being applied across-the-board in generating the service billets. Therefore, the emphasis on use of the allowance changes somewhat. One must conclude that unless formal relief personnel are required, the allowance should not be taken into account. It is believed that only rarely will an allowance be relevant to the service billet.

3. Bulk Task Billet

The dominant characteristic of the bulk task is that it requires the presence of a worker only when there is work to be done. Such work includes many preventive and corrective maintenance functions, facility maintenance, utility tasks and certain administrative support functions. Time taken off from this type of work for the satisfaction of personal needs, rest, etc., serves to increase total task time, and thus to increase the man hours required for task completion. Therefore, the allowance is relevant to the bulk task and should be taken into account in determining billet requirements.

4. Essential Points

The essential points made in the analysis of when to apply the non-productive time (or "productive") allowance may be summarized as follows:

a. A formal allowance appears to be relevant to watch tasks if formal relief personnel are utilized.

b. An allowance is not relevant to service billets where the time off for personal needs, fatigue, etc. does not require the use of formal relief personnel.

c. The allowance is relevant to bulk task billets.

B. Manpower Impact of the Present Non-Productive Time Allowance

1. Assessment of manpower impact

An initial step taken in determining the need for and feasibility of developing and applying more accurate allowances was to investigate the manpower impact of the present allowance. This was accomplished in the present study by selecting a representative sample of SMD's for analysis and determining that portion of the total billets which may be attributed to the allowance. The SMD's included in the selected sample are listed in Table 1. Ground rules used in the analysis to determine the impact of the allowances are listed below.

a. Personnel with condition III assignments are essential to the operation of the ship. Therefore, billets established for such assignments cannot be eliminated from the ship's allowance by increasing the number of hours worked by personnel filling other billets.

b. Personnel with condition I assignments are also essential to the operation of the ship. Such billets can be considered for elimination only if the condition I assignment can be transferred to other personnel.

c. Assignments are transferrable to the same or higher rates but not to lower rates.

d. Cross utilization of personnel takes place within departments on all ships except CVA's where it is assumed to take place within divisions.

e. Because of NEC and organizational requirements, equipment maintenance and administrative support tasks are assumed to be reassignable only within the immediate enlisted chain of command.

f. Tasks requiring specified NEC's are reassignable only to other personnel having the same NEC.

g. A billet cannot be eliminated unless a sufficient number of man hours are available within the work week of remaining personnel to accomplish the billet's functions and thereby permit reassignment of the work.

TABLE 1

Ship Classes Included in Sample

Class	SMD
AO-22	OPNAV 10 - P21
DD-931 (ASW Mod)	OPNAV 10 - P57
LST-1179	OPNAV 10 - P49
LCC-19	OPNAV 10 - P72
DD-710 (FRAM)	OPNAV 10 - P77
DDG-2	OPNAV 10 - P66
AE-26	OPNAV 10 - P78
MSO-422	OPNAV 10 - P71
DE-1033	OPNAV 10 - P80
CG-10	OPNAV 10 - P48
CVA-63	OPNAV 10 - P67
DLG-6	OPNAV 10 - P58

In conducting the analysis, a determination was made initially of the manpower impact of the 20% allowance on billet requirements for each ship. The resulting values were averaged to obtain the mean manpower impact on the sample as a whole. A determination was then made of the manpower impact of 5, 10 and 15% constant allowances. The results were used to construct the relationship shown in Figure 2 between value of the allowance and number of billets added.

A review of Figure 2 shows that the 20 percent allowance actually has a manpower (billet) impact of approximately five percent or less. This is not surprising when it is considered that approximately 87% of the total billets analyzed involve condition III or non-transferrable condition I assignments. An approximately linear relationship is exhibited between the manpower (billet) impact and size of the allowances as the value of the allowance decreases.

One additional constraint, that imposed by the service billet, is not reflected in the figure. It is believed that in most cases the service billet is also an essential billet which cannot be eliminated, even if the value of the allowance were reduced to zero. It is not at this time known just how much the taking into account of the service billet will change the relationship in Figure 2. Obviously, it will tend to reduce the impact of the allowance. Further analysis is necessary to determine how much. Unfortunately, insufficient information is provided in the SMD's to enable service billets to be identified.

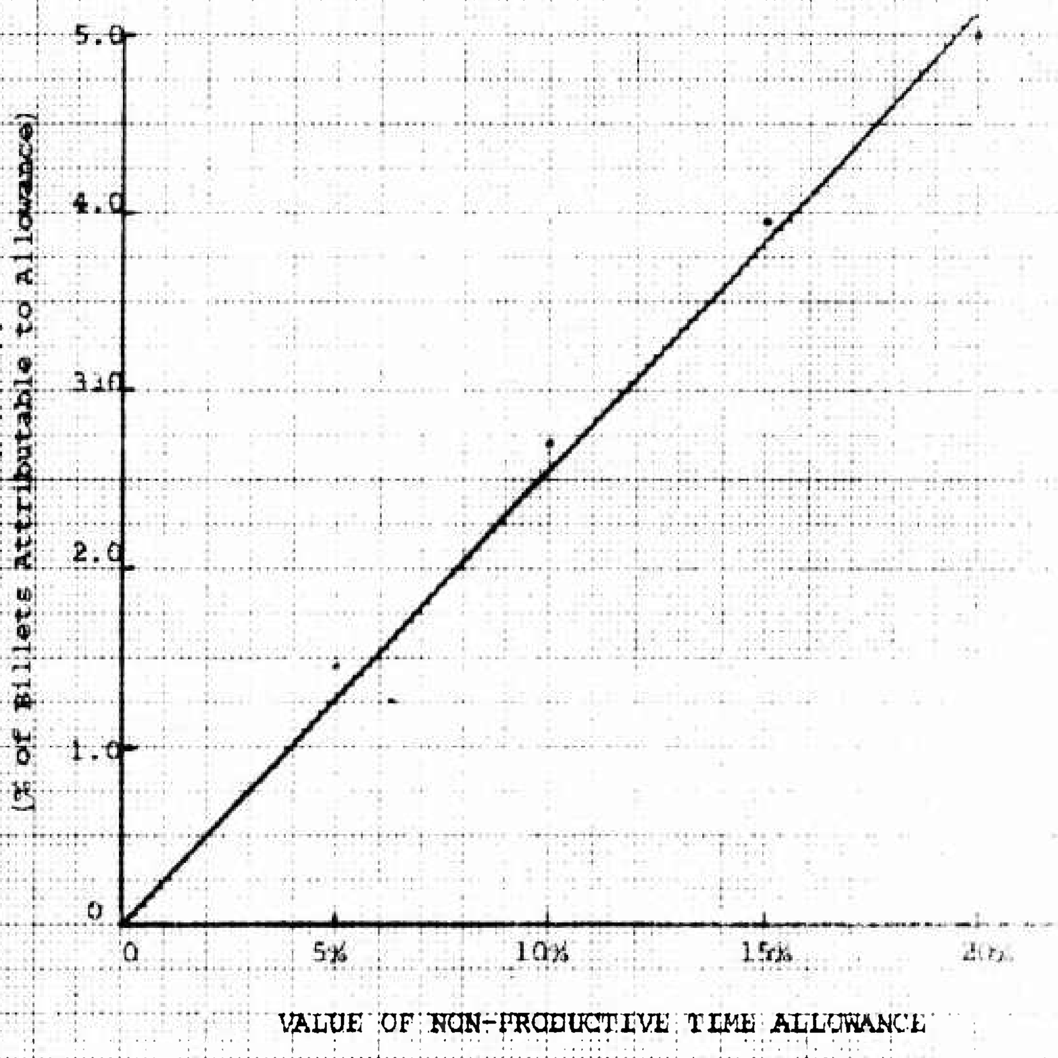
The service billets were identified by the writers for a single ship, the DD 938 which was visited during the course of the study. A dramatic reduction in the impact of the non-productive time allowances was found. The findings resulting from the shipboard visit are reported in Section VII.

C. Analysis of the Present Billet Determination Process

As will be shown later, one should not invest a great deal of time and money in maximizing accuracy of the allowance

Figure 2

MANPOWER IMPACT OF CONSTANT NON-PRODUCTIVE TIME ALLOWANCES*



*Note: Does not take into account the service [illegible].

unless a comparable degree of accuracy in determining workload/billet requirements has already been achieved. The present billet determination process was examined with this requirement in mind. A number of limitations were found which tend to make the process inaccurate. These are identified and discussed below.

1. Preventive Maintenance (PM)

Preventive maintenance and associated manning requirements corresponding to the equipments on board the ship are obtained from MIP's developed by the 3-M System. These cover essentially the "nuts and bolts" aspects of the maintenance functions. An additional allowance of 30% is added to cover make ready/put away operations. Billet requirements are developed on the basis of the MIP data plus the 30% allowance.

An evaluation of the accuracy of data provided by the 3-M System has not been made by the writers. Therefore, comments relative to its accuracy cannot be made. The use of the 30% make ready/put away allowance, however, is open to question. It may be a good average value, but one must recognize that from a statistical point-of-view the workload/manpower requirements generated on the basis of this allowance are too little in 50% of the cases and too large in the case of the remaining 50%. If these errors cancel out or compensate for each other, billet requirements for this ship as a whole may not be affected. There can be no assurance, however, that this will occur. Make ready/put away requirements may be minimal for one ship, and in this event an excess of PM billet requirements would be allocated. In the case of the older ships which have undergone numerous modifications, the opposite may be true, i.e., make ready/put away work requirements may be excessive, and too few billets allocated. From the standpoint of efficient utilization of manpower, both situations are undesirable.

2. Corrective Maintenance (CM)

Corrective maintenance requirements are estimated by applying the ratio of 1 hour of CM for each two hours of PM, except in the case of maintenance performed by ET's and certain FT's where a ratio of 1:1, CM to PM is applied. The ratio is applied to PM after the 30% make ready/put away allowance has been added. For example, 1 hour of PM taken from MIP equates to 1.3 hours of CM.

The use of this ratio suffers from somewhat the same tations as the 30% make ready/put away allowance. At t it can be considered as providing gross approximations to actual billet requirements.

3. <u>Facility Maintenance, Utility Tasks, and Administrative Support</u>

Functions coming under the heading of facility maintenance, utility tasks and administrative support are evaluated by means of activity sampling, supplemented by analytical estimation, records checks, personal interviews, time observations, etc. Activity sampling as used in the billet determination process provides a record of the activities of personnel on board one ship during the survey period. It does not discriminate between essential and unessential work, nor does it take into account the pace at which the work is performed. Other methods used such as analytical estimation, records check, personal interview, time observations, etc., are subject to the bias, etc. of the observer/analyst and to that of the personnel interviewed. Because of the approximate nature of these methods, one cannot expect the results obtained by one survey crew and a given ship to be repeated by a second survey crew and another ship of the same class. Furthermore, any method having such limitations must be considered as a fertile source of errors.

The way work is assigned to billets must also be considered as a negative element which contributes to the difficulty one encounters in attempting to determine the accuracy with which billets have been determined. A single billet may be assigned work in as many as five different categories. The analysts making the assignment do not expect the work actually to be accomplished in this manner. Apparently, an attempt is made only to match billets and man-hour requirements. Since schedule problems have not been taken into account, one cannot determine on the basis of an inspection if the work can actually be accomplished by the assigned personnel nor can one determine the degree of accuracy which has been obtained.

D. Sensitivity of Billet Requirements to Errors in the Non-Productive Time Allowance

It is reasonable to assume that if the sensitivity of billet requirements to errors in the non-productive time allowance is low, one should not spend a great deal of time and money in developing more accurate non-productive time allowances. To investigate this contention, assume that the non-productive time allowance is a constant 20 percent of productive working hours. Let this allowance be denoted by the symbol, K. Also assume that

X = the number of required basic productive hours in the workweek of a non-watch stander.

XK = the number of hours per week required as an allowance

A = the number of hours of service diversion allowance (6 hours).

A = 6 hours

W = total number of hours in the standard workweek.

Since the workweek is made up of the components X, XK and A,

Then,

$$W = X + XK + A$$

For $K = 20\%$,

$$W = X + 0.2X + 6 = 1.2X + 6$$

Now, assume that the error occurs in determining the value of X, the basic productive hours. Also, for the time being, assume that the error in K = 20% is equal to zero. Under these assumptions, and neglecting the constant A, one obtains the work component error relationship in figure 3.

Next, assume that the error in X, the work component, is equal to zero and that the error in K, the allowance, varies from 0 to 50 percent from the nominal value of 0.2. This gives the allowance component error relationship in figure 3. It turns out that for the same percentage error in both components, the impact on total workweek error is six times greater in the case of the work component that it is for the allowance component. This can be demonstrated mathematically as follows:

Let

E_1 = effect of error in X

E_2 = effect of error in K

e_1 = percent error in X

e_2 = percent error in K

Neglecting A,

$$E_1 = e_1X + Ke_1X \qquad (2)$$

$$E_2 = e_2KX \qquad (3)$$

$$\frac{E_1}{E_2} = \frac{e_1X + Ke_1X}{e_2KX} = \frac{e_1 + Ke_1}{e_2K} \qquad (4)$$

For K = 0.2

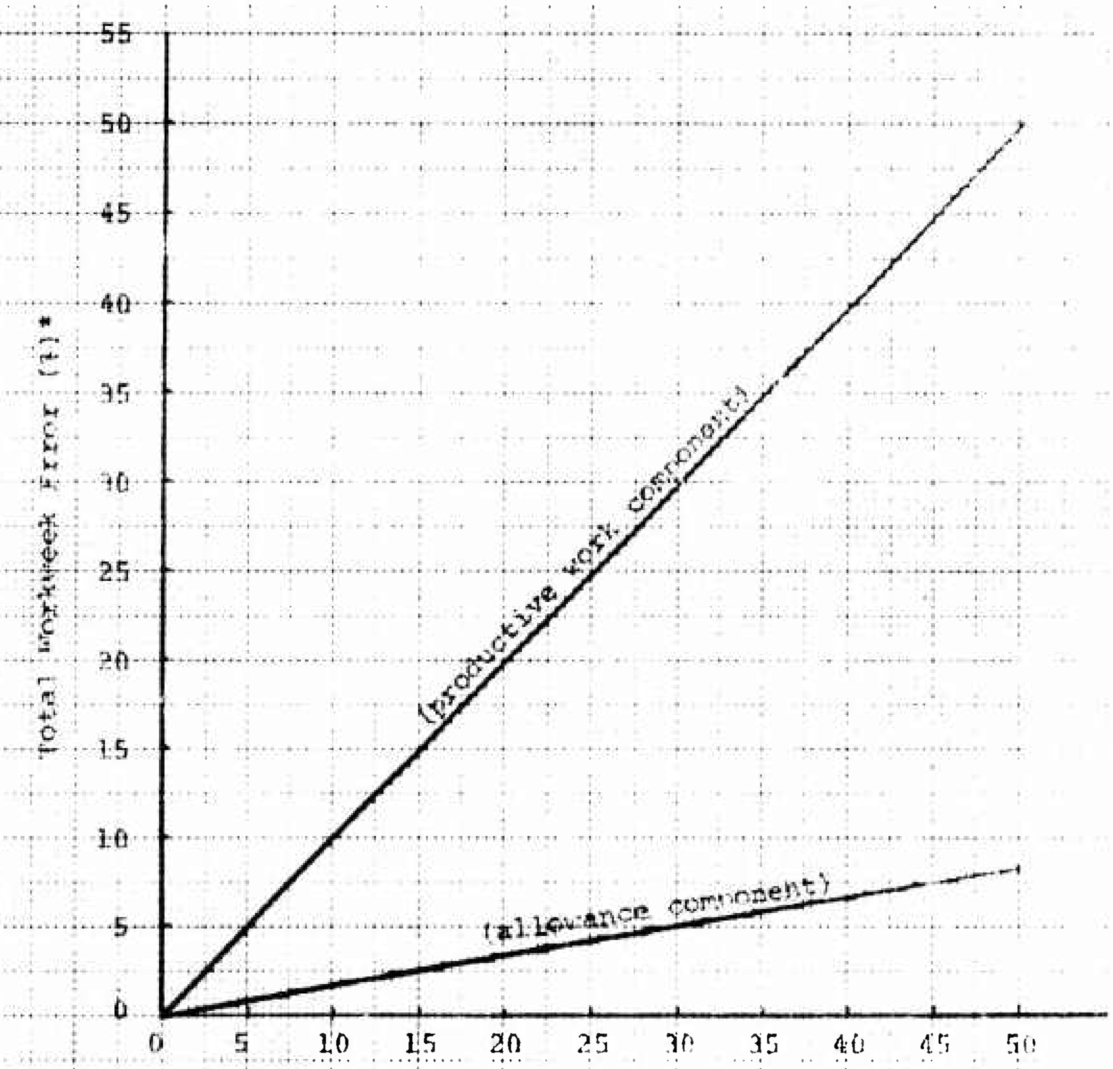
$$\frac{E_1}{E_2} = \frac{1.2e_1}{0.2e_2} \qquad (5)$$

If $e_1 = e_2$,

then

$$\frac{E_1}{E_2} = \frac{1.2}{0.2} = \frac{6}{1} \qquad (6)$$

Figure 3: Comparative Impact of Errors in Work Versus Allowance Components



* Does not include service diversion allowance

Equation (6) shows that if the mean allowance is 20%, effort expended in improving the accuracy of the work component has a six-times greater payoff than does the effort expended to achieve the same percentage improvement in the accuracy of the allowance.

It can also be seen from equation (2) that an error in the work component introduces an equivalent error in the allowance component, i.e., e_1 in equation (2) is in both terms on the right hand side of the equation. Thus, a given percent improvement in K, can be completely canceled out by an error in the work component.

The above analysis leads one to the conclusion that unless considerable accuracy has already been achieved in the work component, there is little to be gained insofar as billet requirements are concerned in expending a great deal of effort to improve the accuracy of the allowance component.

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VI. INVESTIGATION OF NEW METHODOLOGY FOR DETERMINING FATIGUE ALLOWANCES

As was mentioned earlier, the non-productive time allowance is made of three primary components: personal, fatigue and delay allowances. The use of a 5% personal allowance was believed to be sufficiently well established so as not to require further study. The delay allowance is treated in appendix B and discussed in section VII.

The most serious problem of allowances is concerned with fatigue. Consequently, it is the subject of primary interest in this section and in Section VII which follows.

A. The Experimental Methodology

The experimental methodology employed in assessing fatigue allowance requirements in the present study is based upon an approach outlined in reference (g). It consists essentially of the following elements.

1. A listing of the significant parameters affecting the level of fatigue incurred by a worker in the performance of his assigned task.
2. A breakdown of the overall range of values taken by each of these parameters into four discrete categories or levels, including appropriate descriptive criteria covering each category.
3. An assignment of relative scale values to each parameter and paramater level.
4. A listing of fatigue allowances as a function of range of points accumulated by each task being analyzed.

A total of ten parameters were listed in reference g which affect level of fatigue. These, however, include only parameters of the work environment which affect workers on a stationary work platform who put in an eight-hour per day, five-day week. Based on the analyses reported in appendices B, C and D, four additional parameters should be added to take into account the shipboard environment. These include:

1. Type of ship
2. Length of the workday
3. Length of the workweek.
4. Vibration

Type of ship is highly relevant, inasmuch as the motion environment is largely a function of ship type. Since personnel on board ship work both a longer workday and workweek than the eight-hour per day and five-day week of the industrial worker, these two parameters must be included and taken into account. Vibration will be encountered occasionally on board ship and for this reason is included.

The 14 parameters have been separated into four categories or levels each and listed in the boxes in table 2. Those taken from reference (g) have been so identified. The categories listed under type of ship were established by the following procedure: Ships currently in the fleet were identified by means of reference (h). Ship configuration parameters which tend to determine ship motion for each class were then obtained from reference (i), i.e., length of ship, beam and draft. Experienced naval personnel were then requested to separate the various classes of ships into four categories corresponding to relative stablility of each type of ship. Only those classes containing a number of ships or the larger ships were included. The results of this classification process are shown in box 6 in table 2. Vibration levels listed in box 7 are based on reference (j).

The scale of values corresponding to each parameter and parameter category are listed in table 3. Those values for the ten parameters taken from reference (g) are listed as given in the reference. Values for type of ship, length of workday and length of workweek were set by the writers on the basis of a subjective evaluation of the impact on worker fatigue. In making this evaluation, the values taken from reference (g) for the other ten parameters were considered as a base. The estimated values for the four additional parameters are relative to this base.

The fatigue allowances listed in table 4 were also taken from reference (g). To use the table, one proceeds as follows:

1. Identify the task to be evaluated in terms of the 14 parameters listed in table 2.

2. Select the proper level relative to this task for each parameter using table 2.

3. Enter table 3 and select the scale value for each parameter and level. Add the values for the various parameters to obtain a total.

4. Enter table 4 with this total and select the range interval within which it falls.

5. Read off the fatique allowance.

A worksheet for conducting this process is listed in figure 4.

The values included in the total for type of ship, length of workday, length of workweek and vibration, have the effect of increasing the fatigue allowance above the value that would be granted for the same task if performed ashore using an eight-hour day and five-day week. This is considered to be warranted. These four parameters are additional fatigue-inducing factors and should, therefore, have the effect of increasing the required magnitude of the fatigue allowance.

B. Accuracy and Validity Considerations

No claim is made in reference (g) relative to the accuracy of the methodology outlined above. Rather the statement is made that it will ensure greater precision than heretofore has been obtained. In other words, two analysts using this approach have a reasonably high probability of coming up with the same value for the fatigue allowance. Cornman, the author of reference (g), feels that this in itself is a significant advance in the state-of-the-art of assessing fatigue allowances.

The problem of accuracy and, hence, that of validity of the approach remains to be considered. Of concern here are (1) accuracy of the values assigned to categories or levels within a given parameter (table 2), (2) accuracy of the scale values assigned to one or more parameters versus those assigned to the others (table 3) and (3) accuracy of the actual fatigue allowances assigned to the sum or total of the values assessed for a given task (table 4). If one were able to establish highly accurate values for each of these areas of concern and demonstrate their validity, he not only would be doing the Navy a great service, but would be performing a like service for the industrial world as well.

To achieve a high degree of accuracy in refining the values employed in tables 1, 2 and 3, it would be necessary to study each type of task performed by naval personnel in an experimental context. Different allowance values would have to be tested under realistic environmental conditions and that giving the highest productive output would be selected as best.

Considering the large number of different tasks performed aboard ship, such an approach is obviously not feasible. This is not surprising since industry, in general, has not solved the problem either. Most employ what they consider to be an acceptable value rather than go into an extensive program to determine accurate values. Frequently, fatigue allowances are set by collective bargaining where the end results have no real relation to actual needs of the worker.

If one rules out the experimental approach in setting fatigue allowances, any alternative approach that may be selected would involve a great deal of subjective judgement - like that which has already been employed in selecting the values included in tables 2, 3 and 4. The problem at hand, therefore, becomes one of maximizing the accuracy using a subjective approach. A solution to this problem obviously requires further research.

Table 2

Parameters Affecting Level of Fatigue

1. Temperature (Ref (g))

The average temperature expected to be encountered in performing daily duties on the job.

1st Level - Temperature controlled by mechanical or electrical means for the comfort of personnel. Usually from 72 degrees to 75 degrees for inactive personnel; 68 degrees to 70 degrees for normally active jobs.

2nd Level - Temperature controlled by job requirements where heat is generated by machines, etc. Heat ranging from 75 degrees to 85 degrees in inside work, 80 degrees to 90 degrees on outside work, where normal circulation of air is available.

3rd Level - Temperature controlled by job requirements where heat is generated by machines, etc. Heat ranging below 65 degrees or above 80 degrees for inactive personnel. Below 40 degrees or above 90 degrees on outdoor work or where normal circulation of air is available.

4th Level - Temperatures above 90 degrees where normal circulation of air is not available. Temperature above 95 degrees or below 35 degrees where normal circulation is available.

2. Air Supply (Ref (g))

The availability of oxygen has a considerable effect on fatigue. The following are measures of this availability or of the repulsion of the human system to surroundings.

1st Level - Normal operations out of doors or in air conditioned facilities where filtering or washing of air is adequate to supply fresh odor-free air.

2nd Level - Normal plant or office facilities without air conditioning where occasional odors or stuffiness might be present. Movement of air is normally supplied by movement of personnel or machines. No filtration of air.

3rd Level - Extremely small and enclosed surroundings where movement of air is nil. Also dusty conditions caused by the job, regardless of the dust type. Limited smoke either foreign or generated by the operator.

4th Level - Extremely smokey, toxic, or dusty conditions. Fumes so unpleasant as to be nauseating or mentally disturbing even though not injurious to health. Movement of air or exhausting does not remove effects.

3. Humidity (Ref (g))

Humidity affects the comfort of the individual worker. High humidity often enters the allowance by causing motions that are not an actual part of the operation such as, lack of concentration due to perspiration, wiping of the brow, pulling at clothing, etc.

1st. Level - Normal and comfortable humidity level as supplied by air conditioning or heating systems. No sensation of either dry or humid atmosphere. (Usually 40 percent to 55 percent relative humidity with 70 degrees to 75 degrees temperature.)

2nd Level - Unusually dry conditions indicated by skin sensation or burning nostrils after subjection for one-half hour or longer. (Less than 30 percent relative humidity.) High humidity noticeable upon entrance to an area by a clammy sensation to the skin. (60 percent to 85 percent relative humidity.)

3rd Level - Unusually high relative humidity where clothing becomes damp after subjection for any period of time (above 80 percent relative humidity).

4th Level - Humidity of wetting conditions such as steam rooms or outdoors in the rain where special clothing must be worn.

4. Noise Level (Ref (g))

Although noise is a factor of fatigue, it is relative and causes fatigue through the nervous system. Changes in noise level have as much bearing on the nervous system as loudness by itself.

1st Level - Normal noise level experienced in the average office or industrial plant producing lightweight products. (Variations between 30 and 60 decibels.) Intermittent music may be easily heard and enjoyed.

2nd Level - An area where noise is constant but rather loud such as a tin shop, knitting room, city street, etc. (Variations between 60 and 90 decibels constant noise.) Music may not be heard with any pleasure.

3rd Level - Normally quiet surroundings with intermittent loud or annoying noises. Noises are of a sharp nature above the 90 decibel range. (Noises such as a nearby riveter, elevated train, punch press, etc.) Also noises that are not intermittent above 100 decibels, such as encountered in a boiler factory.

4th Level - Noises of high frequency or other annoying characteristics whether intermittent or constant.

5. Light Level (Ref (g)) Light is a factor of fatigue which enters purely through the eye and strains it to focus correctly, unless lighting is so poor as to require extra motions of some other portion of the body. 1st Level - Light as supplied by fluorescent or other indirect lighting spaced to provide from 20- to 50- foot candles for most industrial applications, and 50- to 100-foot candles for office and inspection. Absence of glare is apparent. 2nd Level - Light where occasional glare is an inherent part of the job or where substandard or special lighting is required. 3rd Level - Lighting where continual glare is an inherent part of the job. Also work requiring constant change from lighted area to darkness (less than 5-foot candles). Work requiring a venetian-blind effect such as a shiny and dull surface turning in a lathe. 4th Level - Working in absence of light or where sight is impossible due to obstruction. Noticeable by the feel of fingers or feet. Eyes are obviously not used at all, or are straining in darkness but not really seeing. (Photographic dark room, mechanic working under machine, etc.)	7. Vibration Prolonged exposure to vibrations of less than intolerable levels commonly produces annoyance and fatigue - factors that can be expected to reduce the general performance and effectiveness of the operator. 1st Level - Noticeable vibration not present. Frequencies are below 100cps; acceleration is below 10^{-3}g. 2nd Level - Noticeable but not unpleasant vibration. Frequencies below 100 cps; acceleration between 10^{-3} and 10^{-2}g. 3rd Level - Vibration somewhat unpleasant but not irritating. Frequencies below 100 cps; acceleration between 10^{-2} and $10^{-1.5}$g. 4th Level - Vibration definitely irritating but tolerable. Frequencies below 100 cps; acceleration between $10^{-1.5}$ and 10^{-1}g.
6. Ship Motion Type of ship is factor which contributes to fatigue via the extent of motion induced by various sea states. Type of ship has, therefore, been used to categorize ship motion by levels. 1st Level - CVAN, CVA, CVS, CVT, AOE, AOR 2nd Level - CG, CGN, CLG, DLG, DLGN, DDG 35, 36; DD 963, AE, AO, AS 3rd Level - DD, DEG, DE, LST 4th Level - MSO, AOG, ARS, ATF, PG	8. Duration of Task (Ref (g)) Fatigue varies consistently with the time taken to complete a job and obtain a feeling of accomplishment or being finished. This is a psychological factor which may vary between individuals, but always varies from task to task. 1st Level - Operation or sub-operation which may be completed in one minute or less. 2nd Level - Operation or sub-operation which may be completed in fifteen minutes or less. 3rd Level - Operation or sub-operation which may be completed in one hour or less. 4th Level - Operation or sub-operation which takes more than one hour to complete.

Table 2 (contd.)

9. Repetition of Cycle (Ref (g))

Repetitiveness of cycles has a great effect on fatigue. Operations of short cycles but repeating themselves many times during a day create a monotony and hypnotic effect which adversely affects productivity as the day progresses.

1st Level - Operations on which the operator varies his pattern or may schedule his own work. Operations that vary from day to day or where sub-operations may not even be performed daily.

2nd Level - Operations of a reasonably fixed pattern, or where deadlines or pressure to complete are present. Operations vary from cycle to cycle at operator preference, but task is regular.

3rd Level - Operations where periodic completion is scheduled and regular in occurrence, or where completion of motion or thought patterns is made at least ten times per day.

4th Level - Operations where completion of motion or thought patterns is more than ten times per day. Also operations that are machine paced. (Most piece rated operations fall in this category.) Operators suffer boredom and lack of control.

10. Length of Workday

Length of workday in excess of 8 hours has both a daily and cumulative effect on fatigue.

1st Level - 7 hrs. $<$ workday $\le$ 8 hrs.

2nd Level - 8 hrs. $<$ workday $\le$ 9 hrs.

3rd Level - 9 hrs. $<$ workday $\le$ 10 hrs.

4th Level - 10 hrs. $<$ workday $\le$ 11 hrs.

11. Length of Workweek

Length of workweek is dependent on length of workday but also depends on number of days worked. These criteria take into account cumulative impact of number of days worked on fatigue.

1st Level - $\le$ 4.5 days workweek $\le$ 5 days

2nd Level - $<$ 5 days workweek $\le$ 5.5 days

3rd Level - $<$ 5.5 days workweek $\le$ 6 days

4th Level - $<$ 6 days workweek $<$ 7 days

12. Physical Demand (Ref (g))

Although physical effort has a real effect on fatigue, if effort is intermittent, with physical rest between cycles as a part of the task, its effect is diminished. The following table lists levels applicable for varying situations.

Level Applicable

Equivalent Manual effort	Time effort is applied: Up to 15%	15% to 40%	40% to 70%	Over 70%
Up to 5 lbs.			1	1
5 to 25 lbs.			1	2
25 to 60 lbs.		1	2	3
Over 60 lbs.	1	2	3	4

Add one level to each of the above, with a maximum of four, if the duties are performed in difficult work positions.

Table 2 (contd.)

(Ref (g)) 13. Mental/Visual Demand	(Ref (g)) 14. Working Position
This factor measures the degree of mental and visual fatigue sustained through the concentration and coordination of mind and eye. It depends on the volume and complexity of the work, cycle of application of mental and visual faculties, and the intensity of such application. 1st Level - Only occasional mental or visual attention since either the operation is practically automatic or attention required only at long intervals. 2nd Level - Frequent mental and visual attention where work is intermittent or the operation involves waiting for a machine or process to complete a cycle, with some checking. 3rd Level - Continuous mental and visual attention for either safety or quality reasons; usually repetitive operations requiring constant alertness or activity. 4th Level - Concentrated or intense mental and visual attention in laying out or otherwise performing complex work to very close limits of high accuracy or quality, or in coordinating a high degree of manual dexterity with close visual attention for sustained periods of time. Also all purely inspection operations where checking of quality is prime object.	The physical demands of the body induce fatigue at any time that it is not at rest. Abnormal positions of any part of the body increase fatigue if not alleviated by change. 1st Level - Position either sitting or a combination of sitting, standing, and walking, where change of position is not more than five minutes apart. Arm and head positions at normal working height. 2nd Level - Standing or a combination of standing and walking, where sitting is only allowed during rest periods. Also where work positions of arms and head are out of normal working range, but only for periods of less than one minute. 3rd Level - Operations where workplace requires constant stooping or standing on toes, or where work requires extension of arms or legs. 4th Level - Operations where body is in cramped or extended positions for long periods of time. Also where attention requires motionless body.

Table 3: Assigned Scale for Fatigue Parameters

Parameters	Level			
	1st	2nd	3rd	4th
1. Temperature	5	10	15	20
2. Air Supply	5	10	20	30
3. Humidity	5	10	15	20
4. Noise Level	5	10	20	30
5. Light Level	5	10	15	20
6. Type of Ship	20	40	60	80
7. Vibration	0	10	40	80
8. Duration of Sub-Tasks	20	40	60	80
9. Repeat of Cycle	20	40	60	80
10. Length of Workday	0	10	20	30
11. Length of Workweek	0	10	20	30
12. Physical Demand	20	40	60	80
13. Mental/Visual Demand	10	20	30	50
14. Working Position	10	20	30	40

TABLE 4: FATIGUE ALLOWANCE

Range	Percent	Range	Percent	Range	Percent
0-156	1%	220-226	11%	290-296	21%
157-163	2%	227-233	12%	297-303	22%
164-170	3%	234-240	13%	304-310	23%
171-177	4%	241-247	14%	311-317	24%
178-184	5%	248-254	15%	318-324	25%
185-191	6%	255-261	16%	325-331	26%
192-198	7%	262-268	17%	332-338	27%
199-205	8%	269-275	18%	339-345	28%
206-213	9%	276-282	19%	346-349	29%
213-219	10%	283-289	20%	350-Above	30%

Figure 4: Worksheet for Determining Fatigue Allowances

Billet No._______.

Parameters	Level	Points
1. Temperature		
2. Air Supply		
3. Humidity		
4. Noise Level		
5. Light Level		
6. Ship Motion		
7. Vibration		
8. Duration of Subtasks		
9. Repeat of Cycle		
10. Length of Workday		
11. Length of Workweek		
12. Physical Demand		
13. Mental Demand		
14. Working Position		
Total		

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VII. ANALYSIS OF NON-PRODUCTIVE TIME ALLOWANCES FOR THE DD-938

A. The Fatigue Allowance

As part of the investigation of the need for and feasibility of developing more accurate non-productive time allowances, a visit was made aboard the DD 938 by research personnel assigned to the program. The primary objective of the visit was to make the observations necessary to compute fatigue allowances for the bulk task billets, using the approach outlined in Section VI. This involved the identification of the bulk task billets and the completion of the worksheet shown in figure 4 for each such billets.

The classification of support billets into service and bulk task billet categories was accomplished on the basis of interviews with supervisory personnel. (Primarily the CPO's). The assessment of fatigue levels using table 2 was made on the basis of observations of the work environment associated with each bulk task billet. Of the 110 support billets listed in the SMD for the DD-938, 44 were identified as bulk task billets. The remaining 66 were found to be service billets. A list of the bulk task billets is presented in table 5.

Additional details relative to observations made during the visit aboard ship are presented in Appendix G.

Using the worksheets (figure 4) completed by means of the visit aboard ship, the procedure outlined in Section VI was followed to compute the fatigue allowances for the 44 bulk task billets. Relative frequencies were then calculated and used to develop the histogram in figure 5. The mean value of the computed fatigue allowances was found to be 12.2%. An inspection of figure 5 reveals that the distribution of allowances is bimodel.

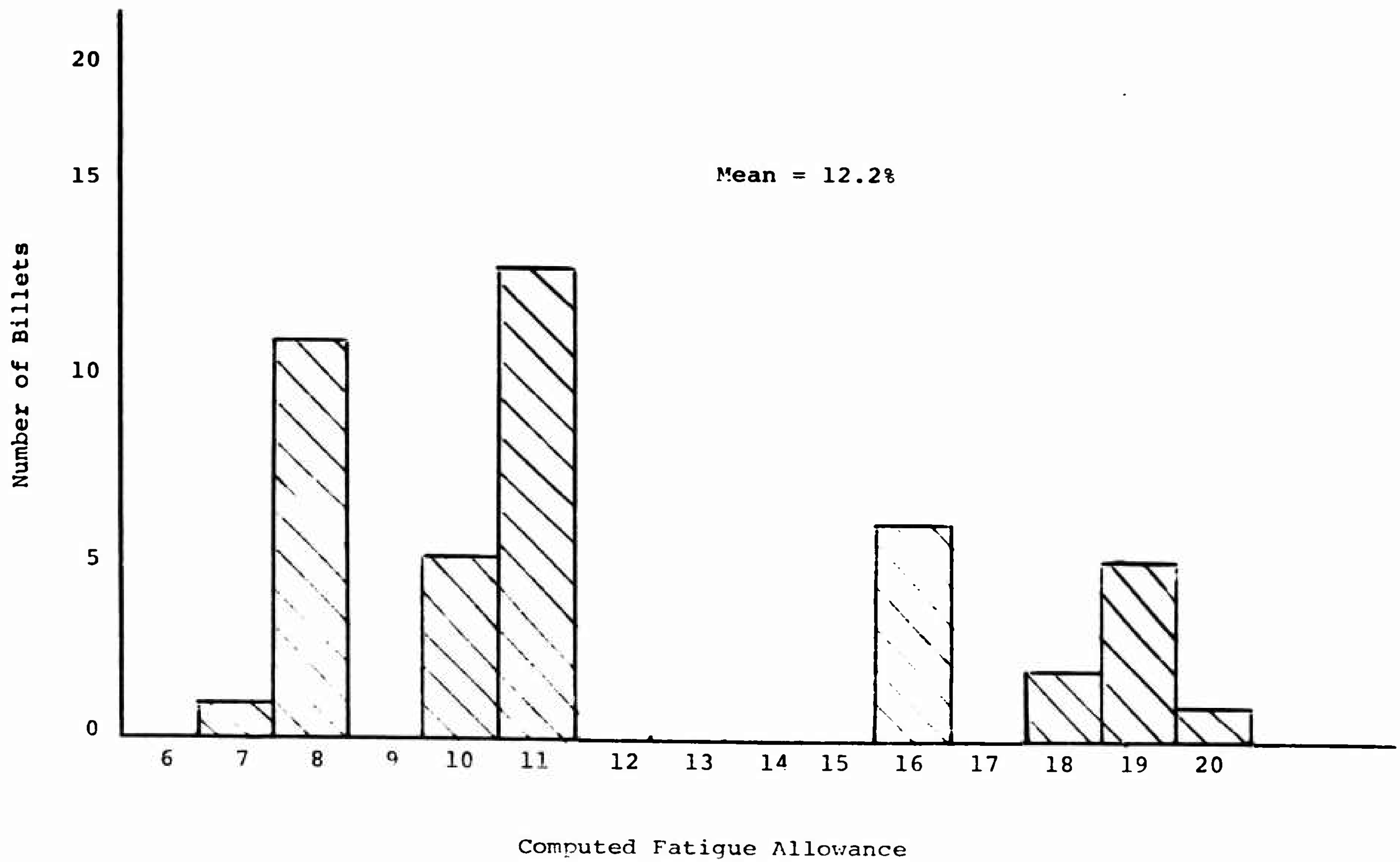
If it is assumed that of the 20% allowance now used in determining billet requirements, 10% applies to fatigue, then the allowance appears to be inadequate for a number of billets on the DD 938. Most of these billets are in the BT and MM ratings. Higher allowances are needed because of the adverse environmental conditions experienced on the job,

Table 5

List of Bulk Task Billets for DD-938

3002	4002	4317	6202	6223
3124	4003	6015	6203	6225
3125	4008	6019	6204	6226
3126	4038	6024	6208	6229
3127	4039	6025	6215	6230
3128	4040	6105	6216	10010
3129	4102	6106	6217	10011
3130	4121	6118	6218	10012
3131	4215	6134	6220	

Figure 5: Distribution of Computed Fatigue Allowances



particularly the very high temperature and humidity. The majority of the tasks for the BT and MM ratings do not require much physical exertion. Of course, on ships of different designs requiring greater physical effort, the required allowance could be still greater. Several other billets appear to require allowances in excess of 10%. These include SH billets assigned to the laundry room and several billets performing chiefly facilities maintenance on the deck.

Allowances for other bulk task billets, as indicated in the figure are near or below the 10% value.

B. Personal and Delay Allowances

No attempt was made during the visit aboard the DD-938 to assess personal and delay allowance. In the case of the personal allowance, any attempt to do so was believed to be unnecessary. Most authorities on the subject agree that a 5% personal allowance is adequate.

The assessment of the delay allowance is beyond the scope of the present study. Reference (b) provides a 5% allowance for unavoidable interruptions. This value is a commonly used figure in industry. However, considering the severity of the motion environment aboard the smaller ships such as the DD-938, it is doubtful that 5% is adequate. Experienced naval personnel all agree that with increasing severity of the sea state, a point is reached where all unessential work aboard the smaller ships ceases. At just what sea state this occurs has not been identified by the writers. On the basis of data in Appendix B, however, it appears that such delays aboard the smaller ships would occur with a much greater frequency than the 5% which is now allocated to this delay factor.

In order to evaluate the impact of the computed fatigue allowances and elimination of allowances from the service billets, one must have estimates of the personal and delay allowances. The 5% personal allowances is believed to be a valid figure for shipboard personnel and, therefore, will be used in the analysis in the following section. Rather than employ a new value which cannot be substantiated at the present time, the 5% figure specified in reference (b) will be used for the delay allowance. These values added to the computed fatigue allowances give total allowances values for the DD-938 which were used in the analysis which follows.

C. Analysis of Billet Impact of Allowances for DD-938

In evaluating the billet impact of the new computed allowances in combination with the elimination of allowances for service personnel, the same ground rules were employed as in Section IV but with the following additions:

1. Service billets were considered to be essential and, therefore, not eligible for elimination.

2. The hours gained through the elimination of allowances for the service billets were assumed to be available for the performance of the duties of bulk task billets which might be eliminated or for which the allowance might be increased.

It was believed essential that the impact of eliminating service billets be considered in combination with the new computed allowances rather than to consider the separate impacts of the two parameters. It may well be that the allowances now allocated to service billets are actually being used to provide required larger allowances to certain personnel aboard ship. If so, to treat them separately would be inappropriate.

The additional ground rule that service billets are essential adds 66 billets to the 185 condition III watch station billets for a total of 251 which are not eligible for elimination. In addition, condition I assignments which cannot be transferred to condition III or service billets create still more essential billets. As a result, only one billet on the entire ship could be found that was considered as both eligible and available for elimination and this was in the Weapons Department. In the Engineering Department where the majority of billets are located for which large fatigue allowances were computed, the excess hours made available by service billet allowances balanced the increase in allowances for bulk task personnel.

The finding that the elimination of the allowance for 66 people aboard the DD-938 would lead to a savings of only one billet is somewhat surprising. With the service billet considered as essential, one finds that complete elimination of all allowances would save the DD-938 only 4 billets. One can only conclude from this that the non-productive time allowance has little real bearing on the determination of billet requirements for DD-931 class of ships.

Confirmation of the minor contribution made by the allowance to billet requirements may be had by referring to Appendix C, Ships Manning Requirement Analysis Chart, in the SMD for the DD 931 class of ships (reference (k)). One finds on page C-7 that a number of the electronics technicians are assigned weekly hours well below the 66 normally allocated to non-watch personnel. Obviously, some factor other than the normal work routine is affecting the number of such personnel required. It appears to be the condition I requirement.

The same short workweek can also be observed for supply personnel on pages C-33 through C-37. It was confirmed during the visit on board the DD 938 that the great majority of personnel in the Supply Department occupy service billets. This and the short workweek listed in the SMD confirm the assumption that service billets are essential and cannot be eliminated by assigning the work to other personnel.

It should be noted that no explanation is given in the SMD (reference (k)), for the short workweeks allocated to the various billets. It also appears that the procedure followed does not conform to SMD Guide (reference (l)).

Observations made aboard the DD 938 failed to uncover any instances where additional personnel are employed to compensate for non-productive time allowances granted to watch station personnel. This negative result does not demonstrate that such practices, e. g., aboard the larger ships, do not exist. It is suggested that further study is needed in order to determine if such billets exist and, if so, to develop means for properly taking them into account.

VIII. DISCUSSION

The objective of the present study, as stated in Section I, was to investigate the need for and feasibility of developing more accurate allowances to account for the non-productive time required by shipboard personnel. In view of the findings outlined in the preceeding sections, it is apparent that a pressing need for more accurate allowances, insofar as the billet determination process is concerned, has not been demonstrated. First of all, it was shown that allowance is not a dominant factor in the determination of billet requirements. The analysis in Section V, based on a sample of 12 ships, reveals that billet impact of the present constant allowance is only a fraction of the allowance itself. This analysis of necessity neglects the service billet. As the evaluation for the DD 938 shows, however, the service billet further reduces the impact of the allowance.

Next, the sensititivy analysis in Section VI shows that, using the 20% allowance as a base, billet requirements are six times more sensitive to errors in the workload/manpower determination process than to errors in the non-productive time allowance. As was indicated in Section V, accuracy of the workload/manpower portion of the billet determination process can be questioned. Moreover, inaccuracies in the workload/manpower determination process can easily negate any improvement in the accuracy of the non-productive time allowance. Thus, insofar as the billet determination process is concerned, the need for more accurate allowances has not been demonstrated.

Although a need for more accurate allowances as part of the billet determination process has not been demonstrated, the analysis of allowance requirements for the DD 938 in Section VII does indicate a need for information relative to the allowances shipboard personnel should actually receive. Some functions aboard ship are more fatiguing than others, and personnel performing these functions require a larger allowance. The analysis in Appendix B also indicates that delays due to severe weather may pose a problem for personnel assigned to the smaller ships. Consequently, a need has been demonstrated for a management tool capable of providing this information.

The experimental methodology employed in the present study appears to have a great deal of merit as a tool for assessing fatigue allowance requirements. Further study is required, however, to refine and validate the process. The benefits provided by such a tool should more than repay development and implementation costs. These latter costs should be minor. For example, the identification and assignment of parameter levels from table 2 can be accomplished by the SMD survey teams without much additional effort. The actual computation of allowances can be done by computer. For all practical purposes, only the R&D effort would involve additional expense. It is reasonable to conclude, therefore, that development of this management tool is feasible.

In a formal evaluation of delay allowance requirements, one needs to take into account inherent delays in normal shipboard processes plus an analysis of those delays incurred because of ship motion. Activity sampling can be employed to evaluate inherent delays in shipboard processes. Delays due to ship motion should be based on a rigorous analysis of the effect of sea states on the ship and its personnel.

As in the case of the fatigue allowance, this effort can be accomplished by means of a slight increase in the workload of the survey crews, plus an R&D effort.

It is apparent as a result of the various analyses reported earlier that second generation improvements in the billet determination process are needed. The present process cannot provide the accuracy required to cope with a situation such as the present where manpower is exceedingly expensive and permanently in short supply. It appears that the most pressing requirement is for the modification of the billet determination process to provide for the formal identification of the service billet and the proper allocation of work and allowances to such billets. It is apparent in the SMD for the DD 938 that the service billet has been recognized, allocated and a non-productive time allowance applied to it.

The next most pressing need is for an improved workload/manpower determination process to replace activity sampling, interview techniques, etc. Activity sampling does not take into account the workpace. Because of this, errors in workload/manpower determination can result. For example, observations made of a crew performing a job at half the normal (or reasonable) workpace would result in the specification of double the manpower that the job actually requires. Moreover, the consequences of such errors are multiplied by the number of ships in the class.

Third on the list of required improvements in the SMD process is the need for more exact assessments of make ready/put away allowances and corrective maintenance requirements.

Lastly, improved procedures are needed for displaying and justifying workload/billet requirements, particularly in the support area. Billets should be accurately associated with the way manpower normally is used on board ship. Careful justification of every billet should be included, i. e., a billet should be justified by a specific, documented work assignment. It should be stated in such a way that naval officers and analysts familiar the given ship can recognize the work assignment and attest to its validity.

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IX. CONCLUSIONS

1. Because of the dominant influence of watch station, service billet, NEC and other requirements, non-productive time allowances have little impact on billet requirements. Complete elimination of the allowance would result in only a minor reduction in billet requirements (Sections V and VII).

2. Primary emphasis needs to be given to the development of second generation improvements in the billet determination process. There is an immediate need to modify the process so that it will discriminate between support billets that should receive an allowance and those that should not. Longer term efforts should emphasize improvements in the workload/manpower requirements portion of the billet determination process (Sections V, VII, VIII).

3. A 5% personal allowance is adequate. Further study of this component is not required (Section IV).

4. Application of the experimental methodology for determining fatigue allowance requirements for ships indicates that the present constant allowance is inadequate. Improvements are required to satisfy the needs of shipboard personnel. Further development of the experimental methodology should be undertaken to provide the tools needed to determine fatigue allowance requirements (Sections VI and VII).

5. The delay allowance component may be inadequate, particularly in the case of the smaller ships. Further study should be conducted to fix its value (Appendix B).

6. The allowance granted for non-productive time associated with shipboard workloads should be designated by the term non-productive time allowance (Appendix E).

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X. RECOMMENDATIONS

1. Research programs are recommended to accomplish the following objectives:

   (a) Development of second generation improvements to the billet determination process (Sections V, VII, VIII)

   (b) Development and validation of the experimental methodology for determining fatigue allowances (Section VI)

   (c) Development of required values for the delay allowance (Appendix B)

2. It is recommended that the allowances granted for non-productive time associated with shipboard workloads be designated as a non-productive time allowance, i.e., as an NPTA (Appendix E).

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XI. REFERENCES

a. OPNAV 10-P23, "Guide to the Preparation of Ship Manning Documents", Vol. I

b. CNO Ltr (OP-01BZ) Ser 11481, re: "Documentation and Analysis of Productivity Allowance Factors Currently Used in the SMD Program", 5 April 1972

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e. Morrow, R. L., Motion Economy and Work Measurement, The Ronald Press, New York, 1957

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j. Morgan, C., et.al, Human Engineering Guide to Equipment Design, McGraw - Hill Book Co., N. Y., N. Y., 1963

k. OPNAV 10-P 57, "Ship Manning Document, DD 931 Class Destroyer", 12 April 1971

l. OPNAV 12 P-4, "Guide to the Preparation of Ship Manning Documents, Vol II", 25 April 1972

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Appendix A

HUMAN EFFECTIVENESS CRITERIA

Summary

Three levels of effectiveness criteria were identified. The first level or basic human effectiveness criteria consists of a clear cut statement of (1) the nature of work to be performed by individuals and teams, (2) the required quality and quantity of this work and (3) the time interval over which it must be performed. The next higher level consists of indices or probability values which serve as the criteria for the accomplishment of total tasks by individuals. The highest level consists of indices or probability values which are relevant to the performance of teams consisting of several individuals. The first level criteria is usually generated in connection with weapon system and ship operations. Further development and use of such criteria as measures of work center effectiveness does not appear to be warranted in a manpower planning context. A research program to develop the higher level criteria must overcome the obstacles inherent in determining if the human can meet or has met the criteria. Research in this area should take the form of a long term human factors program.

It was pointed out that criteria for determining efficiency of manpower utilization is lacking. Such criteria are needed in order to minimize manpower requirements. A research program in this area is recommended.

I. Introduction

As part of the study requested in reference (a)[1.] to this appendix, NPRDL undertook an investigation to determine the feasibility of developing human effectiveness criteria at the work center level and, if their development were found to be feasible, to recommend an approach for doing the job. Human effectiveness in a Navy work or performance context refers to how well an individual or group performs a task, function or mission. As applied to a work center, it refers to the aggregate performance of work center personnel in accomplishing their assigned function(s). Human effectiveness criteria, in turn, refers to the standards or criteria against which such performance must be compared to determine the degree of performance effectiveness.

In accomplishing the above-stated objectives, the nature of the elements or factors constituting human effectiveness criteria was defined, the feasibility of developing such criteria evaluated, and a research program proposed. The work accomplished and the findings and results are outlined in the following sections.

1./ All references cited in this Appendix appear on p. A-10.

II. Elements of Human Effectiveness Criteria

The effectiveness of human beings in carrying out work or mission assignments was separated in the present investigation into two categories: (1) individual effectiveness and (2) group or team effectiveness. The effectiveness of a team is a function of the effectiveness of the individuals comprising it. Therefore, it was appropriate to initiate the investigation with an analysis of individual effectiveness.

Individual Effectiveness Criteria

As stated earlier, the effectiveness of an individual refers to how well he performs his assigned tasks or functions. The quality or worth of his performance may be judged on the basis of a number of parameters. These include such elements as accuracy of performance, response time, amount of work performed and so on. Most of these parameters are task oriented. For example, accuracy of performance or response time has little meaning, unless one specifies the task being performed and what is of interest about the task insofar as accuracy and response time are concerned. Accuracy in reading a meter differs from accuracy in coding messages. A response for which time is a pertinent consideration may be that of making an observation, operating a control or transmitting the spoken work. The particular task being performed, therefore, is a highly relevant consideration when one sets about developing human effectiveness criteria.

As a rule, any one of the basic human performance parameters discussed above refers to a discrete step or to only a part of the total task assigned to a given individual. In taking into account the various steps in a task, a number of such parameters may be relevant. Although one may require values for all of these parameters to be established in generating criteria for a task, these parameter values in themselves may not be sufficient as measures of total task effectiveness. A maintenance technician, for example, may perform a great number of discrete operations adequately most of the time as he goes about the task of maintaining a complex piece of electronic equipment. Yet, one will not really know how effective he is, if he sometimes fails. To provide the additional information needed to assess effectiveness, another measure normally is used, i.e., the probability of successful task performance or what is commonly referred to as human performance reliability. The required value of the reliability of human performance constitutes the effectiveness criteria for the individual.

In assessing the probability of successful task performance, it is customary to identify each step or operation making up the task, specify the criteria for successful performance of each step, estimate the probability that the operator will perform each step at or better than the level defined by the criteria and then mathematically combine the discrete probability values for steps into a total task probability statement. The equation for accomplishing this is as follows:

$$P_{(\text{task success})} = p_1 \cdot p_2 \cdot p_3 \cdots \cdot p_n \qquad (1)$$

where

p_1 = the probability that step 1 is successfully performed

p_2 = the probability that step 2 is successfully performed

p_3 = the probability that step 3 is successfully performed

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p_n = the probability that step n is successfully performed

The criterion or required value of the probability of task success ($P_{(\text{task success})}$) usually is set on the basis of mission requirements or required operational capabilities. Required values of the individual probabilities on the right-hand side of the equation are selected or set so as to permit the required value of $P_{(\text{task success})}$ to be achieved. At a still lower level of detail, accuracy and response time and other parameter values to which the probability values refer are set on the basis of mission requirements and required operational capabilities.

From the above it can be seen that the task of developing effectiveness criteria for the individual involves essentially two levels of criteria, (1) performance criteria for discrete steps or operations and (2) probability criteria for each of these steps and the probability criteria for the task as a whole.

Team Effectiveness Criteria

Work centers aboard ship usually have a number of functions to perform. Some of these may consist of operational functions; others may be support functions. The procedure described above usually is applied to operational functions, although in the case of critical maintenance tasks, it may be applied to support functions.

Let us now assume that a number of personnel from a work center are assigned tasks involved in operating a weapon system on board ship and that effectiveness criteria in the form of human reliability requirements have been developed for each individual. The effectiveness criterion (reliability value) for the crew as a whole is related to that for the individuals by the equation:

$$P_{crew} = P_1 \cdot P_2 \cdot P_3 \cdots \cdot P_n \qquad (2)$$

where the values on the right-hand side of the equation are the effectiveness criteria (required probabilities of success for the performance of individual tasks) for individual crew members. That on the left is the effectiveness criterion for the crew as a whole in manning the weapon system. The value of the term on the left must be determined on the basis of mission requirements for the weapon system together with the ship's ROC. It constitutes the third or highest-level criteria.

Required effectiveness criteria for a weapon system usually are called out in equipment developmental specifications in the form of a required probability of achieving specified results in the anticipated operational environment. Some specifications may assume perfectly reliable human operators. However, if the specifications have been thoroughly prepared the effectiveness criteria for the weapon system will include human performance. Assuming that it does, the probability of successful system performance becomes

$$P_{system} = P_{crew} \cdot P_{equipment} \qquad (3)$$

The term on the right in equation (3), P_{crew}, is the same as that on the left in equation (2).

Non-Critical Functions

Suppose now that the remaining functions performed by the above hypothetical work center are in support areas, e.g., facility maintenance and utility tasks. Such functions usually are not of a sufficiently critical nature as to warrant the effort involved in making a complex reliability analysis. Where this is the case the approach outlined above breaks down and one has no way of generating measures or effectiveness criteria for the work center as a whole.

Although one may not be able to develop a single criterion of effectiveness for all personnel in a work center, it should not be concluded that the effectiveness with which non-critical functions are performed is not relevant. In many cases such functions have an important bearing on the overall effectiveness of the ship.

In considering the effectiveness of non-critical functions, one finds that the approach essentially parallels that employed in the case of critical functions, although one does not make use of the higher level criteria. It is customary, when assigning a support task to an individual aboard ship, for management personnel to define the nature of the work, the amount to be performed during a specified time interval and the quality of work expected. This is fully analogous to the approach used in developing the first level or basic criteria in the case of the critical tasks.

Let us assume that we are concerned with the messing function. The effectiveness criteria for performance of the function as a whole may be that of feeding the ships personnel within specified time intervals. A number of ancilliary criteria may also be applied such as those governing cleanliness, quality of food, etc. Together these constitute the first level criteria for the function. Effectiveness is specified on a go-no-go basis, rather than in the form of a probability statement, i.e., the function is performed in accordance with the specified criteria. Effectiveness criteria can in a similar manner be set for other non-critical tasks aboard ship.

As applied to non-critical functions, effectiveness criteria consists of standards specifying quality and quantity of work be be performed by individuals and groups or teams aboard ship. In specifying amount of work, time intervals during which the work must be performed are identified. It turns out, therefore, that the quality and quantity of work together with the time interval constitutes a definitive statement of the work required of the ship's crew.

III. Feasibility of Developing Human Effectiveness Criteria

Three levels of effectiveness criteria were identified in the preceding section. In the case of non-critical support functions, only the first level or basic criteria were identified as being relevant to individuals and groups. Since first level or basic criteria are relevant across-the-board to all shipboard functions, the discussion of feasibility below has been separated into two categories: (1) basic human effectiveness criteria and (2) higher level effectiveness criteria which refers to human performance reliability as human effectiveness criteria.

Basic Human Effectiveness Criteria

As stated earlier, the basic human effectiveness criteria for a ship consists of a clear cut statement of (1) the nature of the work to be performed by individuals (tasks) and by teams of individuals (functions), (2) the required quality and quantity of this work and (3) the time interval over which it must be performed. Quality of work in the above statements refers to accuracy and response time requirements, etc. Quantity refers to amounts of work required per interval of time. Consideration of just what is denoted by such criteria reveals that they consist of data which must be known if shipboard personnel are to adequately perform their assigned tasks and functions. To accomplish a task effectively, a man must know what it is, how well he must perform it and how much of it he must accomplish per given time interval. Thus, it is not only feasible to develop such criteria, it is essential.

The question of concern, therefore, is not one of feasibility but rather one of whom should develop the criteria. Where shipboard equipment is involved, much of it is developed by contractor personnel. In the support areas it is generated by the commanding officer of the ship with the assistance of personnel in the management chain. In the latter case, a great deal of the criteria generated is never published and, hence, is not readily available to outside analysts.

In examining the question of feasibility one needs to consider the objective of a program to develop basic human effectiveness criteria. If the objective were to develop effectiveness criteria of a detailed nature which one needs to determine weapon system and mission effectiveness, then feasibility is in doubt. In the first place, most of such criteria is generated during weapon system and ship development. It appears doubtful that further development and reformatting of such data would serve a sufficiently useful manpower function to warrant the magnitude of the effort that would be involved. Without doubt, however, a human factors program to develop such criteria for the Navy would serve a useful purpose.

Criteria concerning the efficiency (as opposed to effectiveness) with which personnel are utilized, however, needs further examination. One of the Navy's objectives is to meet required operational capabilities with minimum manpower. At present, criteria do not exist for accomplishing this objective. It appears essential that such criteria be developed, if the Navy is to accomplish its objective.

Higher Level Effectiveness Criteria

The higher level effectiveness criteria referred to above are indices or probability values which serve as effectiveness criteria for the accomplishment of discrete steps and total individual task and team performance. These criteria are simply requirements which individuals and the team must meet in order to satisfy systems requirements. These can be established without undue difficulty. The real question concerning feasibility arises when one turns to the problem of determining if shipboard personnel can meet these requirements. Because of the inherent complexity of the human and the large number of relevant variables, it is difficult to determine the probability that a human operator can and will successfully perform a given task. Furthermore, since the basic parameters are task related, the number of different types of tasks and task steps is very large. Consequently, the job of developing a usable and comprehensive body of "human reliability data" is difficult indeed. To date attempts to do so have been sporadic and very limited in scope. A program to accomplish such a development cannot succeed without substantial and sustained support.

Serious attempts have been made to examine the problem of developing human reliability data. Reference (b) constitutes one such effort. It is recommended to the reader who wishes to examine the problem further.

Turning again to the question of feasibility, one must conclude that as long as data is lacking which permits one to determine that the criteria can be or have been met, it really is not feasible or worthwhile to develop the higher level effectiveness criteria. This is not to imply that such criteria are not needed. On the contrary, these criteria and supporting human capabilities data are badly needed. However, their development is properly the function of a long range human factors program.

IV. Conclusions and Recommendations

In the earlier discussion two categories of human effectiveness criteria were identified: (1) basic effectiveness criteria and (2) higher level criteria consisting of human performance reliability requirements. Insofar as basic human effectiveness criteria are concerned, there is no question as to feasibility of its development. Such criteria are essential to the operation of the ship. Their development, however, is being accomplished primarily as a part of the equipment and ship development and deployment effort. Further work in this area is recommended only as part of a long range human factors research program.

Development of higher level criteria and the human reliability data required to support the program would involve extensive, long range funding. It involves primarily a human factors-type effort. It is recommended that it be pursued as a long range human factors program to define scope, cost effectiveness, etc.

A program to develop methods for achieving efficient utilization of manpower on board ship is feasible and is recommended.

V. References

a. CNO Ltr., (OP.01B(Z)), Ser 11481, re "Documentation and Analysis of Productivity Allowance Factors Currently used in SMD Program", 5 Apr 1972

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Appendix B

PRELIMINARY STUDY OF SHIPBOARD MOTION ENVIRONMENT

Summary

A preliminary study of limited scope was conducted to determine the effect of ship motion on crew performance. In this study frequency of occurrence of the relevant sea states was determined and related to ship roll amplitude as a function of ship beam. Crew performance, in turn, was related to roll amplitude and to sea-state frequency. By using this approach it was possible to determine how often crew performance is likely to be adversely affected by ship motion. It was concluded that in the case of the smaller ships that motion of the ship has a significant fatigue-inducing effect.

I. Introduction

Reference (a)[1.] requests that NPRDL undertake an investigation to determine if there are variables associated with a ship's size, configuration or age that can be isolated and shown to contribute to an increase or decrease in human productivity. A limited study, consistent with the scope of the present effort, was undertaken in response to this request. In this study the primary emphasis was directed toward the investigation of ship motion, since it is known that severe motion has a detrimental effect on human performance.

This investigation also provided environmental data which is needed in developing the methodology for generating and evaluating more accurate non-productive time allowances. Factors which adversely affect crew performance may need to be taken into account in generating such allowances. The present investigation made it possible to consider what is believed to be the most important of these factors, i.e., ship motion.

1./ All references cited in this Appendix appear on p. B-15.

II. Background

Although a ship's motion above certain levels may adversely affect crew performance, one needs to know how often such motion is likely to occur in order to evaluate the significance of the effect. The primary contributors to ship motion are size of the ship and the sea state. Ship size may be taken as an independent variable, i.e., as a given or specified parameter value. Thus, given a ship of certain size, configuration, etc., the problem is to determine how frequently it will encounter sea states of sufficient magnitude to introduce significant amounts of motion.

When considering a class of ships which may be deployed on a world wide basis, it appears reasonable to determine and use sea state frequencies which may be encountered on a world-wide basis. Any given ship deployed in a specific area may encounter sea states with frequencies either less than or greater than the world wide frequency. However, the world-wide value should be a better value to apply to a class of ships as a whole. This is particularly true when the objective, as in the present study, is to investigate requirements for non-productive time allowances for classes of ships.

III. Approach

In establishing frequency of occurrence of sea states on a world-wide basis, information was obtained from reference (b) giving frequency of sea states 3, 4, 5, 6 and 7 for 66 different locations around the world. Average values were then computed by adding the frequencies under each state and dividing by 66, the number of locations included in the sample.

A ship's motion is affected by sea states in several different ways. Also, a number of different ship construction parameters affect motion. Therefore, given the average sea-state frequencies, the next problem is to find a way to relate sea state to ship motion. To date, no comprehensive body of information or study relating the two parameters has been uncovered. However, sufficient information has been found to permit a preliminary analysis to be conducted and like conclusions to be drawn. Reference (c) consisting of a ship motions chart, giving roll amplitude as a function of ship's beam and sea state, was provided by the Naval Ship Engineering Center. Information relating operator performance to ship's motion was obtained from reference (d). Using this information, it was possible to estimate how often ship's motion is likely to degrade or increase the difficulty of crew performance.

IV. Analysis

The approach used in computing average sea state frequency on a world-wide basis was outlined in the preceeding section. Table 1 (obtained from reference (b)) lists the various areas, sea state frequencies for each, and the computed averages. Figure 1 obtained from reference (c) gives roll amplitude as a function of sea state and ship's beam. These two sets of data were used to construct figure 2 which presents frequency as a function of ship's beam and roll amplitude. The frequencies in figure 2 were determined as follows: Sea states which will induce a roll of 6 degrees or more were identified and their corresponding frequencies summed. This sum constitutes the estimated average frequency with which a ship of given beam can be expected to encounter roll amplitudes of 6 degrees or more. The same approach was used in developing the 10 degree curve.

The values of 6 and 10 degrees were chosen in order to relate roll amplitude to the curve presented in figure 3. This curve was obtained from reference (c) and is essentially the results of a subjective evaluation by a team of analysts of the effect of roll angle on crew performance. Figure 3, for example, states that some fatigue occurs and increased effort is required when the roll amplitude reaches 6 degrees. Figure 2 can be used to determine that the smaller destroyers with a beam of about 35 feet will encounter fatigue inducing or worse conditions about 85-90 percent of the time. At about 10 degrees, according to figure 3, the roll amplitude reaches a point where some additional manpower is required to accomplish the ship's functions. One can determine from figure 2 how often such manpower is likely to be needed. Such a need is reflected in a requirement to increase the non-productive time allowance.

Table 1

FREQUENCY OF SEA STATES

AREA	SS 3	SS 4	SS 5	SS 6	SS 7
Rota	20.0	27.7	31.6	9.0	1.2
Tangier	20.7	27.4	30.4	10.8	1.1
Malaga	24.2	25.4	38.8	6.1	0.7
Sardinia	33.9	27.1	16.4	5.8	1.0
Annaba	22.1	23.4	25.8	9.0	2.6
Rome	31.7	17.2	8.4	2.0	0.3
S. Tyrrhenian Sea	32.5	23.4	14.0	3.9	0.4
Rhodes	32.9	22.1	17.5	4.1	0.8
Central Levantine Basin	21.4	27.5	28.2	7.4	1.3
Alexandria	21.4	28.3	30.8	6.2	1.5
N. Cyprus	37.5	23.3	16.2	3.0	0.3
Argentina	10.5	23.3	36.8	18.6	6.9
Bermuda	16.6	27.2	32.0	13.9	4.4
Guantanamo	32.8	28.4	18.4	2.7	0.1
Charleston	17.4	27.4	35.7	13.0	2.7
Norfolk	29.2	30.5	22.2	7.1	1.5
New Orleans	24.4	31.7	26.9	5.4	0.5
Corpus Christi	24.5	35.8	27.2	5.1	0.4
Baja	19.1	32.8	35.0	7.0	0.6
Santa Rosa	15.2	28.0	37.1	14.7	2.1

Table 1 (contd.)

FREQUENCY OF SEA STATES

AREA	SS 3	SS 4	SS 5	SS 6	SS 7
Marcus Island	11.8	25.5	39.4	16.7	2.5
Hawaiian Windward	11.3	27.6	42.2	13.5	1.8
Hawaiian Leeward	16.2	33.1	34.8	9.6	1.9
French Frigate Shoals	11.1	25.7	41.2	16.6	2.6
Kwajalein	19.1	30.9	35.7	7.6	0.1
Eniwetok	25.7	28.6	29.0	6.9	0.7
Truk	17.2	32.5	34.4	7.0	0.3
Pagan	12.1	27.4	42.5	13.4	1.6
Saipan	13.7	28.6	41.3	11.3	1.2
Koror	17.5	29.5	34.5	7.9	0.0
Akyab	22.8	24.5	28.2	8.4	1.3
Visakhapatnam	24.3	25.1	28.9	7.5	1.5
Masulipatnam	24.6	30.0	26.6	7.2	1.8
Madras	22.9	29.9	29.2	7.0	1.1
W. Ceylon	16.9	30.6	36.1	6.7	0.3
S. E. Ceylon	16.1	28.2	39.6	9.1	0.5
Mangalore	28.2	27.1	21.8	5.6	0.5
Bombay	25.8	26.0	23.2	8.9	2.5
Gulf of Cambay	25.0	26.6	25.9	9.1	1.1
N. E. Arabian Sea	22.4	24.4	27.1	13.1	3.3

Table 1 (contd.)

FREQUENCY OF SEA STATES

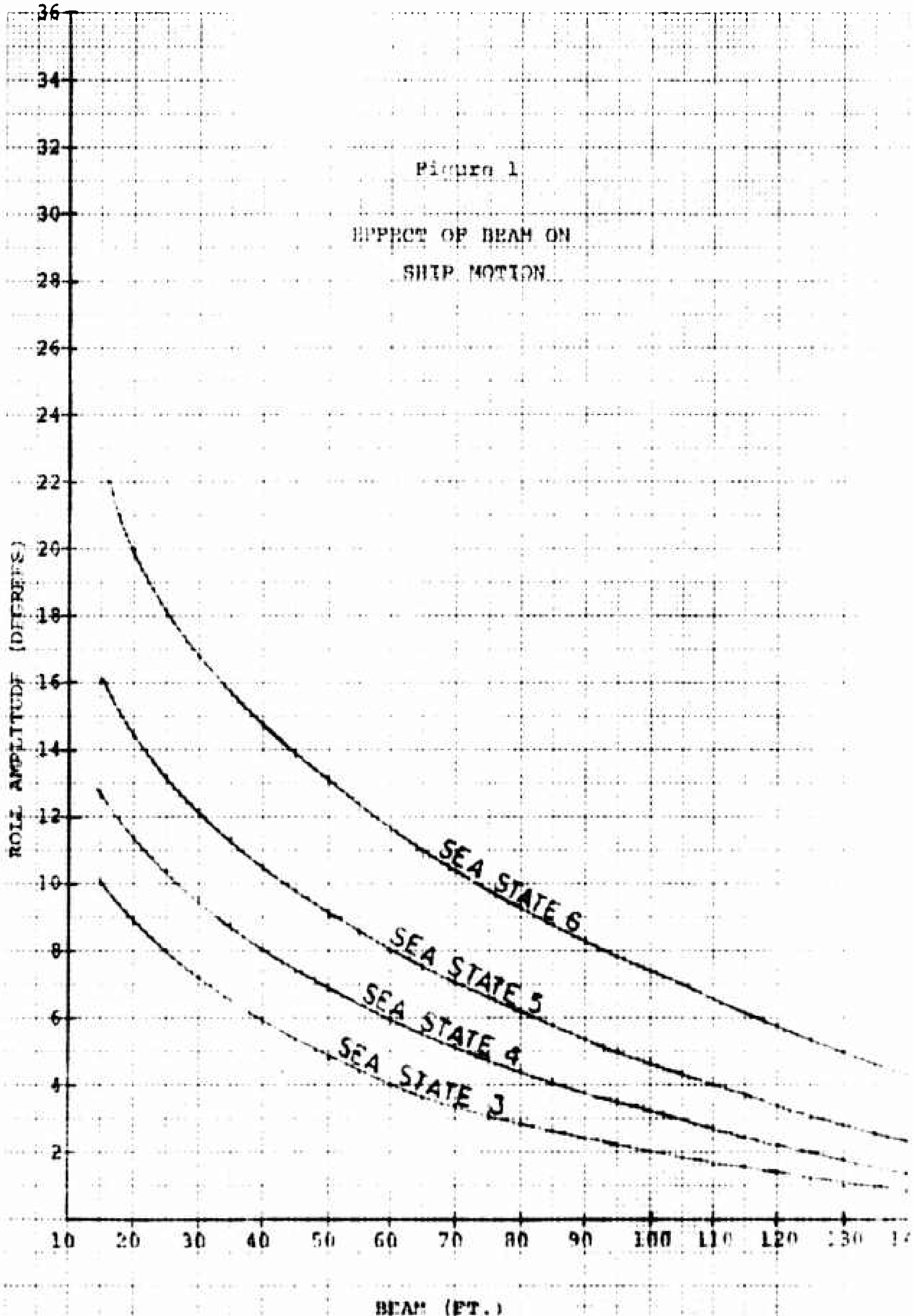
AREA	SS 3	SS 4	SS 5	SS 6	SS 7
Eureka	10.2	23.4	36.4	21.9	4.7
Newport	8.5	21.7	42.5	20.7	4.3
Cordova	10.9	21.7	35.9	19.3	5.8
Unimak	10.7	20.7	32.0	18.4	6.5
Attu	14.9	20.1	23.3	12.9	6.2
Nunivak	23.6	28.2	19.2	6.3	0.0
St. Lawrence	31.7	23.3	16.4	8.4	1.5
Barrow	17.2	10.9	7.7	2.8	0.0
Nagasaki	24.7	30.4	25.6	7.6	1.1
Central E. China Sea	18.3	26.8	33.7	13.6	3.1
Northern E. China Sea	19.8	27.8	30.9	12.2	3.0
Inland Sea	30.6	10.1	4.1	0.8	0.1
Matsue	21.3	28.3	26.2	11.5	2.2
Akita	21.1	27.1	27.5	11.4	2.2
Hakodate	22.5	23.7	27.7	9.3	1.7
Wonsan	26.8	31.1	20.4	8.4	0.8
Cheju Island	22.6	29.9	27.1	9.5	1.1
Inchion	34.9	26.1	17.8	4.4	0.4
Bonin Islands	12.4	26.4	39.2	15.1	2.6
Volcano Islands	14.4	26.6	39.0	13.2	2.5

Table 1 (contd.)

FREQUENCY OF SEA STATES

AREA	SS 3	SS 4	SS 5	SS 6	SS 7
N. W. Arabian Sea	21.6	23.0	23.9	13.5	3.6
S. E. Oman	24.5	22.8	23.5	9.4	1.2
Gwadar	24.3	23.5	25.3	9.4	1.7
N. Gulf of Oman	32.1	20.1	9.7	1.0	0.1
S. E. Persian Gulf	33.1	18.1	7.5	0.9	0.0
N. W. Persian Gulf	29.2	17.8	9.1	1.1	0.0
AVERAGE	21.73	25.89	27.38	9.25	1.71

Source - reference (b)



Source - reference (c)

Figure 2

FREQUENCY OF EXCEEDING
ROLL AMPLITUDE

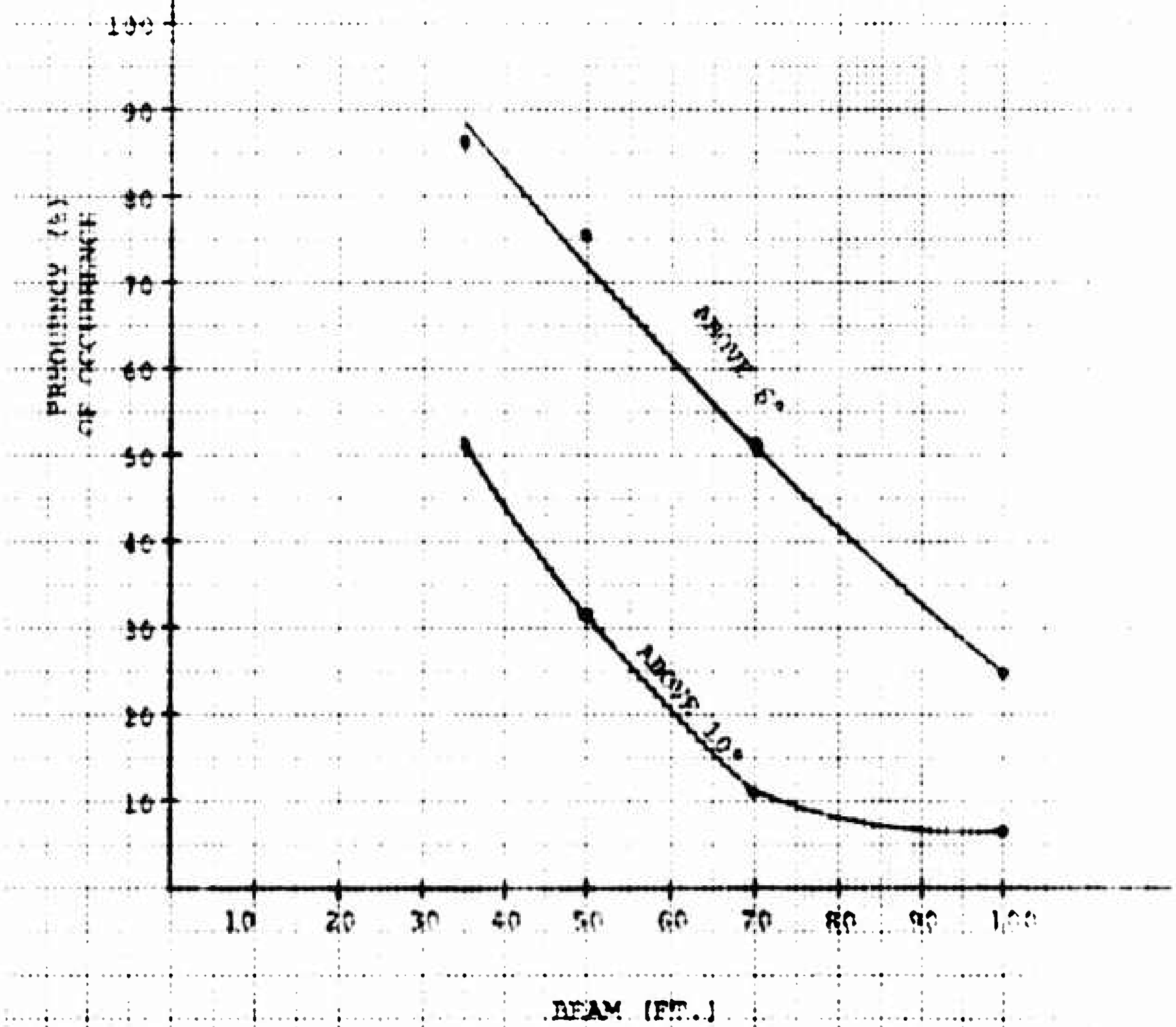
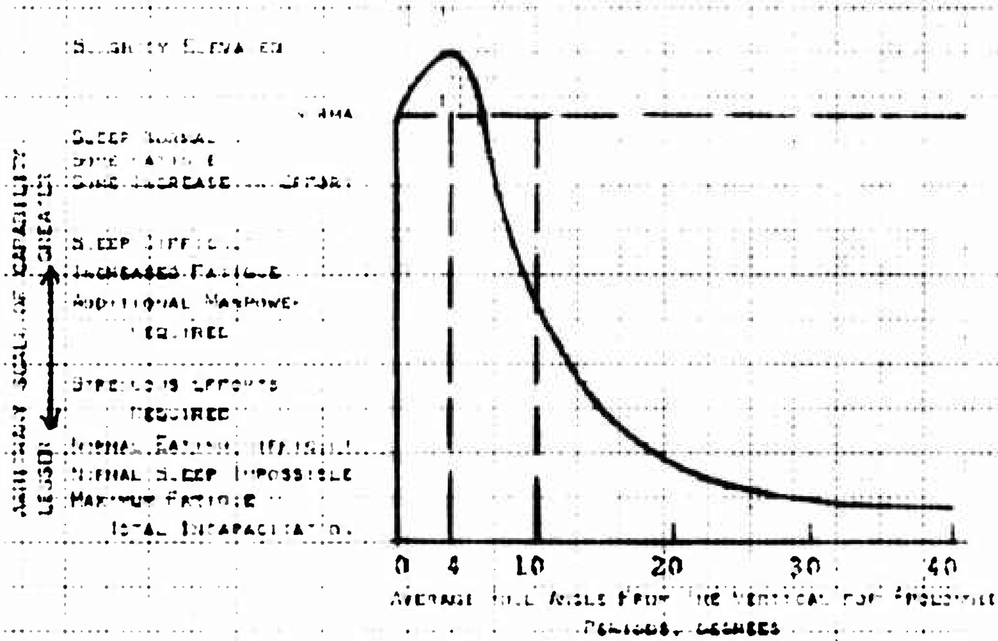


Figure 3

EFFECT OF ROLLING ENVIRONMENT
ON AVERAGE PERSONNEL CAPABILITIES



Source - reference (6)

IV. Discussion

It is emphasized that the findings presented above are tentative. In computing the average frequencies in table 1, the simplifying assumption was made that ships of a class will enter any one given area as frequently as another. This may not be the case and to the extent that such inequalities occur, the computed average frequencies will be in error. However, it is believed that for the purposes of the present study, i.e., the investigation of non-productive time allowances, the obtained accuracy is adequate to conclude that ship's motion is a highly relevant parameter.

The same conclusion holds in relation to figures 2 and 3. Figure 2 is based on unpublished data and no information was provided by NAVSEC relative to its accuracy. Since it includes only the one independent variable, ships beam, its use is obviously an approximation. If used to provide only a general rather than an exact indication, however, it is believed to be adequate for present purposes.

As was stated earlier, figure 3 is based on the subjective impressions of a team of analysts who conducted the study reported in reference (d). Certainly, valid statistical data would have permitted more soundly-based conclusions. Lacking such data one should not discard the subjective information. If it is the best data available, it should be used, but with due caution. Certainly, it is sufficiently accurate for one to conclude that a fatigue problem is frequently encountered on the smaller ships.

V. Conclusions

The findings of this investigation indicate that the motion of a ship in the more severe sea states has a detrimental effect on crew performance. Ship motion in turn is a function of ship size. The effect of ship motion is exhibited primarily in the form of added fatigue. Above certain levels, however, it may delay task performance. Therefore, in any attempt to develop more accurate non-productive time allowances, consideration should be given to ship size in determining the magnitude of the allowance.

VI. <u>References</u>

(a) CNO Ltr., (OP-01B(Z)), Ser 11481 re: "Documentation and Analysis of Productivity Allowance Factors Currently used in the SMD Program", 5 Apr 1972.

(b) Survey of Synoptic Meteorological Observations, U. S. Naval Weather Service Command, Washington, D. C.

(c) Ship Motions Chart, Naval Ship Engineering Center, Hyattsville, Maryland

(d) "Evaluation of the Performance of Human Operators as a Function of Ship Motion", Naval Ship Research and Development Laboratory, Annapolis, Maryland, Apr 1969.

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Appendix C

INVESTIGATION OF PARAMETERS AFFECTING REQUIREMENTS FOR NON-PRODUCTIVE TIME ALLOWANCES

Summary

A study was conducted to further identify the parameters affecting human productivity aboard ship, derive and document their potential impact, and determine the potential long range benefits that can be attributed to more accurate non-productive time allowances. Work in conducting this study was separated into two phases. The first involved a survey of the relevant literature and reporting of the findings. The second involved the review and analysis of the findings of a number of shipboard surveys conducted by NPRDL's Motivational and Survey Research Division. Evidence was obtained in the literature survey indicating that a number of environmental parameters have a detrimental effect on worker performance. Data identifying the quantitative impact of pertinent variables was not available. Lacking such data, use was made of the findings obtained in a number of attitude and motivational surveys conducted by NPRDL. Relevant variables covered in these surveys included length of work week, working space and quality of shipboard life including lighting, messing, noise levels, bunk and mattress, head and shower facilities, locker and stowage space and lounge facilities. No evidence was obtained in the surveys to indicate that any of these variables or factors have a significant impact on human productivity. Inasmuch as the impact of length of workweek appears not to be significant, one can tentatively conclude that the non-productive time allowances actually granted are at least adequate. One cannot determine on the basis of the available data if they are excessive.

I. Introduction

Reference (a)[1./] requested that an investigation be conducted to identify the variables affecting human productivity aboard ship, derive and document their potential impact and determine the potential long-range benefits that can be attributed to the development of more accurate non-productive time allowances. A study of the impact of ship size and motion is reported in appendix B. The impact of length of workday and workweek is covered in appendix D. The study reported in this appendix had as its objective the investigation of other relevant variables.

1./ All references cited in this Appendix appear on pp. C-19 - C-21.

II. Parameters Affecting the Requirements for an Allowance

Environmental effects and fatigue are so closely related that they can be separated only conceptually. In practice there is a significant interaction which would make any attempt to establish independent allowances for these two factors an unrealistic effort. A fatigue allowance may be thought of as one that is applied to account for rest periods and decreased efficiency due to the nature of the work, independent of the environmental conditions. Similarly, an environmental allowance could be considered to account for loss of efficiency due to environmental conditions, independent of the nature of the work. This theoretical independence of fatigue and environment is often found to be fallacious. For instance, raising the temperature from a comfortable level to a higher level has a more adverse effect on the performance of a strenuous task than on a light task. Because of the interdependence of the type of work and the environment, it is necessary to treat both of these factors concurrently in determining the necessary allowances. In this section brief discussions of several environmental factors will be presented, including work and fatigue, an approach to quantifying fatigue and environmental allowances, and a method for verifying allowance requirements.

References in this section are arranged in alphabetical order and referred to by name of the author to facilitate the relating of findings to authorities on the subject.

A. Environmental Factors

There are a multitude of environmental factors that can affect the performance of various tasks. The factors to be considered here are those which have been shown to significantly influence performance in certain settings and which are prevalent enough aboard ships to have a potential effect on allowance requirements.

1. High Ambient Temperature

It has been demonstrated convincingly that high temperatures have an adverse effect on human performance where the work involves a significant amount of physical effort. The magnitude of this effect varies with the energy required by the task, the ambient temperature, the humidity, air movement, and the time the person has been exposed to the high temperature (Grandjean, 1969; Jones 1970). The effect on the performance of monitoring tasks, mental tasks, and various simple low exertion tasks is not as clear, partly because of the great variation in the conditions studied (Jones, 1970). However, the effect of high temperature on tasks of medium and high physical exertion are great enough to be apparent, even under the variety of conditions studied. There are no generally accepted standards for temperature tolerance limits; several guides exist. For instance, Woodson and Conover (1966) consider 75°F the temperature at which physical fatigue begins and 85°F the temperature at which mental activities slow down and errors increase. A tolerable temperature for one hour is estimated to be 120°F.

During the shipboard visit aboard the DD-938, the extent of personnel exposure to high temperatures was observed. While most of the compartments of the ship were air-conditioned, there were several areas that remained hot. The temperature in the fire rooms was between 100°F and 120°F. At this temperature, continuous work of even moderate physical difficulty quickly leads to fatigue. However, most of the tasks performed in these compartments required little physical exertion or were intermittent in nature. There were several other locations where the temperature was above 90°F. However, only a few billets were affected. It was concluded that the vast majority of the billets are not adversely affected by high temperatures. Some experience moderately elevated temperatures, and a significant minority are exposed to very high temperatures. This latter group requires a higher allowance. In fact, it is possible that the experimental scale used in the present study underestimates the impact of the temperature factor at the levels encountered on the DD-938.

2. Air Supply

The availability of ample oxygen has a considerable fect on fatigue. The more complex motor tasks are affected sooner than the simpler ones (McCormick, 1957) when oxygen is deficient. Strenuous physical tasks lead to fatigue sooner than when oxygen is plentiful. Dust, gases, and vapors can also reduce personnel effectiveness as well as constitute a health hazard. This factor was not observed to be significant aboard the DD-938.

3. Humidity

Humidity influences an individual's comfort and can lead to impaired performance. If humidity is present, together with high temperature, the effect is intensified since body cooling by sweat evaporation becomes insufficient if physical activity is maintained. The effects of heat and humidity are generally considered in conjunction with each other, rather than independently. In fact, heat stress is defined as the result of the body's integration of the effects of air temperature, humidity, air movement, and radiant heat (Jones, 1970). On the DD-938 only a small percentage of the personnel were exposed to high humidity. However, these individuals were also exposed to high temperatures in almost all cases (in the fire room, scullery, laundry room), thus making them more subject to fatigue.

4. Noise

Where tasks have a significant auditory component associated with them, any extraneous noise will impair the performance of that task. However, in non-auditory tasks the effect is not clear. The number of studies showing a decrement in performance appears to be about equal to those showing no decrement. It is possible that a physiological measure may show that a greater effort is required to perform under the effects of loud noise; however, only fragmentary evidence has been found to support this hypothesis. It appears that only a few areas aboard a typical ship have high ambient noise levels (aircraft carriers are an exception to this general rule). Examination of detailed noise measurement data for several ships showed that except for a few compartments, such as engine rooms, noise levels rarely exceeded 85 db, which is often considered to be the highest noise level that personnel can experience for long periods of time without adverse effects (McCormick, 1957). Wafford (1968) in presenting guidelines for Air Force aircraft recommends ear protection at 82 db and considers it mandatory at 92 db. Louder noise can lead to physical damage, although the effect on the performance of non-auditory tasks is not clear. In reviewing some of the literature in this field, Grether (1971) states that noise causes performance decrements in reaction time, two-hand coordination, and vigilance. The decrement more often manifests itself in the form of more errors than in the decrease of speed. The effect of noise may depend on factors other than just its physical characteristics. For instance, Matsui and Sakamoto (1969) found that the effect of noise depended on whether the noise was produced by the workers experiencing it or by a process unrelated to the work done. Noise not intrinsic to the work performed was more deleterious.

Approximately 70 personnel aboard the DD 938 are continuously exposed to high noise levels while on the job. These are the billets assigned to the fire rooms and engine rooms. Although relatively few billets would be affected by the noise factor in their non-productive time allowance, it cannot be implied that noise has a negligible effect on personnel. Adverse effects on morale and hearing (if ear protection devices are not used) are likely.

5. Lighting

A wide range of light levels is acceptable to most people before there is a significant decrement in performance due to an improper lighting intensity. Exceptions include tasks that require high levels for fine inspection tasks or very low levels of light for observation of CRT screens, etc. Even when ambient light levels are within the acceptable range, the presence of glare can adversely affect performance. Therefore, both the light levels and the existence of glare need to be taken into account. Woodson and Conover (1966) and McCormick (1957) list recommended lighting levels for various types of tasks. Although most of these tasks pertain to industrial settings, some of them are applicable to shipboard activities. Few personnel were found working under unfavorable lighting conditions. Where illumination was very low, as in the sonar room and the CIC, this condition was necessary to ensure good visibility of displays.

6. Ship Motion

The motion a ship encounters at sea has an obvious detrimental effect on human performance. This problem is discussed in Appendix B.

7. Vibration

Vibration has been studied in numerous contexts. It is known that vibration can produce physiological damage to humans if the amplitude is sufficiently great. Different regions of the body are affected by different frequencies of vibration (Bender and Collins, 1969). However, long before serious physiological damage is sustained, there can be a significant impairment in the performance of various tasks. The use of hand tools in maintenance tasks appears to be affected most by vibrations under 10 Hertz. Vibration at these and somewhat higher frequencies are known to impair performance on visual tasks such as reading dials (Townsend, 1967). The effect of vibration depends on several factors such as frequency, amplitude, direction, and duration. Because of the relatively large number of factors that influence the effects of vibration on humans, it has been difficult to develop standards that are universally acceptable. The existing standards need to be studied to determine which are the most closely related to the shipboard environment and can best be tied to a non-productive time allowance.

8. Physical and Mental Demand

Even in the most favorable work environment there will be some fatigue resulting from continuous work. The extent of the fatigue depends on such factors as the energy expenditure, the number of muscle groups used (Morioka, Numajiri, Onishi, and Sasaki, 1971), the amount of static muscular work performed, and the body position maintained during work. The longer the work period, the greater the fatigue effect. For this reason it is not possible to directly apply data obtained under typical industrial situations, with the 8-hour day, to the Navy's problem. While physical effort is probably the most common source of fatigue, and the easiest to measure, fatigue can also be produced by purely mental tasks, particularly if great concentration is required. During the ship visit an estimate of the potential for fatique for the various billets was made. The assessment of mental fatigue was based largely on interview data while physical fatigue was estimated by observation. It is recognized that both techniques are subjective and serve only as rough first approximations.

9. Quantifying Fatigue and Environmental Allowances

There is little consensus on how to account for on-the-job fatigue. As was mentioned earlier, many organizations employ a constant fatigue allowance for all jobs regardless of the differing job demands. Others recognize that existing differences in task difficulty require different allowances. However, there is no single systematic method that has been widely accepted for setting allowances. There are a number of scales that are currently being used which include most of the factors that are relevant to the shipboard environment (e.g., Cornman, 1970; DSAM 1100.2, 1969). Vibration and ship motion are the main environmental variables that are not accounted for in any of the existing scales.

When using any of the existing scales, an estimate is made of the working conditions and the physical (or mental) difficulty of the work. Each environmental and work factor is evaluated and scaled. Each scaled factor, or all factors collectively, is converted to a fatigue allowance. Most scales have a linear relationship between the level of the environmental and work factors and the allowance. In some cases a certain threshold must be reached before any fatigue allowance is specified. Once this threshold is passed, the allowance increases linearly with any rises in the environmental or work factor levels.

An experimental scale of this type was developed for the present study. It contains some factors not appearing in previously constructed scales. It may be necessary to have other than a linear relationship between the levels of various factors and the allowance, i.e., high levels of two factors may warrant a higher allowance than simply the sum of the allowances for the two factors taken separately. However, this was considered too complex a question to be resolved in the present study. The data gathered in the ship visit were applied to this experimental scale to determine the fatigue allowance for the various billets. It is recognized that this approach has a large subjective component. The results must be considered only as a first approximation for use in determining the need for and feasibility of developing a more accurate allowance. Before there can be any implementation of such an approach, considerable refinement and validation would be necessary.

10. Fatigue, Objective Assessment, and Verification

An objective basis is needed for use in developing fatigue environmental allowances. The present allowances in the SMD are set arbitrarily as are allowances in industry in most cases. A major reason for this lack of objectivity is the difficulty in determining what the effect of various environmental factors and work conditions is on an individual's performance. An empirical determination of the effects of various factors on performance in a given situation is usually costly and time consuming. Consequently attempts are frequently made to develop "rules of thumb" to permit an estimate of the fatigue effects of certain types of work performed under certain conditions. Since multiple factors are typically operating in any situation, it is necessary to account for the interactions between the various factors, which makes this a complex problem. Because of the hazards of inferring fatigue from performance levels, regardless of whether one or more factors are significant in a given situation, it is necessary to have other techniques available to verify any tentative fatigue allowances that are based on available studies.

If fatigue allowances are grossly inadequate, this will become apparent eventually. Some of the symptoms of this condition are increases in complaints about overwork and fatigue, more errors in the performance of various tasks, decreased morale, increases in the number of sick bay visits. It may take some time before these trends become apparent, however. If the problem is confined only to a few divisions, it may be more difficult to detect. In any case there is little precision in this "wait and see" approach.

There are a number of work study techniques that can reveal insufficient or excessive fatigue allowances. However, they require considerable familiarity with the job being studied as well as much subjective judgement.

Greater accuracy can be obtained by utilizing a number of objective physiological principles that are applicable to a large proportion of the shipboard billets. It is known that several physiological factors are closely related to the physical exertion required by the work performed. At some levels of exertion these factors are very highly correlated with each other. There also appears to be excellent correlation between certain of these physiological factors and subjective estimates of fatigue over a large range of work load.

A series of studies indicate that the maximum daily energy expenditure available for work is about 2500 kcal. for a normal healthy male (Brouha, 1960). Greater energy outputs for sustained periods of time can be harmful physiologically. Somewhat lower limits (e.g., 2000 kcal.) have been recommended to allow a margin for safety (Lehman, 1958). Normally no direct measurement is made of energy expenditure. However, by measuring oxygen consumption the energy expenditure can be calculated (Bonjer 1969).

Heart rate is accepted by many researchers as the best single indicator of physical exertion. It is affected not only by the work being performed, but also by environmental conditions (such as heat and humidity) that contribute to the physiological stress in the work situation (Burger, 1969). Within certain limits there is a linear relationship between heart rate and energy expenditure for physical work provided that environmental conditions remain constant. For relatively light tasks heart rate quickly reaches an equilibrium point where it remains throughout the work session. If very strenuous work is performed continuously pulse rate increases until exhaustion halts the activity (Grandjean, 1969). Thus, in any work situation the requirements placed on an individual must be such that heart rate can level off at some constant rate. Although there is not complete agreement as to what this level should be, there is enough consensus to permit rather close agreement even when several different approaches are taken.

Not all billets on a given ship involve work where stress or fatigue effects are realistically reflected by the heart rate. If fatigue in the work is due primarily to factors other than physical exertion the heart rate may not be a good measure of the fatigue level (and the need for a rest pause). Thus, a sedentary task requiring great concentration may produce a high level of mental fatigue requiring a rest period for the operator to avoid a major decrement in performance. However, monitoring of his heart rate may not give an accurate indication of his fatigue or stress level.

The physiological stress on the body, which is the parameter that determines the rest pause requirement, is not determined solely by the energy expenditure. For instance, a given energy output will lead to more fatigue if the work involves only a single muscle group than if several muscle groups or the whole body is involved (Astrand and Rodahl, 1970). This phenomenon is reflected by heart rate data. In addition static muscular work places a greater physiological stress on the body than dynamic work (Davis, Faulkner, and Miller, 1969). This fact is also evident from heart rate data but not from energy expenditure data. The ambient heat is another factor that increases physiological stress. This is readily detected by monitoring heart rate, although energy expenditure (or oxygen consumption) is not sensitive to this factor (Kamon and Belding, 1971).

There are a number of similar guidelines that are currently being used in industry or are recommended by researchers concerning acceptable heart rates for workers. Often an average heart rate for a full day is specified, generally in the range of 110 to 120 beats per minute for an eight-hour working day (Astrand and Rodahl, 1970; Snook and Irvine, 1969). It is assumed, of course, that there will not be great fluctuations in this parameter, since there is not a linear relationship between heart rate and physiological stress (e.g., an hour of a heart rate of 60 and an hour of a heart rate of 180 is more fatiguing than two hours at a heart rate of 120). An alternative criterion is to specify the allowable increment in pulse rate between rest and work, typically 30 or 40 beats (Grandjean, 1969). Still another variation involves an increment above the resting rate and the maximum rate attainable (Leynik 1971). For all of these guidelines it is assumed that extreme heart rates will not be reached. Heart rates above 85% of the maximum attainable rate (which is a function of age) are not recommended for any work situation (American Heart Association suggestion).

Considerable study is still required to permit the assessment of the feasibility of utilizing heart rate measures (or other physiological techniques) in the Navy. At this stage only the rationale for its use is fairly clear. In brief, a physiological measure, of which heart rate appears to be the best candidate by far, would provide an objective measure of the fatigue produced by the work and the work environment. This would end dependence on the various subjective approaches that are commonly used. The allowance required for various types of work under various environmental conditions could be determined empirically. It appears that physiological techniques of fatigue assessment are applicable to all, or nearly all, shipboard billets. It would still be necessary to determine whether the equipment typically used in industrial situations is suitable onboard ships. This question is particularly relevant where telemetry techniques are concerned. Some assessment of the costs involved would also need to be made before any significant program in this area could be recommended.

It appears that a thorough physiological approach to fatigue allowance assessment would be costly. A more feasible program would involve a more limited reliance on physiological measures. Only selected ratings may need to be studied to provide a number of objective "anchor points" from which fatigue allowances for other ratings could be scaled by the more commonly used techniques discussed above. Thus, selective application of physiological techniques would serve as a means of refining or validating the scale developed by the more traditional approaches.

III. Parameters Investigated in NPRDL Surveys

A. Survey Findings

The relevant parameters covered in NPRDL surveys (references (x) through (z)) are listed in table 1 and in figure 1. Those listed in table 1 are considered as major parameters and include length of workweek, working spaces and quality of shipboard life. The parameters listed in figure 1 are an amplification of the latter parameter, i.e., quality of shipboard life.

The findings listed in table 1 relative to length of workweek indicate that length of the workweek has little impact on career intentions. About the same percent of personnel working the shorter workweek intend to leave the Navy as that of personnel who work a longer workweek. The six in ten who indicated in a later survey that length of workweek is an influence against a Navy career is numerically consistent with the earlier findings. One cannot be certain, however, that this finding is a significant factor in terms of retention. Before one could reduce the workweek on board ship, he would have to make certain that a more serious problem was not encountered in the form of boredom, etc., resulting from an inability of shipboard personnel to make effective use of the increased leisure time.

The finding that long hours at sea are experienced in greater degree by the more experienced and career-oriented personnel may stem from a tendency to use such personnel for manning watch stations. It may indicate a tendency to make greater use of such personnel because of their experience and superior efficiency. It could be indicative of a higher level of motivation among such personnel. In any event, it fails to indicate that the long hours actually affect retention and the morale of these people.

The findings relative to working spaces appear to lack statistical significance. Although 50 percent of the enlisted personnel felt that working spaces were unsatisfactory, apparently an equal number were unconcerned. However, those indicating concern were primarily career-oriented personnel. It is reasonable to conclude that such personnel are concerned with their personal comfort in a chosen career. This, however, does not constitute evidence that a significant effect is exerted on retention, morale or human productivity.

Table 1: Analysis of Relevant Parameters

Parameter	Findings	Conclusions	Source Documents
Length of workweek	Hours of duty have little impact on career intentions. Among enlisted men with less than six years of service, 70 percent with long work-weeks (60 or more hours) intended to leave the Navy. Of those with the shortest workweek (40 hours or less) 66 percent intended to leave.	Hours of duty have little or no effect on retention and morale.	Ref x
	Dissatisfaction with working hours was greater for non-career oriented than for career oriented enlisted men. The great majority report that they work 20 hours or more per week longer while at sea than at shore stations. Six in ten report that hours worked at sea was an influence against a Navy career.	The six in ten indicating a negative attitude toward working hours is consistent with above finding. Does not conclusively demonstrate a true relationship between hours of work and an impact on retention and morale.	Ref y

Table 1: Analysis of Relevant Parameters (contd.)

Parameter	Findings	Conclusions	Source Documents
	Long hours at sea were experienced to a greater extent by men who had served at sea or been deployed two years or more, those assigned to aircraft squadrons or detachments and those in second and greater enlistments.	Greater use tends to be made of experienced personnel than of those who are relatively inexperienced.	Ref(y)
Working Spaces	Five in ten enlisted men aboard their present ship at the time of the survey considered working spaces to be unsatisfactory. Those holding a low regard for working spaces were primarily career oriented personnel.	Does not constitute evidence that a positive effect is exerted on retention and morale.	Ref(y)
Quality of Shipboard Life	Half of the enlisted men sampled in this particular survey and who were undecided against reenlistment said the Navy could do nothing (other than increase pay and allowances) to make them stay. Of these men, 50 percent were on sea duty at the time of the survey.	Indicates that quality of shipboard life in terms of creature comforts is not a significant factor	Ref(z)

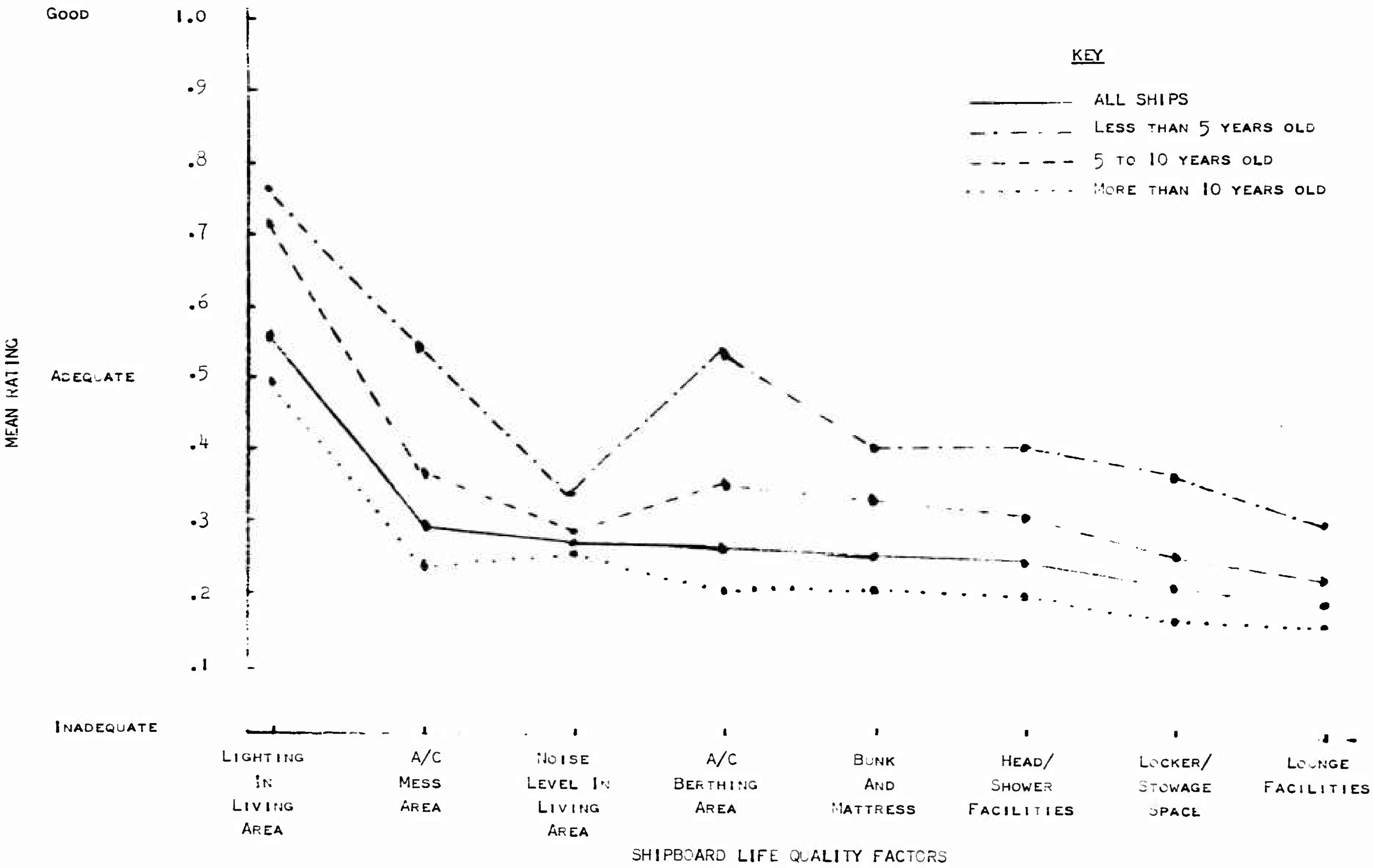

FIGURE 1

MEAN RATING OF SHIPBOARD LIFE QUALITY FACTORS BY AGE OF SHIP

FROM WSR 73-1

The finding that the quality of shipboard life is not a relevant factor affecting retention is believed to be highly significant. It appears that financial conditions, not working or living conditions, are the more dominant factors affecting retention and morale. Apparently, length of the workweek, working spaces, fatigue and other factors contributing to quality of shipboard life are relatively minor considerations.

As can be observed from figure 1, age of the ship causes a noticeable difference in the responses made to the various life quality factors. Of the other responses made to the various factors, only the lighting in the living areas appears to be fully adequate. All other factors appear to be less than adequate but not completely inadequate. About the only conclusion one can reach, however, is that improvement is possible and desirable.

B. Discussion of Survey Findings

In no instance do the survey findings summarized above indicate that any of the various factors has an effect upon the work output or productivity of shipboard personnel. This is especially true in the case of the length of the workweek. Hours of duty appear to have little or no effect on retention and morale. It is possible to extrapolate from this finding to arrive at a tentative conclusion relative to the non-productive time allowances currently being granted to shipboard personnel. To make this extrapolation one must employ the following logic. If crew members were suffering from chronic fatigue at the time of the survey, which was brought on by inadequate time off, it is likely that a strong aversion to length of the workweek would have been exhibited. Moreover, such fatigue would have been one of the primary factors listed as contributing to lowered quality of shipboard life. However, this was not the case. No indications are to be found in the survey findings that chronic fatigue or inadequate non-productive time allowances are considered as matters of serious concern.

As was pointed out in the main body of the report, there is little or no relationship between the 20 percent allowance used in developing the SMD and the actual time off granted to shipboard personnel. If a ship is being excessively manned because of factors other than the 20% allowance, then the actual time off granted to shipboard personnel could be much larger on the average than 20 percent. One cannot conclude, however, that this is actually the case without knowing how shipboard personnel are used.

The finding that longer hours are worked by personnel with two or more years at sea and by those in their second or greater enlistments appears to indicate that personnel in higher ratings may require greater non-productive time allowances than those in lower ratings. Results of the survey appear to indicate, however, that even these personnel are actually receiving adequate allowances.

IV. Conclusions

Conclusions reached on the basis of surveys which were conducted for other purposes can only be considered tentative. However, considering the available evidence it does appear that none of the listed factors have a significant effect on retention and morale. In turn, it appears reasonable to conclude that the actual non-productive time allowances personnel were receiving at the time of the surveys were adequate. It is assumed that the ships were essentially fully manned. One cannot determine on the basis of the available information, however, if the allowances are larger than necessary.

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Appendix D

RELATIONSHIP BETWEEN NUMBER OF HOURS WORKED AND THE EFFICIENCY OF WORK PERFORMANCE

Summary

A brief study was conducted to determine the relationship between number of hours worked and the efficiency of work performance. It was found that the number of hours a man works per day or per week exerts an effect on hourly production, total production, absenteeism, and accident rate.

It appears that the optimum workweek aboard ship is 8 hours per day and 48 hours per week. A longer workweek may require a larger non-productive time allowance than would be the case with one which is shorter. Further research is required to establish the optimum relationship among the parameters: length of workweek, work output and non-productive time allowance.

I. Introduction

In any attempt to improve the accuracy of the non-productive time allowance (NPTA) used in generating billet requirements, consideration must be given to the length of the workweek currently employed. The standard workweek for personnel assigned to watch stations is 74 hours. That for non-watch personnel is 66 hours. These workweeks are, of course, considerably longer than those used in industry. Therefore, in developing an NPTA one must determine if the longer workweek is a relevant factor and, if so, take it into account in generating the new allowance.

II. Effect of Number of Hours Worked on Rate of Work

The number of hours a man works per day or per week appears to affect both the rate at which work is performed and the total output. In general, a shorter workweek is required to maximize output per man hour than is required to maximize the total output. Chapanis (ref.(a))[1/] makes the statement that "the many studies seem to agree that production per hour is greatest with approximately 36 to 44 hours of work per week." The optimum number of hours (Ref.(b)) between 36 and 44 is dependent upon the type of work being performed and will vary from plant to plant. For example, in a study by Pressy of production in a box factory, the 40 hour week is best. The results of Pressy's study are shown in Figure 1.

In a study by Kossoris, U.S. Department of Labor, of production in 12 metal working plants (ref.(c)), it was also found that the 8-hour day and 40-hour week combination yields the highest output for each hour worked. In this study, of less than 40 hours, weeks were not investigated.

No information was found to indicate that a man should work more than 8 hours per day. Figure 2 shows the effects of two different length working days on average hourly production in metal-working plants (ref. (c)). As indicated by the graph, the 7 1/2 hour day is consistently superior to the 9 1/2 hour day.

1/ All references cited in this Appendix appear on p. D-14.

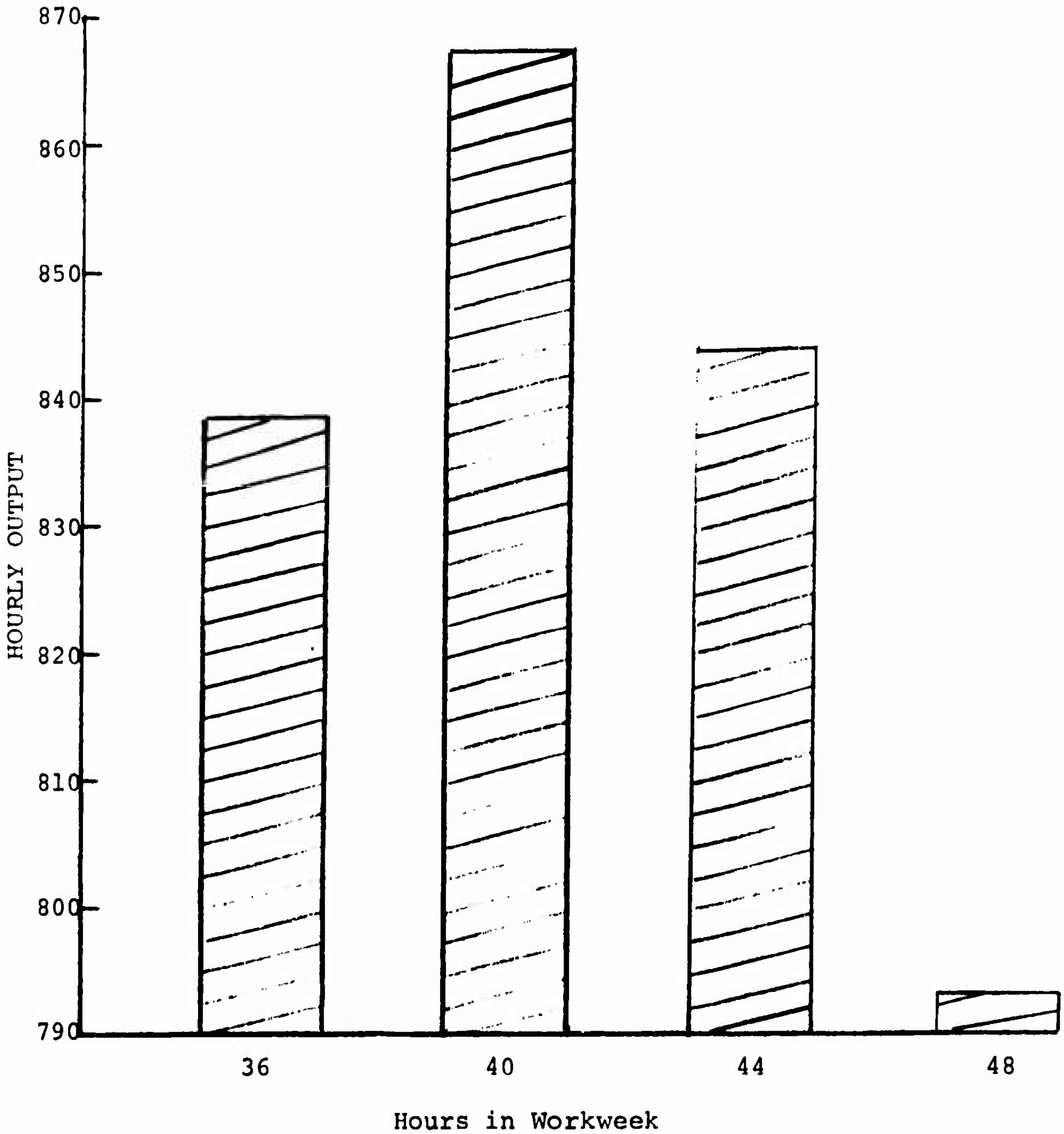

Figure 1: Production Output in Box Factory

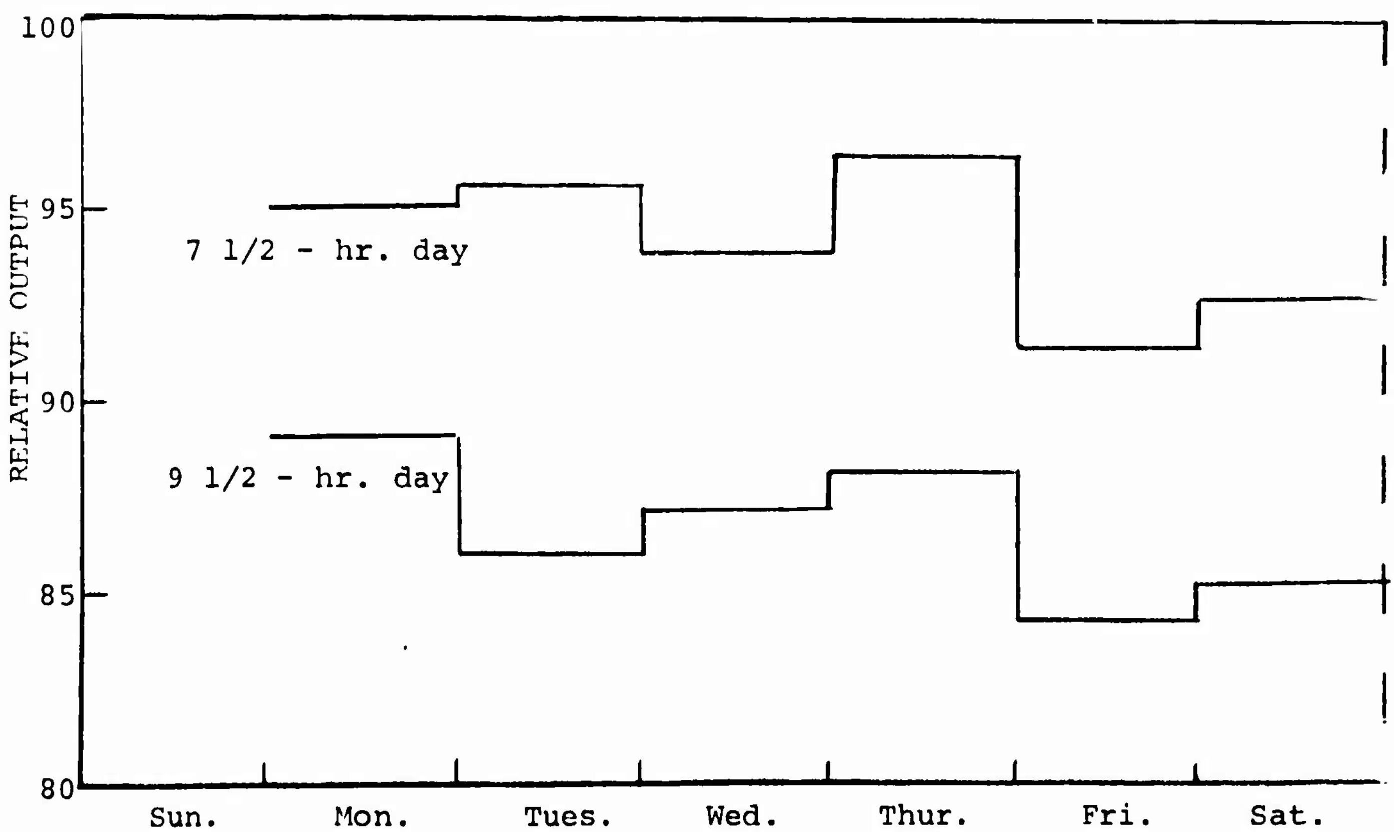

Figure 2: Comparison of Outputs from Different Length Workdays

Most studies of the effect of overtime on hourly production agree that production is lower both on the day on which the overtime occurs and on the following day. Kossoris (ref. (c)) states that "workers adjust themselves to longer hours by slowing down, not because they want to but because they have to."

III. Effects of Hours Worked on Total Output

If the production goal is to maximize total output from a given number of workers, then a longer workweek is required. According to Chapanis (ref. (a)), "to get the maximum work per week from each worker, a man on the average should work about 48 hours per week." Again the number of hours per week required to maximize total output will vary from plant to plant and from one type of work to another. In the absence of specific information as to the number of working hours required to maximize output, it appears that the 8-hour day and 48-hour week is the best choice.

In support of the 48-hour week, Kossoris (ref. (c)) states that the 5-day week and 8-hour day is more efficient on the whole than a work schedule of longer hours, but that there is little sacrifice in efficiency if a sixth day of 8 hours is added. The sharp break comes, according to Kossoris, when the daily hours are raised from 8 to 9 1/2, 10, or 11, or when the days per week are increased from 6 to 7.

IV. Effect of Number of Hours Worked on Absentee Rate

It frequently happens when the length of the workweek is increased above the standard 40 hours, the gain in total output is partially offset by an increase in absenteeism. Kossoris (ref. (c)) noted little difference in absenteeism between 5 and 6-day weeks as long as the daily hours were limited to 8. In a plant working a 6-day week, the absentee rate was nearly doubled when daily hours were raised to 9 1/2 and the 5-day week restored.

Blum (ref. (d)) indicates that the 8-hour day and the 6-day week will increase the absentee rate, although he does not present any data to support his position. He states that the "Increase in absenteeism with the 8-hour day and 6-day week is probably due to more a desire for leisure time or recreation than to an accumulation of physical fatigue."

V. Effect of Hours Worked on Accident Rate

A study by the U. S. Public Health Service (ref. (●)). indicates that accident rate is more sensitive to rate of production than to fatigue. Thus, workers who are required to speed up in order to increase total output would be expected to have more accidents than workers who are required to work longer hours to accomplish the same goal. However, fatigue does increase the accident rate. In the U. S. Public Health Service study, the effect of fatigue was obtained by dividing accident rate by rate of production to obtain accident per unit of production.

Table 1 lists the ratio of accidents to production for machine work in a munitions plant on a 10-hour day. As can be seen in the table, the accident rate per unit of production is the highest for the last hour of the day.

[illegible] shows the ratio of accidents to production in the same plant for dexterious hand work. Again an effect is evident. The accident rate per unit of production is much higher for the last hour of the day.

Table 3 shows the ratio of all plant accidents to production in an automobile plant working an 8-hour shift. The effect of fatigue is not evident for the last hour worked as is the case for the 10-hour plant. (table 4)

A number of years ago an analysis was made of records of industrial accidents from Germany, England, and the United States. Many of these data were obtained when 6 hours of consecutive work was common. Figure 3 shows the percent of all accidents plotted against successive hours of work. About 45 percent of all accidents occurred during the 5th and 6th hours.

VI. Effect of Number of Hours Worked on Frequency of Human Errors

Data concerning the effect of number of hours worked on the human error rate are not available. It is believed, however, that human errors stem from the same causes as accidents. Actually, many accidents result from human errors.

According to Chapanis (ref. (a)), an "effect of fatigue can be found by analyzing errors made in production over a period of time. Frequently the number of errors will increase, even though there has been no serious drop in the quantity of production. Such a rise in errors is an indication of fatigue just as much as does a drop in production."

TABLE 1

Ratio of Accidents to Production in Consecutive Working Hours, Ten Hour Plant, Machine Work

(Percentage Variation From Average Hourly Rate)

HOUR OF DAY

	1	2	3	4	5	6	7	8	9	10
Accidents (Relative to average of 100)	71.5	94.4	105.2	112.2	100.4	84.1	106.2	146.6	110.7	108.7
(Actual No. of accidents - 1916 & 1917)	346	457	409	543	486	407	514	516	536	526
Production (Relative to average of 100)	93.6	102.1	104.7	106.3	101.9	101.1	101.7	100.7	99.8	88.1
Ratio of Accidents to Production	76.4	92.5	100.5	105.6	98.5	83.2	104.4	105.9	110.9	123.4

TABLE 2

Ratio of Accidents and Production in Consecutive Working Hours, Ten Hour Plant, Dexterous Hand Work

(Percentage Variation From Average Hourly Rate)

HOUR OF DAY

	1	2	3	4	5	6	7	8	9	10
Accidents (Relative to average of 100)	72.4	95.2	106.9	120.7	94.5	80.7	116.6	102.1	100.0	113.8
(Actual No. of accidents - 1916 & 1917)	105	138	153	175	137	117	169	148	145	165
Production (Relative to average of loo)	96.7	106.4	107.6	106.1	99.5	99.3	101.6	99.1	96.6	84.1
Ratio of Accidents to Production	74.9	89.5	99.3	113.8	95.0	81.3	114.4	103.1	100.4	135.3

TABLE 3

Ratio of Accidents and Production in Consecutive Working Hours Eight Hour Plant Total

(Percentage Variation From Average Hourly Rate)

HOURS OF WORK

	1	2	3	4	5	6	7	8
Accidents	80.2	105.3	107.9	94.0	No Data	107.4	111.7	93.9
(Actual 3 months, all shifts)	1505	1988	2037	1774		2029	2109	1773
Production	95.5	102.6	103.5	100.5		100.3	100.2	95.3
Ratio of Accidents and Production	83.9	102.6	104.2	94.5	No Data	107.1	111.5	98.5

TABLE 4

Ratio of Accidents and Production in Consecutive Working Hours, Automobile Plant, Total

(Percentage Variation From Average Hourly Rate)

HOUR OF DAY

	1	2	3	4	5	6	7	8	9	10
Accidents (Relative to mean of 100)	76.4	99.0	112.9	116.1	86.5	91.9	105.9	107.4	106.3	97.8
(Actual No. of Accidents - 1916 & 1917)	785	1018	1161	1193	889	945	1089	1104	1093	1005
Production (Relative to Mean of 100)	98.5	106.1	106.6	106.6	99.3	102.9	102.2	99.3	98.0	80.3
Ratio of Accidents to Production	77.6	93.3	105.9	108.9	87.1	89.3	103.6	108.2	108.5	121.8

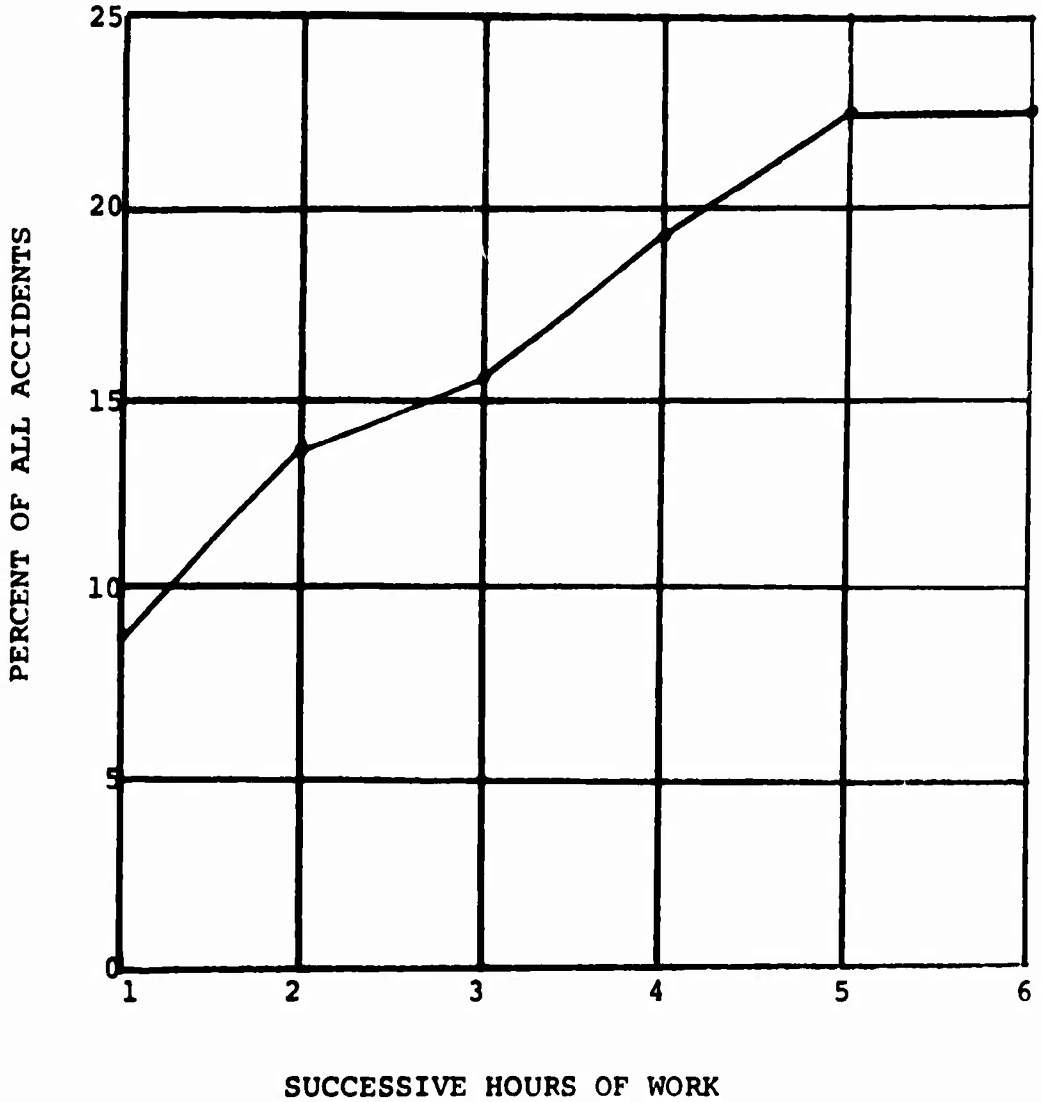

Figure 3: Effect of Hours of Work on Accident Rate

VII. Discussion

The data presented above indicates that up to a 48-hour week, the number of hours worked per day is a more important consideration than length of workweek. However, above 48 hours per week, total production output starts to decrease. The Navy workweek on board ship, as was indicated earlier, is considerably in excess of 48 hours. Therefore, it may be that something less than maximum output is being realized. Several factors must be considered, however, before one can conclude that this is the case. The work of a watch stander, for example, is far different in most cases from that of the production worker. The same is true of the work performed by the occupant of a service billet. It appears likely on the basis of the finding in Appendix B that personnel in these billets may have ample time to rest during the course of the work period. On the other hand it may be that something less than the maximum total output is being obtained from personnel in bulk task billets. It may well be that they are of necessity taking longer rest periods than would be the case with a shorter work day or week. If so, some increase of an as yet unknown amount in the NPTA may be necessary to compensate for the longer work day/week. Certainly, further research in this area is in order.

VIII. Conclusions and Recommendations

The number of hours a man should work per day or per week depends upon the production goal. If the goal is to maximize the output per hour, then an 8-hour day and 40-hour week combination is best. If the goal is to maximize total output, then an 8-hour day and 48-hour week combination is best.

Since in a shipboard context the goal is maximum total output, this latter combination is preferred over the shorter workweeks. Inasmuch as the workweek exceeds 8 hours per day and 48 hours per week, it is possible that a larger non-productive time allowance may be necessary. Additional research will be required to establish the optimum relationship among the parameters; workweek length, total work output and magnitude of the NPTA.

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Appendix E

DETAILED RESPONSES TO QUESTIONS POSED BY OP-01B(Z)

Reference (a)[1] listed a series of questions from OP-01B(Z) which have to do with the utilization and productivity of manpower aboard ship. A number of studies were conducted and reported earlier in order to respond to these questions. The questions and a summary of the responses developed in the various studies are outlined below.

Question (a): Are there variables associated with ship size, configuration, or age that can be isolated as contributing to the increase or decrease in human productivity? If so, derive and document their potential impact on Navy ships.

Response: Studies dealing with variables associated with ship size, configuration and age are reported in Appendices B, C and D. Variables affecting human productivity were found to include ship motion and ship size, length of the work day, length of the workweek, temperature, noise, etc. Ship motion causes additional fatigue above and beyond that resulting from the normal workload. When extremes of ship motion occur, all but essential work ceases. Lost time due to motion of the ship contributes to unavoidable delays and affects allowance requirements.

Ship size is a relevant variable primarily because of the relationship between ship motion and size of ship. The study reported in appendix B indicates that ships of the size of the smaller destroyers incur fatigue inducing motion about 85% of the time when they are at sea.

Length of the work day beyond 8 hours and length of the workweek beyond 48 hours were shown to decrease total output in production line work and to increase the accident rate. However, a survey of the factors affecting personnel retention and morale aboard ship failed to indicate that length of the work day or workweek as constituting a problem area. A possible explanation for this apparent inconsistency may be found in the type and degree of difficulty of shipboard work and in the level of motivation found aboard ship. It may be that

1/ All references cited in this Appendix appear on p. E-6.

the non-productive time allowances actually granted to shipboard personnel tend to compensate for the longer hours.

Appendix C shows that the more experienced and the career-oriented personnel tend to work the longer hours, so perhaps motivation is a factor.

Appendix C also indicates that Navy personnel in evaluating the adequacy of the quality of shipboard life tend to rate the newer ships well above those which are ten years or more older. One cannot determine on the basis of the available data, however, if the age of ship actually affects human productivity. The same is true of other variables covered in appendix C. Improvement in parameter values leading to higher quality of shipboard life is certainly in order. No evidence was available, however, to indicate that these variables have any meaningful quantitative effect on productivity.

Question (b): Are there variables that can be isolated and analyzed in terms of the environments that work is performed in and can these identified variables be determined so they apply to basic rating groups?

Response: Fourteen variables were identified and employed in the experimental methodology of Section VII to evaluate allowance requirements. The evaluation of fatigue allowance for the DD 938 using this methodology demonstrated that these variables can be isolated and applied to basic rating groups. The results of this application are discussed in Section VII and in Appendix C. It was indicated in Section VIII and in the conclusions stated in Section IX that the benefits to be obtained by employing this methodology as a management tool definitely exceed the costs that would be incurred in its refinement and validation.

Question (c): Can human effectiveness criteria be determined, at the work center level and on a variable basis, which are based on the work required? If so, what is the recommended approach for their derivation?

Response: The problems associated with the development of human effectiveness criteria are discussed in appendix A. It is pointed out that human effectiveness criteria are primarily relevant to the operational effectiveness of weapon systems, ships, etc. The development of such criteria to date has been accomplished primarily as a part of the equipment and ship development and deployment effort. Further work in this area is recommended only as part of a long-range human factors research program.

Criteria concerning the efficiency (as opposed to effectiveness) with which personnel are utilized needs further study. One of the Navy's major objectives is to meet required operational capabilities with minimum manpower. At present, criteria do not exist for accomplishing this objective. It appears, however, that it is not only feasible but essential that such criteria be developed.

Question (d): Are additional research efforts cost effective in terms of the potential pay-offs?

Response: It is recommended in Section X that priority be given to a research program to obtain second-generation improvements in the SMD methodology. Additional research is recommended to refine and validate the experimental methodology employed in the present study and to generate the data and procedures needed to more accurately assess delay allowance requirements. Costs of and benefits from the research programs are discussed in Section VIII.

Question (e): Can standard allowances used in industry be useful in validating or updating standard Navy allowances or are empirical studies required for validation? If so, identify their source, applicability, and usefulness in terms of updating current productivity allowances. If not, recommend approaches for empirical validation of the allowances.

Response: Standard allowances as used in industry generally are not applicable to Navy ships, primarily becuase of the more severe working environment found aboard ship. Further research was recommended earlier to refine and validate the experimental methodology. Problems and approaches associated with this recommended effort are discussed in Section VI.

Question (f): What are the potential long-range benefits (i.e., retention, morale, quality of work performed, etc.) that can be attributed to a study of the human factor allowances related to shipboard work?

Response: The investigation of variables affecting human productivity is reported in Appendices B, C and D. It was tentatively concluded on the basis of this investigation that the actual non-productive allowances shipboard personnel have been receiving are adequate, since no effect on retention and morale was found. Data used in arriving at this conclusion was obtained from reports of earlier surveys conducted by NPRDL. The fact that actual allowances received appear adequate does not mean that the constant 20% allowance is correct. If implies rather than an adequate number of billets have been provided in the past. However, as number of billets are reduced, an increased benefit from the correction of imbalances in the allocation of allowances should be realized.

Question (g): Should the name (currently Productivity Allowances) associated with human factors allowances be changed to a more appropriate term and/or should the allowances currently applied in the SMD methodology be included in a different method of application?

Response: The workday of shipboard personnel may be thought of as consisting of productive and non-productive components. Assuming a high degree of motivation, the non-productive component arises as the result of time required off for the satisfaction of personal needs, rest in order to recover from fatigue and unavoidable delays beyond the control of the worker. In industry, the allowance granted to cover such non-productive time is called a personal, fatigue and delay (PFD) allowance. If the only time granted off in a given plant is for personal needs, it may be referred to as a personal allowance. The Air Force normally grants time off only for personal needs and rest (time off for delays is granted only after rigorous justification), so they refer to it as a P&R allowance. If one has to refer to the time granted off without identifying the components, it appears that the only relevant generic term is non-productive time allowance (NPTA). It is recommended, therefore, that it be so designated.

Question (h): Are specific rating groups more inclined to have a sensitive relation to the human factor allowances and if so, what are they and does the fractional man concept reduce the necessity for study in other rating groups that are not sensitive to the allowance?

Response: It was pointed out in Section V that all personnel aboard ship receive an allowance in one form or another. This question is interpreted as referring to the allowance such personnel should receive without concern for the impact of the allowance on billet requirements. The answer is that certain rating groups require larger allowances than others because they work under more difficult environmental conditions, etc. The problem is explored for the DD 938 in Section VII. It is treated from a more general point of view in Appendix C.

The scope of the present study did not permit any conclusion to be drawn to the effect that given rating groups are not sensitive to the allowance. Further study along the lines recommended will be necessary to obtain an answer.

It does not appear that the fractional man concept affects the need for or the application of allowances.

Reference

a. CNO Ltr (OP-01BZ), Ser 11481, re: "Determination and Analysis of Productivity Allowance Factors Currently Used in SMD Program", 5 April 1972

APPENDIX F

List of Organizations Contacted or Visited

1. Eastman Kodak Corporation, Rochester, N. Y.

2. IBM Corporation, Manasas, Va.

3. Westinghouse Electric Corporation, Pittsburgh, Pa.

4. Defense Supply Agency, Washington, D. C.

5. G. A. Schwenk and Associates, (Incorporated) Charlotte, N. C.

6. Mitchel Feiu, Research Director, Handwork, Measurement Division, AIIE, Hillsdale, N. J.

7. Work Physiology Symposium, Ann Arbor, Michigan, 12-15 Sept 1972

Appendix G

SUMMARY OF OBSERVATIONS ON SHIPBOARD VISIT

During the visit to the U.S.S. Jonas Ingram (DD-938), working conditions were observed during Condition III readiness. Physical difficulty of the tasks performed and the environmental conditions were observed to the extent possible. Observations were recorded on work sheets for the 14 different environmental and work factors that were believed to have the greatest effect on fatigue. Each factor was quantified in discrete levels according to previously determined criteria. Observations were supplemented with discussions with various enlisted personnel. Information obtained and opinions expressed by enlisted personnel include the following:

1. There is some exposure to temperature extremes. This is primarily in the fire rooms and engine rooms, where temperatures are typically in the 100°F to 120°F range.

2. No billets were identified that required strenuous physical work for long periods of time. Short periods of considerable physical exertion were observed for a number of billets and were stated to be required for many others.

3. No billets exist specifically for the purpose of relieving watchstanders for brief periods of time. This function is typically performed by the supervisor, or another watchstander who is able to time-share both watchstanding tasks for a short time.

4. Few personnel are subjected to outside weather for extended periods of time. The personnel exposed to the weather are primarily watchstanders who do not receive a productivity allowance.

5. In many of the divisions the workload fluctuates widely. Consequently there are substantial periods of idle time interspersed with periods of peak activity.

6. Exposure to high noise levels (approximately 100 db) occurs in the fire rooms and the engine rooms. In both cases it occurs in conjunction with heat stress. However, there are few strenuous physical tasks performed in these compartments. In addition, since the vast majority of the tasks involve watchstanding, the magnitude of the allowance has little effect on the manpower requirements.

7. The 20% allowance appears to be excessive for many billets. The environment is often quite comfortable, the work often requires little exertion, and there are adequate lulls in activity to avoid fatigue.

8. There is relatively little repetition of activity for most billets. Thus, an assessment of the nature of the work of a given billet cannot be done accurately on the basis of a short period of observation.

9. A number of "service" billets can be identified. They are defined as billets which require the incumbent to be available for a specific set of duties, making him unavailable for reassignment to another task even during a temporary lull in his normal duties.

10. In several divisions over-staffing was acknowledged by the supervisors. This admission can presumably be taken at face value since there is no reason to claim a non-existant personnel surplus.

11. Several CPO's complained of personnel shortages. However, the brief observations made of the work activity in their divisions could not verify their contentions.

12. In the opinion of a large proportion of the enlisted men contacted, excessive emphasis was placed on facilities maintenance at the expense of corrective maintenance, preventive maintenance, and even watchstanding. This may have significant morale implications as well as manning effects.

13. Lack of spare parts was cited by one CPO as the greatest maintenance problem. Often for lack of a minor spare part, several hours need to be spent in fabricating it. Thus a potential surplus in manning can be turned into a deficit.

14. Preventive maintenance tasks are often postponed in favor of corrective maintenance and facilities maintenance, most frequently the latter.

15. There is conflict of opinion concerning the value of performing some of the preventive maintenance tasks. While some CPO's endorsed the practice of performing all the specified preventive maintenance tasks, others observed that in the process of checking various components, others are sometimes damaged, thus requiring corrective maintenance.

16. Only a few enlisted men worked under unfavorable lighting conditions, primarily in the sonar room and the CIC. However, since the tasks consisted almost entirely of watchstanding, this factor would have no impact on the productivity allowance.

17. No billets were identified that required prolonged working in an uncomfortable position.

18. No enlisted men complained of being over-worked or identified any others who were. However, several CPO's stated that during peak workloads some of the men were required to work considerably longer than scheduled.

19. The seas were not rough enough to cause any obvious impairment in the performance of the various tasks.

20. Since the Jonas Ingram is manned at the SMD level, unlike most other ships, the observations made on this ship may not be fully applicable to others. The ship visit was intended to assess conditions at full SMD manning.

21. It was not possible to specify a "typical" amount of time spent by watchstanders on other work. Some spent almost no time on this work except for some facilities maintenance prior to inspections. Others sometimes spent nearly as much time on maintenance tasks as on watchstanding.