ALRAND

REPORT 60

REPLACEMENT FACTORS FOR REPAIR PARTS

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REPLACEMENT FACTORS FOR REPAIR PARTS

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Submitted by: ______________________
J. K. LERCH
Operations Research Analyst

Approved by: ______________________
J. A. WHITE, Commander, SC, USN
Director, Operations Analysis Department

____
D. H. LYNESS, Captain, SC, USN
Commanding Officer, Navy Fleet Material
Support Office

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I. INTRODUCTION

Since 1963, FMSO (Fleet Material Support Office) has been developing replacement/usage factors for projecting repair parts requirements. The studies, under the guidance of NAVSUP (Naval Supply Systems Command) have progressed from the initial EDRFs (Experienced Demand Replacement Factors) based on system data of a single segment of the Navy Supply System, to EDRFs for several segments of the Navy Supply System, and currently to establishing usage rates based on data from the individual ship.

Originally repair parts projections were based on technical estimates of usage. Experience indicated that the technical replacement factors were characteristically conservative and resulted in the procurement of excessive repair parts. EDRFs were developed for use in follow-on provisioning and for developing specific fleet repair parts requirements. As the name indicates, experienced demand placed on the supply system and the total known installed population were used to arrive at a replacement factor per installed part for a specified time period. The computed values were usually less than the original estimated replacement factors and provided a means for selectively reducing support expenditures. Certain limitations were placed on the acceptance of the EDRF as explained in detail in a later chapter of this report.

Where no demand experience existed, the technical replacement factor was used as before. In the absence of sufficient demand experience, a composite factor was developed considering the experience available and the technical replacement factor. The result became known as the BRF (Best Replacement Factor), which is either an EDRF, a technical replacement factor or a combination of the two.

The MFRF (Mean Family Replacement Factor) is a statistical estimate of the usage rate for a repair part developed for use in initial provisioning. For items new to the supply system, an average replacement factor was computed based on demand experience for similar items operating under similar conditions. The result is considered to be the least accurate of the rates developed, but until further research provides a better way, the MFRF is much preferred to a guess.

The original EDRF was developed for SPCC (Ships Parts Control Center) based on system demand and the installed population as recorded in the technical files. It was recognized that even with absolutely accurate data the EDRF would be inflated to some extent. To improve the accuracy of the computed replacement factors, effort was made to gather repair parts requirements closer to the actual user.

Periodically ships are subjected to a supply overhaul as part of the SOAP (Supply Operations Assistance Program). Teams are assigned to assist the crew, and the actual usage of repair parts for known periods of time are recorded. The findings of these teams were used to compute usage rates. The impact of management policies on the completeness of SOAP data is discussed in a later chapter.

A third source of repair part usage is the 3M (Navy Maintenance and Material Management Program). The 3M Program promises to give the most accurate usage when completely implemented. At present, the reporting by fleet units varies as to accuracy and completeness and ashore usage reporting is still to be implemented. Eventually the reporting should become complete and the accuracy will improve. Then the person actually using the repair part will report usage to MSO (Maintenance Support Office) and demands will be shown in such a manner that usage rates can be developed by weapon system or by ship or by any desired category.

The Navy uses a unique means to inform the user of the inventory manager of the individual repair part. An alpha character prefaces the FSN (Federal Stock Number). This character is commonly called the cognizance (cog) symbol. Not only does the cog symbol indicate the inventory manager but also implies the type of material involved. For example, SPCC manages hull, mechanical, and electrical equipment for ships under the cog symbol "H". Electronics material managed by ESO (Electronics Supply Office) carries the cog symbol "N". A numeric symbol precedes the alpha character and for Navy managed material indicates the source of funding; 1H, for instance, is hull, mechanical, and electrical equipment supported by the Navy Stock Fund. Repair parts managed by DSA (Defense Supply Agency) use "9" as the numeric symbol. For example, 9N is electronics material managed by DSA.

One of the purposes of this report is to document the various studies made to date and to indicate current status of studies under way. The following table lists chronologically the various efforts in each cog.

Year	EDRF	BRF	MFRF
1963	H cog	H cog	
1964	H cog	H cog	H cog
1965	H cog A cog 1N-8N cog (30% sample) SOAP (190 ship sample)	H cog 1N-8N cog (30% sample)	H cog 1N-8N cog (30% sample)
1966	H cog A cog 1N-8N cog 9N cog	H cog A cog 1N-8N cog	H cog A cog 1N-8N cog (Revised)
1967	1N-8N cog 9N cog 3M (destroyer sample)	1N-8N cog (Revised) 9N cog	
1968	H cog (Revised) A cog (Revised) 3M (DSA items)	H cog A cog 3M (DSA items)	H cog A cog

Programs are currently operational for computing the EDRF and BRF for Navy managed items and for 9N cog material. Currently, emphasis is being placed in the development and refinement of the 3M usage rate, a rate based purely on ship usage, for all cog materials.

This report is presented in three major sections. The first section, Chapter II, contains a history of the different methods of computing replacement factors tried by the Operations Analysis Department, and the results of each. The next three chapters contain comparisons and evaluations of the three major demand feedback systems. The last chapter is devoted to recommendations for future research. The proposed studies are directed toward improvement of the usage factors by more precise methods of computation and application.

II. HISTORY OF NAVY REPLACEMENT FACTORS

A. Background.

All inventory control models currently being used within the Navy, initially determine the expected demand for a given time period, and then compute a stock level based on this mean but allowing for the variability in demand patterns. Demand forecasting (the method of determining expected demand) is probably the most important and most sensitive element in the computation of stock requirements.

The demand forecast at the ship and tender level is usually obtained by multiplying the item replacement factor, an estimate of the percent of installed population expected to fail in a given time period, by the item population. It is desirable, therefore, to attempt to improve the human estimate of the replacement factor, based on the judgment and experience of a provisioner, with the actual demand experienced by the item. The degree of improvement caused by the use of a demand based replacement factor rests on two factors:

1. Completeness and accuracy of the demand data. Although the demand data may not be 100% accurate, it must fall within an acceptable limit of error or the computed replacement factor will be as question-able as the human estimate.

2. Completeness and constancy of the population data. Population data is constantly changing as a result of component changes and ship alternations. However, the selection of a short time base will minimize the effect of the changing population. The more complete the population data, the more accurate will be the computed replacement

factor.

B. EDRF (Experienced Demand Replacement Factor).

An EDRF is a replacement factor based on actual demand over a specified time period. The term EDRF was originally applied to a replacement factor based on feedback from the transaction reporting system. However, it has since been extended to apply also to replacement factors based on SOAP or 3M. In this report, all replacement factors will be expressed as yearly rates for the sake of conformity.

1. System EDRF. A system EDRF is a replacement factor based on system demand as reported to an ICP (Inventory Control Point) through the transaction reporting system or as recorded through a DSC (Defense Supply Center) collection system. The first system EDRFs were computed in July 1963 for H cog items (hull, mechanical and electrical materials) by dividing the average demand for an item over a given time period by the item population.

$$\text{EDRF} = \frac{4 \text{ x demand over n quarters}}{\text{n x population}}$$

The basic concept for computing EDRFs is the same for all items. The problem in extending the concept to other types of material lies in obtaining good demand and population data. To date, EDRFs have been computed for all H cog items, A cog items (ordnance repair parts), and N cog items (electronics material).

The demand used in the computations includes only those issues made to fill demands expected to recur periodically for an indefinite period. These are referred to as replenishable demands, recurring demands, or random maintenance demands. Among issues not included are (1) cash sales other than recurring sales, (2) issues for new construction, conversion, alteration, initial outfitting and any other initial or one time issues, (3) issues to Government departments, except for normally recurring issues, and (4) issues to foreign governments, except for normally recurring issues.

The demand data for H cog and A cog material is obtained from SPCC. The time base n used in the computation is normally the past four quarters. However, if there was no demand in the past year, the demand history is searched back as far as 5 3/4 years (the maximum demand history maintained in the old SPCC Perpetual Inventory Record) until a quarter with demand is found. For example, if there was no demand in the past seven quarters, but demand was recorded eight quarters ago, an eight quarter base would be used in the computation. This scheme allows a longer base to be used for slow moving insurance items.

The demand data for electronics items managed by the Navy (1N-8N cog) is obtained from ESO, and covers the entire demand history available up to the seven quarter maximum history maintained by ESO.

The past year's demand history for electronics items managed by a DSC (9N cog) is obtained from the DESC (Defense Electronics Supply Center). The four quarter time base should provide adequate time for demand to develop as these items are mostly fast movers.

The population data used to compute the EDRF is the total applications of an item across all components across all ships in the active fleet and all shore bases (to the extent that the data is maintained by the ICPs). The population also includes applications on Navy aircraft, when applicable.

With the implementation of UICP (Uniform Inventory Control Point) programs, the ICP files containing the demand history were revised and thus system EDRF programs for Navy managed items were revised. In order to maintain reasonable computer time requirements in using the revised file structure, the new EDRF is based on a smoothed demand average rather than a simple average. The new system EDRF is computed by dividing the smoothed demand average by population

$$\text{EDRF} = \frac{4 \times \text{smoothed average quarterly demand}}{\text{population}}$$

The smoothed average quarterly demand is obtained by weighting the new quarterly demand observation with the previous average. The weighting factor varies according to item characteristics. Since the revised EDRF program is currently being implemented, the effects of this change have not yet been analyzed.

2. SOAP EDRF. System rates are computed for H, A, and N cog items only, as these are the only items for which system demand data is available. As rates are needed for items of all cogs, efforts were directed toward the use of SOAP data as a source of the demand quantity for the EDRF computation. The SOAP demand quantity covers ship usage since the last overhaul, for all items regardless of cog. This data is recorded by the SOAP team when a ship comes in for overhaul, and is forwarded to the SOAP central data processing center, NSC (Naval Supply Center) Oakland.

In February 1965, the first SOAP rates were computed based on data from a sample of 190 ships. The rate was computed by summing over all ships, the ship demand since the date of last overhaul divided by the time elapsed since the last overhaul divided by the ship population for the item. The demand figure in this case represented only ship usage. It did not include issues for any other purpose. Likewise, the population figure included population from only those ships for which usage data was available.

$$\text{EDRF} = \sum \frac{\text{ship usage over n years/n}}{\text{ship population}}$$

This rate is usually referred to as a usage rate rather than a replacement factor, emphasizing the fact that it is based on ship usage.

While SOAP data did provide the rates needed for DSC managed items, the computation was never extended beyond the sample and the rates were never updated because all efforts were directed toward the development of rates based on 3M usage data.

3. 3M EDRF. About the same time that the first SOAP rates were computed, a new program was implemented within the Navy - the 3M program. A portion of this program known as Shipboard MDCS (Maintenance Data Collection System) provides usage data for all cogs. Under the 3M system, the usage is further reported by equipment thus allowing rates to be computed by item by application. However, equipment application rates will not be computed until the quality of 3M usage reporting by equipment improves.

Initially the 3M EDRF was computed by summing over all ships on the 3M reporting system, the total ship usage to date divided by the length of time the ship was on the 3M system divided by the ship population for the item.

$$EDRF = \sum \frac{\text{total ship usage to date/time on system}}{\text{population}}$$

This allowed the full data base to be used in the computation by providing a means of phasing in ships new to the reporting system while at the same time using the entire usage history for ships which had been on the system for longer periods of time. With the complete implementation of 3M at the organization (ship) level, this is no longer a major problem. The 3M EDRF is now computed by dividing the total usage for a given time period for all ships on the 3M system by the item population on these same ships.

$$EDRF = \frac{\text{usage over n years}}{\text{n x population}}$$

Rates based on 3M data are also referred to as usage rates, rather than replacement factors, emphasizing the fact that the rates are based on usage.

C. BRF (Best Replacement Factor).

1. Computation. The different types of EDRFs discussed above are basically computed in the same manner - by dividing demand by population. The variation arises in the source of the demand data and the special routines required to most accurately match the demand data with the population that created the demand. It was earlier mentioned that the accuracy of the replacement factor depends on the completeness and accuracy of the demand data and the completeness and constancy of the

population data.

Early in the development of the EDRF it was learned that certain conditions produce replacement factors which are intuitively and statistically suspect. These conditions are (1) a very low item population and (2) a very short demand development period. It was attempted to develop a more reliable replacement factor for these items by weighting the EDRF with a technician's estimate of the item replacement factor (TRF). This new rate is known by several names - a weighted replacement factor, a Best f or a BRF. It is based on the assumption that the accuracy of an item EDRF as an estimate of the true item failure rate increases with time and population.

The first BRFs were computed at SPCC in October 1963, for H cog material. With the concurrence of SPCC technical personnel, it was assumed that full confidence in the EDRF is reached when an item has been on the stock list for four years or more <u>and</u> the item population is ten or greater. It was further assumed that no confidence exists in the EDRF for items that have been on the stock list for one year or less <u>or</u> have an item population of five or less. There is no theoretical or empirically derived basis for these numbers, but rather a general collective opinion of technical personnel.

Given these assumptions, a BRF is determined by computing a weighted average of the EDRF and the TRF where the weighting factor α is a function of age and population:

$$BRF = \alpha\ (EDRF) + (1-\alpha)\ (TRF)$$

The weighting factor α is also referred to as the confidence level.

It is composed of two separate elements - an age confidence α_a and a population confidence of α_p. The weighting factor for H cog items is determined as follows:

$$\left.\begin{array}{l}\text{age} \leq 1 \text{ year} \\ \quad \text{or} \\ \text{population} \leq 5\end{array}\right\} \alpha = 0$$

$$\left.\begin{array}{l}1 < \text{age} < 4 \\ \quad \text{or} \\ 5 < \text{population} < 10\end{array}\right\} \alpha = \sqrt{\alpha_a \alpha_p}$$

$$\left.\begin{array}{l}\text{age} \geq 4 \text{ years} \\ \quad \text{and} \\ \text{population} \geq 10\end{array}\right\} \alpha = 1.0$$

The age confidence for H cog items is computed such that an age of four years or more will yield full confidence ($\alpha_a = 1$) and an age of one year or less will yield no confidence ($\alpha_a = 0$).

$$\alpha_a = \frac{\text{age-1}}{4-1} = \frac{\text{age-1}}{3} \text{ where } 0 \leq \alpha_a \leq 1$$

The population confidence for H cog items is computed such that a population of 10 units or greater will yield full confidence ($\alpha_p = 1$) and a population of 5 units or less will yield no confidence ($\alpha_p = 0$).

$$\alpha_p = \frac{\text{population - 5}}{10-5} = \frac{\text{population - 5}}{5} \text{ where } 0 \leq \alpha_p \leq 1$$

In order to preclude the above computation, a table was built whereby knowing the item age and item population one could easily determine the confidence level α.

Recommended Values for α

age (yrs) \ population	≤ 5	6	7	8	9	≥ 10
≤ 1	0	0	0	0	0	0
1 - 2	0	.25	.35	.45	.50	.60
2 - 3	0	.35	.50	.60	.70	.80
> 3	0	.45	.60	.80	.90	1.00

The theory of BRFs has been extended to all rates based on system demand. In computing the BRF for different cogs, different limits may be used for full confidence and no confidence, but the logic remains the same.

In 1966, the first A cog item BRFs were computed using the same confidence limits as were used for H cog items.

The first item BRFs for 1N-8N cog items were also computed in 1966. The confidence limits remained the same for age, but with the concurrence of ESO and the Naval Supply Systems Command, the population full confidence limit was raised to 25. Thus,

$$\left.\begin{array}{l} \text{age} \leq 1 \text{ year} \\ \quad\text{or} \\ \text{population} \leq 5 \end{array}\right\} \alpha = 0$$

$$\left.\begin{array}{l} 1 < \text{age} < 4 \\ \quad\text{or} \\ 5 < \text{population} < 25 \end{array}\right\} \alpha = \sqrt{\alpha_a \alpha_p}$$

$$\left.\begin{array}{c}\text{age} \geq 4 \text{ years} \\ \text{and} \\ \text{population} \geq 25\end{array}\right\} \alpha = 1$$

Where

$$\alpha_a = \frac{\text{age}-1}{4-1} = \frac{\text{age}-1}{3}$$

$$\alpha_p = \frac{\text{population}-5}{25-5} = \frac{\text{population}-5}{20}$$

The concept was extended to 9N cog material in 1967. In this case, the item age is not known by the ICP, and thus the confidence level is based completely on item population.

population $\leq$ 5	$\alpha = 0$
5 < population < 25	$\alpha = \alpha_p$
population $\geq$ 25	$\alpha = 1$

Where

$$\alpha_p = \frac{\text{population} - 5}{20}$$

The basic concept of the BRF was recently extended to 3M rates, however the routine for determining confidence levels was revised. As in all the above computations a population of less than or equal to 5 or an age of less than or equal to 1 year yields a weighting factor α of Ø indicating no confidence in the item EDRF. In all remaining cases, regardless of age or population, the BRF is determined by weighting the EDRF with the BRF from the previous run, where the weighting factor α = .4.

$$\text{BRF} = \alpha\,(\text{EDRF}) + (1-\alpha)(\text{previous BRF})$$

As mentioned previously, the choice of age and population values yielding full confidence or no confidence was based on the collective opinion of technical personnel. Further research is being made in this area to determine the effects of changing these values.

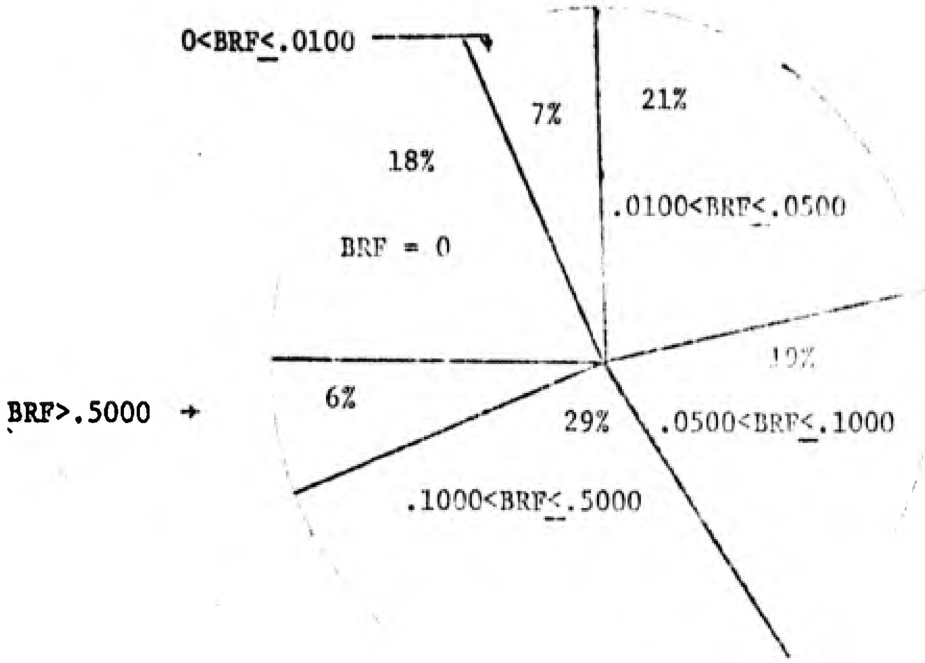
2. Frequency Distributions. A replacement factor expresses the expected number of failures per unit installed over a given time period, in this case, one year. Today's emphasis on equipment reliability (the probability that an equipment will perform its intended function for a specified period under stated conditions) attempts to keep item replacement factors to a minimum. The distributions of the most current BRFs for H cog, A cog, 1N-8N cog, and 9N cog are shown below. The table below offers a comparison among cogs while the pie charts on pages 16 and 17 show graphically the relative distribution of values for each cog.

Distribution of BRF Values

Range	H Cog	A Cog	1N-8N Cog	9N Cog
0	18%	34%	31%	28%
0 < BRF ≤ .01	7%	26%	34%	19%
.01 < BRF ≤ .05	21%	20%	20%	27%
.05 < BRF ≤ .10	19%	8%	8%	11%
.10 < BRF ≤ .50	29%	9%	5%	11%
.50 < BRF	6%	3%	2%	4%

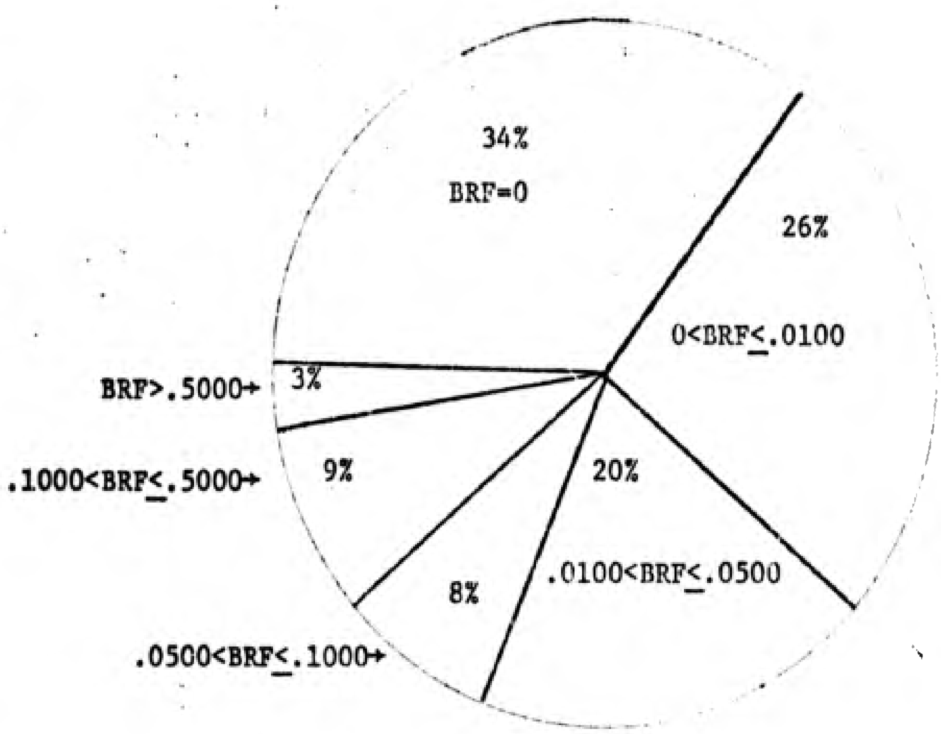
H Cog

(November 1966)



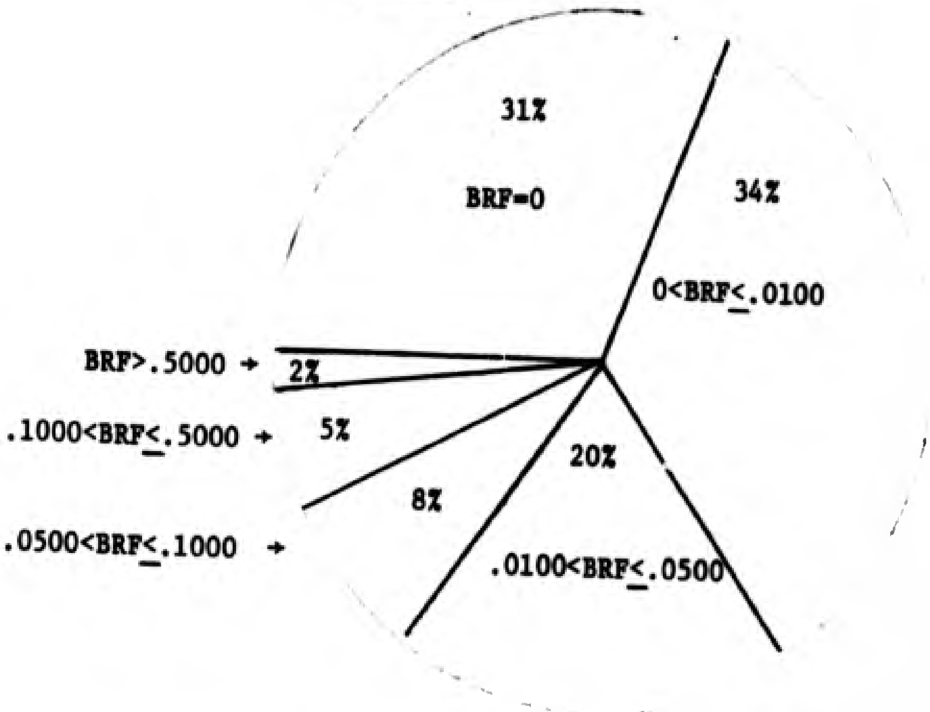
A Cog

(November 1966)



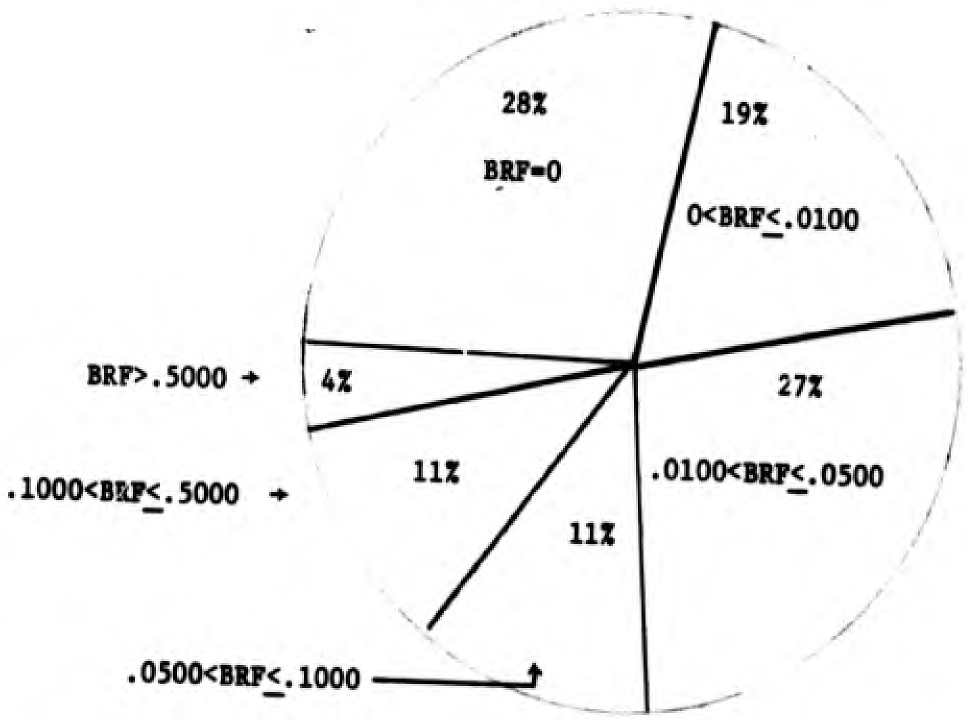
1N-8N Cog

(December 1967)



9N Cog

(December 1967)



D. MFRF (Mean Family Replacement Factor).

1. Introduction. All rates discussed so far have applied to repair parts already stocked in the system. However, there is an equal need for demand estimates for new items at the time of initial provisioning. New equipments are installed at a seemingly ever increasing rate in our modern Navy. These equipments tend to be more complex and more expensive. So too are the repair parts required to adequately support the equipments once they become operational. Personnel at the ICPs are faced with a difficult problem in making decisions on how much of which parts to procure initially. Demand history is nonexistent, and thus the initial stock levels are based on estimates. If the estimate is excessive, funds are invested needlessly and long supply is experienced. Quite possibly this material will become disposable excess. On the other hand, if the estimate is too conservative, the fleet will not receive adequate support in a timely manner. This will cause much effort in expediting actions and conceivably could adversely affect the successful completion of the ship's mission.

In order to provide better estimates for initial stock level determination, a replacement factor, the MFRF, was developed for families of similar items. This factor can be applied when provisioning consists of new items on new components similar in design or function to established items on established components. The MFRF is only a tool to give the provisioner a better picture of past demand experience. The demand estimate is still made by the provisioner.

2. Computation of MFRF. The major problem in computing an MFRF

is that of finding a meaningful method of grouping items. The first MFRFs were computed in 1964 for H cog items, grouping all established stock list items into families by noun name and further grouping them into subfamilies according to application as denoted by the first two digits of the CID (Component Identification Number).

Grouping items by noun name proved to be a frustrating task on the computer due to the nonstandardized nomenclature and format. Among the problems encountered were (1) various abbreviations for the same word and (2) various methods of separating the adjective modifier from the noun name.

A scheme was developed to eliminate unnecessary adjective modifiers from the item name. Using this scheme, the family name consists of all characters prior to the first number, positive sign, or negative sign. If such an indicator does not exist, the family name consists of all characters prior to the first comma or first space. The following examples illustrate how the scheme works.

Item Nomenclature	Family Name
valve+safetyrelief	valve
relaysubassy-trmlovld	relaysubassy
resistor50OHM	resistor
bearing conrod upr	bearing
lamp,indnt36AMP	lamp,icdnt
resistor adj 5000OHM	resistor adj

The above scheme does not solve the problem of abbreviations or of separating the noun name and adjective modifier when they are run together in the files or are separated by an x. For example, the following are several different families which should have been grouped into one family.

<u>Item Nomenclature</u>

coilxrelay coil relay coil rly	should be one family
plunger and barrel plunger x barrel	should be one family
pinion shaft pinion x shaft pinionxshaft	should be one family

Most of these problems were solved with the ICP adoption of standardized federal nomenclature as provided by the DLSC (Defense Logistics Support Center). However, further refinement in this area is still needed.

Once the families are established, the subfamilies for H cog items are created by sorting on the first two characters of the CID which uniquely define an equipment application as shown in APPENDIX A.

In 1965, the MFRF concept was extended to N cog material. Items were originally grouped into families by the ECC (Electronic Components Code). No further breakdown into subfamilies was possible, nor necessary.

The sixteen digit ECC has been used in various forms for over 15 years by the Navy, Army; Air Force, and Department of Defense. The present code was developed by ESO as an adaption of the Standard Commodities Index Code used by the Department of Commerce and the Bureau of the Census, which can be expanded to cover all commodities manufactured in the United States.

The ECC groups items according to the industrial practices required to make the items. The first six digits identify a basic classification within electronics. The remaining digits group items with similar physical and electrical characteristics such as physical makeup, power input, power output, etc., which would experience similar maintenance problems. The items do not necessarily have the same nomenclature; for instance, certain types of relays and contacts may have the same ECC.

An index to the codes used by ESO (first eleven digits) is included in APPENDIX B. Also included are several samples indicating the method for assigning the final five digits. The number of digits used for sorting into families can be limited by the user according to the degree of detail desired. Thirteen digits were used in the initial MFRF computation.

The ECC was manually assigned by ESO and maintained on card. As the coding was not used for any purpose other than MFRF, it was decided in late 1965 that the effort involved in assigning and maintaining the ECC was not justified, and the coding system was therefore discontinued.

In 1966 the N cog MFRF was computed based on the Item Name Code, which groups similar items based on DLSC nomenclature. This grouping provided broader families of items than that produced by the ECC, and the item BRFs did not tend to cluster as closely about the mean. It was also observed that the Item Name Code 77777, a code assigned whenever the correct code cannot be determined, was assigned to 35% of the items, thus producing one extremely large heterogeneous family.

The N cog MFRF based on Item Name Code proved unsatisfactory and further research is still required in this area. The ECC codings for 220,000 N cog items are still available if it should be decided to revert to the ECC codings.

In late 1966, the first MFRFs for A cog material were computed. The A cog MFRF is based on the same family and subfamily groupings as those used for H cog.

Having grouped similar items by some logical means, the MFRF is computed by averaging the BRFs for all items in the same group.

$$\text{MFRF} = \frac{\text{sum of item BRFs}}{\text{number of items}}$$

It has from time to time been suggested that the median (middle BRF) or mode (most frequent BRF) be used in place of the average BRF. The advantages and disadvantages of these proposals have not yet been studied.

3. Statistical Tests. Statistical methods can be used to determine confidence intervals for the MFRF. APPENDIX C describes the methods to determine the following:

a. How close the MFRF is to the unknown true mean replacement factor.

b. How constant the MFRF value is from one run to the next.

c. If the difference between the MFRF values from any two runs is significantly different.

d. The dispersion of item BRFs about the MFRF.

e. How constant the dispersion is from one run to the next.

f. If the difference in the dispersions from any two runs is significantly different.

Most of the tests described in APPENDIX C are dependent on either the existence of a large sample size (large number of items in the subfamily) or on the normality of the subfamily item BRFs. A sample study made on the MFRFs for H cog items revealed that the latter condition usually does not exist.

4. Normality of BRF Distribution. There is a tendency to claim that the BRF is an average, and therefore, by the Central Limit Theorem the BRF distribution is normal. Actual examination of the data, however, reveals that this is not always the case. In only one out of twenty-five SPCC subfamilies graphed was the distribution normal.

The BRF is a weighted average of the EDRF and the technician's estimate and, therefore, may be a pure average for some items, a pure replacement factor for other items, or a mixture of the two for still other items. The BRF distributions for five SPCC subfamilies are shown in APPENDIX D. The shaded areas represent those cases in which the BRF is not a pure EDRF. It is noted that even considering only items for which the BRF equals the EDRF, the distribution seldom approaches the normal.

5. Further Research. Many factors concerning the MFRF computation

require further research. To date, the major efforts have been directed toward improving the BRF with little or no emphasis on the MFRF. Several areas requiring improvement are:

a. The method of grouping items into families and/or subfamilies.

b. Determination of the BRF distribution of the subfamily.

c. The computation of the MFRF.

(1) Mean, mode, or median?

(2) Inclusion of all subfamily items, only the items with the BRF equal to the EDRF, or only the items where the BRF is other than a technician's estimate?

III. COMPARISON OF NAVY REPORTING SYSTEMS

A. Background. Replacement factors are required for computing all COSAL (Coordinated Shipboard Allowance List) quantities. They are also required when no ship demand history is available for the computation of tender and repair ship load list quantities, conventional submarine tender (AS) load list quantities, and Fleet Ballistic Missile submarine tender (AS FBM) load list quantities.

There are currently three systems collecting demand/usage data which can be used for computing replacement factors. These are:

. The ICP (Inventory Control Point)/DSC (Defense Supply Center) collection systems.

. SOAP (Supply Operations Assistance Program).

. 3M (Navy Maintenance and Material Management Program).

The basic concept in computing EDRFs, BRFs, and MFRFs may be applied regardless of the source of the demand data.

The following factors are considered in comparing the three systems:

. Reporting system.

. Response time.

. Completeness of reporting.

. Demand - population relationship.

. Cog coverage.

. Input error.

. Flexibility.

. Costs.

The use of a replacement factor based on one system as compared to any other system will probably have a small effect on COSAL quantities due to the low installed population on any given ship. However, the choice between the three alternatives will have a more significant effect on load list quantities which are designed to support the installed populations of many ships.

B. Reporting System. In comparing the three demand collection systems, one must first understand the basic operation of the systems and what types of demand are included in each.

1. System. System demands for Navy managed items are reported to the ICPs through the transaction reporting system or through the passing of a requisition to the ICP. System random maintenance demand, which is used for computing replacement factors, does not necessarily represent ship usage. This demand data may result from ship usage, shore base requirements, or additional stocking requirements at a resupply point. It also includes overhaul demands which were not anticipated early enough to establish a Planned Program Requirement and buy stock. All issues made by reporting activities are reported to the ICP through transaction item reports.

System demands for DSC managed items are reported to the DSCs by two methods: (1) if an issue is made by a wholesale activity, a transaction report is submitted to the appropriate DSC; (2) if an issue is made by a retail activity, no transaction report is submitted but demand is recorded when the retail activity submits a requisition for resupply of the item. Similar to Navy managed items, this demand data covers the entire Navy demand, not just ship usage.

2. SOAP. The SOAP program was implemented in 1958. When a ship comes in for overhaul, a SOAP team performs a complete inventory on equipment - related items and forwards inventory data and demand data as recorded in the ship stock record cards and DTO (direct turnover) requisition files to NSC Oakland. This demand data includes only ship usage. The SOAP usage data is maintained on magnetic tape by NSC Oakland. However, most data for ships overhauled prior to 1968 is no longer available.

3. 3M. In January 1965, the first Navy ships started reporting under the 3M system. Under this system each ship is required to submit weekly reports to MSO on all material usage for ship maintenance actions (other than material for routine preservation or daily or weekly Planned Maintenance Actions). Usage on a stock numbered item is reported on an F0 or F1 card. The basic source of data for the F series card is the DD 1348 (Single Line Item Requisition Document) for mechanized ships or the NAVSANDA Form 1250 (Single Line Item Consumption/ Management Document) for manual ships. Usage is also supposed to be supplied on the back of the OPNAV 4700-2 series form for all parts obtained outside normal supply channels. However, it appears that this data, if supplied by the maintenance man, is seldom key-punched into an F series card.

It is noted that the 3M demand data, like the SOAP data, includes only ship usage.

Based on the MSO structure file, the various Type Commanders

(Tycoms) phased into 3M reporting over varying time periods.

Tycom	Entry - 3M Reporting
Commander Cruiser Destroyer Force Atlantic	1/65 - 6/65
Commander Naval Air Force Atlantic	5/66*
Commander Submarine Force Atlantic	11/65 - 6/66
Commander Amphibious Force Atlantic	11/65 - 7/66
Commander Service Force Atlantic	11/65 - 7/66
Commander Mine Force Atlantic	10/65 - 7/66
Commander Cruiser Destroyer Force Pacific	1/65 - 11/65
Commander Naval Air Force Pacific	5/66*
Commander Submarine Force Pacific	11/65 - 3/66
Commander Amphibious Force Pacific	8/65 - 3/67
Commander Service Force Pacific	8/65 - 11/66
Commander Mine Force Pacific	8/65 - 3/67

The dates mentioned above cover the time period during which nearly all ships under the Tycom entered the 3M reporting system. Reporting is still weak in the areas of service forces, carriers, and amphibious units, especially in the Pacific. These represent the latest activities to enter the 3M system. Surface reporting appears to be covering nearly all ships with the exclusion of small craft and the above exceptions.

Although reports are being received from nearly every ship, it will take time until complete reporting is obtained. This became very

*3M reporting includes surface only; air reporting is not included above apparent in comparing two sets of usage data extracted for the CRUDESLANT (Cruiser-Destroyer Force Atlantic) destroyers. The first set of data, covering the time period from January 1965 through December 1965, contained 108,570 FO cards. The second set of data, covering the time period from September 1965 through August 1966, contained 238,075 FO cards.

C. Response Time. The response time is defined as the elapsed time between the issue of an item and the receipt of the demand for the item at the major collection point - an ICP or DSC for system demand data, NSC Oakland for SOAP data, or MSO for 3M data. Any advantages and/or disadvantages of a short response time are intuitive. No study has been made in this area.

1. System. It is difficult to determine the system response time as a ship demand may follow many paths before arriving at the ICP or DSC. A ship may or may not initiate a requisition at the time of usage. If a ship is at sea, it may be as long as thirty days before the requisition is passed. The requisition may go to a tender, a non-reporting activity or a reporting activity. If the requisition cannot be filled by the receiving activity, it will be forwarded to the next higher echelon of supply. When a requisition is filled by a tender or non-reporting activity, the transaction is not reported until the item hits its reorder point and is requested from a reporting activity. When a requisition for a Navy managed item is filled by a reporting activity, the transaction is immediately reported to the ICP. If the requisition cannot be filled by the reporting activity, the requisition will be

forwarded to the ICP.

When a requisition for a DSC managed item is filled by a wholesale activity such as NSC Oakland or NSC Norfolk, the transaction is immediately reported to the appropriate DSC. If the requisition for a DSC managed item is filled by a retail activity, no demand is recorded at the DSC until the activity submits a requisition for the item. It may be a matter of days, weeks, or months from the time an item is used on board ship until a corresponding demand arrives at the ICP or DSC.

2. SOAP. Since SOAP data is recorded at the time of overhaul and no usage data is reported between overhauls, the response time may vary from several days for one issue to several years for another. The length of time between overhauls is normally two to three years.

3. 3M. The average time interval between the time that an item is issued on a ship and the time that an F series card is received at MSO was computed from card submissions for 1 April 1965 through 30 November 1966.

5% of the issues of a given month are received the same month.

46% of the issues of a given month are received the following month.

29% of the issues of a given month are received 2 months later.

10% of the issues of a given month are received 3 months later.

5% of the issues of a given month are received 4 months later.

The remaining 5% of the issues of a given month trickle in during the next several months.

It is noted that 90% of the issues are reported to MSO within three months.

D. Completeness of Reporting. The differences in the type of demand received from each of the three systems was discussed earlier. In evaluating the three systems it is necessary to determine if there are further differences due to incomplete reporting on the part of one or more systems.

The 3M system, being the newest of the three systems, creates the most doubts concerning completeness of reporting. The implementation of 3M within the different Tycoms was discussed earlier. Reporting completeness is here discussed in terms of whether ships on the reporting systems are reporting all usage.

A study was made by MSO on all maintenance actions and all usage cards, other than pre-expended bin issues, received from the ships operating under the COMCRUDESLANT (Commander Cruiser Destroyer Force Atlantic) and from the ships operating under the COMCRUDESPAC (Commander Cruiser Destroyer Force Pacific) for the calendar year 1966. (COMCRUDESLANT and COMCRUDESPAC were the first two Tycoms to implement the 3M reporting system.)

The maintenance action reports were divided into the following four categories by matching the MCN (Maintenance Control Number) on the maintenance action against that on the usage cards.

1. Parts used and parts reported - Action Taken Code in the Maintenance Action Form indicates that parts were used in the maintenance action; usage cards were submitted for the action.

2. No parts used but parts reported - The Action Taken Code in

the Maintenance Action Form indicates that no parts were used in the maintenance action, but usage cards were submitted for the action. This condition is probably created by errors in recording the Action Taken Code, and the usage most likely represents valid ship usage.

3. No parts used and no parts reported - The Action Taken Code in the Maintenance Action Form indicates that no parts were used in the maintenance action; no usage cards were submitted for the action.

4. Parts used but no parts reported - The Action Taken Code in the Maintenance Action Form indicates that parts were used in the maintenance action, but no usage cards were submitted. This condition may have been caused by several different factors:

a. The Action Taken Code may have been incorrectly reported.

b. The parts used may have been pre-expended bin items which are not reported in connection with any given maintenance action.

c. The parts used may have been obtained from a "battle spares locker" or from sources outside the normal ship supply channels and not reported on the Maintenance Action Form, or if reported, not key-punched.

d. Usage cards may have been forwarded to MSO without the correct MCN, thus preventing a match to the maintenance action.

e. Parts usage may not have been reported to MSO.

All usage cards not matching a maintenance action were grouped together. These fall in two categories: (1) usage cards forwarded to

MSO without a MCN, thus preventing a match to a maintenance actions and (2) usage cards forwarded with a MCN for which the maintenance action was not reported.

The action breakdown for COMCRUDESLANT and COMCRUDESPAC is shown below:

Type Action	COMCRUDESLANT
Parts used/parts reported	118,558 (13%)
No parts used/parts reported	40,462 (5%)
No parts used/no parts reported	663,595 (75%)
Parts used/no parts reported	57,270 (7%)
Parts reported/no action	80,700

Type Action	COMCRUDESPAC
Parts used/parts reported	80,193 (13%)
No parts used/parts reported	26,681 (4%)
No parts used/no parts reported	479,061 (74%)
Parts used/no parts reported	57,267 (9%)
Parts reported/no action	71,080

The primary statistic of interest in determining the completeness of reporting is the category containing those actions reporting parts used but for which no parts were reported. Twenty percent (20%) of the COMCRUDESLANT actions indicated that parts were used; parts were reported for 13%, but not for the remaining 7%. Similarly, 22% of the COMCRUDESPAC actions indicated that parts were used; parts were reported for 13%, but not for the remaining 9%. The usage may actually have been reported for some of these actions by means of pre-expended bin issues or usage cards without a MCN.

It is further noted that in the cases where parts were reported used and usage cards were received, there is no guarantee that a usage card was received for every part used. Thus, it is difficult from this study to reach any firm decisions on the completeness of the 3M usage reporting.

In an attempt to obtain more concrete results, a detailed comparison of SOAP usage and 3M usage was made for several ships. This study is presented in Chapter V.

E. Demand - Population Relationship. In computing a replacement factor using either of the three data collection systems, demand is divided by the item installed population. It is,therefore, important that this population figure represent the population that created the demand.

1. System. At the time of computation, population data is extracted for all active ships. Population data for small craft and for many ESO shore base activities is not recorded in ICP files. The demand data, however, will reflect demands for these activities.

2. SOAP. Population data can be extracted from ICP population files or from the SHF (Ship History File) at the time of computation for all ships having undergone a SOAP within the time interval under consideration. Both population figures, however, reflect the ship configuration after overhaul and may or may not be the same as the population that created the demand.

3. 3M. At the time of computation, population data can be extracted from ICP population files for all ships reporting demand during the time interval under consideration. Demands reported by ships for which no population data is available can be dropped. Since the 3M response time is normally three months or less, it can be safely assumed that the population extracted from the ICP files is the same as the one that created the demand, unless the ship has undergone overhaul or major conversion within the past several months.

4. Population Files. There has been some question concerning the completeness of the population files being used. Seventeen percent (17%) of the H cog items have a population of zero; studies have shown that most of these items have no component application and are included in the COSAL as non-equipment related items or general use consumable items and included in the load lists on the basis of demand history. Fifty-seven percent (57%) of the A cog items have a population of zero. These items are mostly repair parts and miscellaneous parts for degaussing stations, mines, torpedoes, and guided missiles. These items have no ship population and are included in allowances and load lists, when applicable, by manually prepared supplements. Thus the inability to compute replacement factors for these items does not seriously affect the COSAL or load list.

Forty-nine percent (49%) of the 1N-8N cog items and 37% of the 9N cog items (electronics) have a zero population. No real study has been made to determine what type of items are involved; however, these items do not appear on ESO or SPCC APLs (Allowance Parts Lists). Why they are not on APLs is unknown.

In addition to the population voids, there is the problem of incomplete population data. These problems will affect rates computed under any system.

F. Cog Coverage. Since replacement factors are required for the production of allowance and load lists, it is important that rates be computed for most of the items that may appear on these lists. Figure 1 page 37, shows the range distribution by cog for several different load lists and COSALs. It is significant that DSA managed items account for 50 to 75% of the items.

1. System. Usage rates based on system demand are computed by several different programs. Rates for H, A, and 1N-8N cog items are based on system demand and population data from the three ICPs. Rates for 9N items are based on demand data from the Defense Electronics Supply Center and population data from the three ICPs. Programs have not been developed to compute replacement factors for the remaining cogs. For the sample load list and COSALs shown in Figure 1, page 37, the cogs for which replacement factors have not been computed under this system, represent from 18% to 49% of all items.

2. SOAP. Using SOAP usage data from NSC Oakland and population data from SPCC and ESO, usage rates can be computed for all cogs included in allowance or load lists.

3. 3M. Using 3M usage data from MSO and population data from SPCC and ESO, usage rates can be computed for all cogs included in allowance or load lists.

Figure 1: Range Distribution by Cog

	A Cog	H Cog	N Cog (excluding 9N)	9N Cog	DSA Cog (excluding 9N)	Other
AS(FBM) 33 Load List (4/66)	9%	26%	11%	16%	35%	3%
AS(FBM) 34 Load List (4/66)	8%	27%	11%	17%	35%	2%
AS 11 Load List (11/67)	3%	15%	4%	29%	49%	
AD 17 COSAL (7/66)	7%	16%	8%	40%	29%	
AO 63 COSAL (8/66)	1%	17%	8%	43%	31%	
CLG 8 COSAL (6/66)	6%	10%	14%	43%	27%	
DLG 14 COSAL (5/66)	7%	11%	9%	47%	25%	1%
SSBN 643 COSAL (2/66)	6%	27%	10%	39%	17%	1%
SSN 621 COSAL (8/66)	4%	21%	12%	44%	18%	1%

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G. Input Error. There are several input errors that may seriously affect the quality of the usage rates computed. These include quantity errors, FIIN (Federal Item Identification Number) errors, and unit of issue errors.

Once the demand data is received by the activity computing usage rates, there is no practical means of determining if the reported quantity is the quantity actually issued. What can be done in this area is to check for excessively large demand quantities or excessively small demand quantities. These checks should be included in any usage rate program.

The second type of error occurs where the reported FIIN cannot be identified to a FIIN currently recorded in ICP files. These may be old FIINs, keypunch errors, transposition errors, etc.

The third type of error occurs where the unit of issue reported in the demand data is not the same as the standard unit of issue at the ICP. Obviously the usage rate cannot be computed when the unit of issue reported is not compatible with that in the ICP files.

1. System. ICP system demands are recorded when a requisition for an item arrives at the ICP or when a Stock Point reports an issue. When a requisition arrives at the ICP, it is immediately matched to ICP files. If no match is found, it is matched against the old FIIN file. If the item still remains unidentified, it is forwarded to the technical division for further research. If the requisition has a high priority, it may be returned to the sender for correction. All unit of issue errors are corrected at the ICP before recording the

demand. When a Stock Point reports an issue, it is also updated to current FIIN and unit of issue, and an error report printed for all corrections. It is assumed that the reported unit of issue and quantity were compatible.

The procedures for updating DSC demands are unknown.

2. SOAP. As a result of requirements by other users of SOAP data, a procedure for correcting FIIN and unit of issue errors was developed within the SOAP program. During a ship overhaul, a SOAP team validates the ship inventory records for current FIINs and units of issue. Any FIINs or units of issue not matching those in the COSAL prepared by the ICPs are further researched. The extent to which unidentified FIINs are researched depends on the amount of time available before completion of overhaul. An attempt is made to validate every FIIN. When the SOAP data reaches the ICP, it is again matched to ICP files by FIIN and unit of issue. Any errors are printed out for technical review and correction. Only valid FIINs and units of issue are entered in the SHF.

3. 3M. To date there has been no validation on FIIN other than an error listing of FIINs on 3M input not matching FIINs in ICP files. There is no system established to research these FIINs, nor has there been any validation on units of issue. An initial attempt at FIIN and unit of issue validation is being incorporated into the 3M BRF computation scheduled for production in 1968.

H. Flexibility. There has been much discussion concerning the need for other than universe usage rates. Among the proposals considered are rates by application, by ship, or by fleet. Until recently, data was not available to compute these tailored rates, therefore, the merit of such rates in improving allowance or load lists is unknown.

1. System. Rates based on system demand may be computed only over the entire universe.

2. SOAP. Rates based on SOAP data can be computed by universe, by ship, or by any group of ships. Rates by application cannot be computed using this demand data.

3. 3M. Rates based on 3M data can be computed by universe, by applications, by ship, or by any group of ships. At the present time, CID reporting is not considered accurate enough to permit computing rates by application. The percent of 3M records having FIIN/applications matching FIIN/applications in ICP files is small. MSO is currently performing studies to determine the accuracy and completeness of CID reporting.

I. Costs. Any comparison of the three systems must consider the relative costs in manpower and machine time of each system. Since demand data is currently being collected under all three alternatives for uses other than usage rates, there will be no requirement for additional data storage space. Computer processing time will vary over the three systems mainly as a result of the amount of summarization already done by other activities. To date, no summarization is done on 3M data available from MSO. SOAP data, as stored in the ICP SHF, is summarized by NSC Oakland to an average yearly demand per ship. System demand data available from the ICPs is currently accumulated by total quarterly demand.

Under the ICP/DSC system, demand data is collected by each ICP and DSC. Each DSC has its own method of summarizing and maintaining this data, while the ICPs have another method, thus requiring many unique programs for computing replacement factors for items managed by different activities. Under the SOAP or the 3M system, all usage data is centrally collected and only one standard program is required for computing a replacement factor.

Computation of tailored rates by ship type or component application under SOAP or 3M will significantly increase computer time requirements. The increased requirements would lead us to consider computing tailored rates for only selected groups of ships or selected equipments.

As mentioned earlier, implementation of the 3M usage rates would also require that a system be established to research and validate unit of issue and FIIN errors. Such a system will definitely be required as other programs using 3M data are implemented.

IV. COMPARISON OF REPLACEMENT FACTORS

A. Background.

Thus far, the reporting systems and methods of computing rates from them have been discussed. The actual differences, however, are revealed by comparing the rates themselves. As there is no means of defining the "best" estimate of the true replacement factor, this study is limited to a comparison of the rates produced by the three systems and the differences between them.

As mentioned earlier, EDRFs have been computed based on data collected from each of the three reporting systems. However, each set of rates available at the time of this study was based on data covering different universes and different time periods. These differences may bias the data and thus create some difficulty in reaching firm conclusions.

The system rates available at the time of this study covered the following:

1. H cog and A cog items computed in November 1966 using demand data for the past year (or, in cases where there was no demand in the past year, as many as five and one-half years were searched until demand was found.)

2. 1N-8N cog items computed in June 1966 based on the past demand data available up to a maximum of six quarters.

3. 9N cog items computed in July 1966 using demand data for the time period from October 1964 through September 1965. An additional

bias on the high side exists within the 9N cog rates as the demand data includes the entire Navy demand while the population data includes only SPCC and ESO population. The Navy Aviation Supply Office (ASO) has a large number of 9N items for which they are a program support activity. 9N cog rates have been recomputed since the comparison study was made using recent demand data and population data from all three ICPs.

The available SOAP rates were based on data from 190 ships going through supply overhaul between December 1963 and September 1964, thus covering demands back as far as December 1961. The data received from NSC Oakland was the entire usage as reported in the ship stock record cards, not yearly averages as are currently being received. Data from approximately 25 other ships was not used because there were demands for fewer than 50 FIINs and it was felt that this was due to bad records. This also creates some doubt concerning the accuracy of the data that was accepted.

The 3M rates used were based on usage data from 105 destroyers operating under COMCRUDESLANT for the time period from September 1965 through August 1966. As the 3M system was still very new at this time, the completeness of the reporting may be questioned. Although the volume of monthly reports varied over the year by ship, the total monthly receipts from the COMCRUDESLANT destroyers were consistent.

The rates for all three systems were matched by FIIN to form three sets of data - system and 3M matches, SOAP and 3M matches, and system and SOAP matches. All matches with either rate equal to zero or greater than 25.0 were omitted. Random samples of approximately 1000 items were selected from the 9N cog matches and the H cog matches. The universe and sample sizes were as shown below:

Sample Size

	System/3M	SOAP/3M	System/SOAP
9N cog matches	7,060	875	1,736
9N cog sample size	986	828	847
H cog matches	4,787	2,097	10,086
H cog sample size	1,000	1,000	1,000

B. Relative Magnitude.

The rates in the system and 3M sample, the SOAP and 3M sample, and the system and SOAP sample were plotted for 9N cog and H cog as shown in APPENDIX E. The rates in each of the six samples were plotted on two separate graphs: one covering only those items with both rates less than .1, and the other covering all other items. It is obvious from the graphs that there is no mathematical relationship between any two sets of rates. A better picture of the size of the differences between the rates in any two systems is obtained from the frequency distributions below.

1. System and 3M Matches. Based on a knowledge of the reporting systems, one would expect system rates to be slightly higher than the 3M rates, since the system rates are based on total system demand while the 3M rates are based only on ship usage. The two samples supported

this belief as 85.4% of the 9N cog sample items and 77.2% of the H cog sample items had a higher system rate.

9N Cog

Difference (d_i)	System > 3M	3M > System	Total
$0 < d_i \leq .1$	54.7%	9.4%	64.1%
$.1 < d_i \leq 1.0$	27.3%	5.1%	32.4%
$1.0 < d_i \leq 10.0$	3.1%	.1%	3.2%
$10.0 < d_i \leq 25.00$	.3%		.3%
Total	85.4%	14.6%	100.0%

In addition to the above there were four items excluded from the original sample because the system rate was greater than 25.0.

The system and 3M rates for 9N cog items were reasonably close as evidenced by the fact that 64.1% of the differences were less than .1, and 96.5% were less than 1.0.

H Cog

Difference (d_i)	System > 3M	3M > System	Total
$0 < d_i \leq .1$	46.8%	14.7%	61.5%
$.1 < d_i \leq 1.0$	28.1%	7.1%	35.2%
$1.0 < d_i \leq 10.0$	2.0%	.9%	2.9%
$10.0 < d_i \leq 25.0$	.3%	.1%	.4%
Total	77.2%	22.8%	100.0%

There were no items in the H cog sample with either rate greater than 25.0.

Again, the rates were reasonably close as evidenced by the fact that 61.5% of the H cog differences were less than .1, and 96.7% were less than 1.0.

2. SOAP and 3M Matches. It was originally assumed that the SOAP usage and 3M usage would be very close. Contrary to this assumption only 36.4% of the 9N cog items had a rate difference of less than .1 and only 66.7% had a rate difference of less than 1.0. The two rates were closer in the H cog sample with 65.1% of the differences less than .1 and 97.2% of the differences less than 1.0. 6% of the 9N cog differences were greater than 10.0 while none of the H cog differences were greater than 10.0.

9N Cog

Difference (d_i)	SOAP > 3M	3M > SOAP	Total
$0 < d_i \leq .1$	20.1%	16.3%	36.4%
$.1 < d_i \leq 1.0$	26.8%	3.5%	30.3%
$1.0 < d_i \leq 10.0$	26.8%	.5%	27.3%
$10.0 < d_i \leq 25.0$	6.0%	———	6.0%
Total	79.7%	20.3%	100.0%

In addition to the above, there were 44 items dropped because of unusually high rates. Both rates were greater than 25.0 for three items, while only the SOAP rate was greater than 25.0 for the remaining

41 items.

H Cog

Difference (d_i)	SOAP > 3M	3M > SOAP	Total
$0 < d_i \leq .1$	39.1%	26.0%	65.1%
$.1 < d_i \leq 1.0$	20.0%	12.1%	32.1%
$1.0 < d_i \leq 10.0$	1.3%	1.5%	2.8%
$10.0 < d_i \leq 25.0$	___	___	___
Total	60.4%	39.6%	100.0%

There were no H cog items with either rate greater than 25.0.

All differences greater than 10.0 and most differences greater than 1.0 were caused by high SOAP rates. These high differences were most frequent in the 9N cog sample; 33.3% of the 9N cog sample had a rate difference of greater than 1.0, while only 2.8% of the H cog sample had a rate difference of greater than 1.0. The reasons for these large differences are not known. Several possibilities include incomplete 3M reporting, the age of the SOAP data, the different ship base used in each system, the demand-population problem in SOAP, etc. More recent comparisons between SOAP and 3M data for given ships over a given time period are presented in Chapter V.

3. System and SOAP Matches. As in the system and 3M match, system rates were expected to be consistently higher than SOAP rates since the ICP/DSC reporting system includes all Navy demand while SOAP includes only ship usage. This belief was not supported by the sample comparisons

as only 54.8% of the 9N cog sample and 60.6% of the H cog sample had higher system rates.

9N Cog

Difference (d_i)	System > SOAP	SOAP > System	Total
$0 < d_i \leq .1$	22.2%	8.1%	30.3%
$.1 < d_i \leq 1.0$	27.4%	18.3%	45.7%
$1.0 < d_i \leq 10.0$	5.0%	14.5%	19.5%
$10.0 < d_i \leq 25.0$	.2%	4.3%	4.5%
Total	54.8%	45.2%	100.0%

In addition to the above items, 37 items were dropped because at least one of the rates was greater than 25.0; both rates were greater than 25.0 for 35 of the items, only the system rate was high for one item, and only the SOAP rate was high for one item.

H Cog

Difference (d_i)	System > SOAP	SOAP > System	Total
$0 < d_i \leq .1$	33.4%	19.0%	52.4%
$.1 < d_i \leq 1.0$	24.5%	18.1%	42.6%
$1.0 < d_i \leq 10.0$	2.7%	2.3%	5.0%
$10.0 < d_i \leq 25.0$			
Total	60.6%	39.4%	100.0%

In addition to the above items, there were three items dropped from the sample because the SOAP rate was greater than 25.0.

Although the system rates were not consistently higher in either sample, the two rates in the H cog sample were reasonably close as evidenced by the fact that 95.0% of the differences were less than 1.0. Only 76.0% of the 9N cog differences were less than 1.0. As was noted in the SOAP and 3M comparison, the large differences were more frequent in the 9N cog sample. Once again, there is no known explanation for this situation.

4. <u>Summary</u>. The results of the three comparisons are summarized in the following chart.

Difference (d_i)	System/3M	SOAP/3M	System/SOAP
9N Cog			
$0 < d_i \leq .1$	64.1%	[illegible]4%	30.3%
$.1 < d_i \leq 1.0$	32.4%	30.3%	45.7%
$1.0 < d_i \leq 10.0$	3.2%	27.3%	19.5%
$10.0 < d_i \leq 25.0$	.3%	6.0%	4.5%
H Cog			
$0 < d_i \leq .1$	61.5%	65.1%	52.4%
$.1 < d_i \leq 1.0$	35.2%	32.1%	42.6%
$1.0 < d_i \leq 10.0$	2.9%	2.8%	5.0%
$10.0 < d_i \leq 25.0$	.4%		

It is noted that the two rates were reasonably close in every comparison for the H cog sample. However, for the 9N cog sample, only the system and 3M rates appeared reasonably close. The large differences in the other two 9N cog comparisons were usually caused by high SOAP rates.

C. Tests for Significant Difference.

1. Approach. Having reviewed the differences between the three systems, nonparametric tests were used to determine if the differences were significant. In applying these tests only two systems could be compared at a time. A new set of data was obtained by computing the algebraic difference of each sample data pair, i.e. given a sample pair (system EDRF, 3M EDRF) the difference d_i = system EDRF-3M EDRF was computed, and the nonparametric tests were applied to the new sample of d_i. The underlying mathematics of the sign test and the Wilcoxon signed-rank test may be found in APPENDIX F.

2. Sign Test. The objective of the sign test is to test the hypothesis that there is no significant difference between two samples of data. If this is true, the number of positive differences should not differ significantly from the number of negative differences. A significant difference between the number of positive and negative differences is determined by setting up a confidence band, dependent on a specified significance level, about the median frequency (the point at which there would be an equal number of positive and negative differences). (See APPENDIX F.) A significant difference exists if the number of times the less frequent sign occurs is less than the lower limit of the confidence band.

In applying the sign test to the 9N cog samples and H cog samples, a significance level of .01 was used. This significance level indicates that there will be only one chance in a hundred of concluding that a significant difference exists when in fact it does not. The results of the test were as follows:

Systems Compared	Sample Size	Median	Lower Limit	Observations of less Freq. Sign
System/3M				
9N Cog	986	493	452	144
H Cog	1000	500	458	228
SOAP/3M				
9N Cog	828	414	376	168
H Cog	1000	500	458	396
System/SOAP				
9N Cog	847	423	385	383
H Cog	1000	500	458	394

In each of the above cases, the number of times the less frequent sign occurred was less than the lower limit of the confidence band. It was, therefore, concluded in each case that a significant difference existed between the two sets of data.

3. Wilcoxon Signed-Rank Test. This procedure tests the same hypothesis as the sign test, however, this test is somewhat more sensitive as both the magnitude and the sign of the differences of pairs of rates are considered. The differences are sequenced low to high, without regard to sign; each difference is assigned a numeric value

(rank), starting with a value of one for the lowest difference. The rank is assigned the sign of the difference. It is assumed that if there is a significant difference between the sum of the positive ranks and the sum of the negative ranks, then there is a significant difference between the two sets of data.

A significant difference between the sum of the positive ranks and the sum of the negative ranks is determined by setting up a confidence band, dependent on a specified significance level, about the median sum of ranks (the value at which the sum of positive ranks and the sum of negative ranks are equal). (See APPENDIX F.) A significant difference exists if the smaller sum of ranks is less than the lower limit of the confidence band.

In applying the signed rank test to the 9N cog samples and H cog samples, a significance level of .01 was again used. The results of the test were as follows:

Systems Compared	Sample Size	Median	Lower Limit	Smaller Sum of Ranks
System/3M				
9N Cog	986	243,296	235,109	64,281
H Cog	1000	250,250	226,717	101,186
SOAP/3M				
9N Cog	828	171,603	162,736	32,130
H Cog	1000	250,250	226,717	193,513
System/SOAP				
9N Cog	847	179,564	161,222	156,054
H Cog	1000	250,250	226,717	220,259

In each of the above cases, the smaller sum of ranks was less than the lower limit of the confidence band. It was, therefore, concluded in each case that a significant difference existed between the two sets of data.

D. Summary.

The following conclusions were reached from this comparison study:

1. There was no mathematical relationship between any two sets of rates.

2. System rates were generally higher than 3M rates; the system rates and 3M rates were reasonably close in both samples.

3. SOAP rates and 3M rates were reasonably close with the SOAP rate high 60% of the time in the H cog sample; the rates were not so close in the 9N cog sample and the SOAP rate was high 80% of the time.

4. In the system and SOAP comparison, the system rate was high for 60% of the H cog sample and 55% of the 9N cog sample; the rates were reasonably close in the H cog sample but not in the 9N cog sample.

5. There was a significant difference between all three sets of rates.

While the system and 3M rates were close and the 3M rate was generally smaller as was expected, it has not been shown that the 3M rate was not too low. There till remains the possibility that 3M is not reporting a high percentage of ship usage.

In many cases the above results were not those expected. At the present time it is still difficult to determine whether the conclusions are valid or a result of the bias in the data. Many SOAP rates in the 9N cog sample were unusually high as compared to the other two systems. Several questions may be asked:

- Why are the SOAP rates unusually high only in the 9N cog sample?
- Are the SOAP rates the true rates, while the other two systems are low? This seems unlikely as it was previously stated that the 9N system rates are inflated due to the omission of ASO population.
- Is the high SOAP rate caused by bad usage data or bad population?

Another study was initiated to compare SOAP and 3M usage in an attempt at finding answers to some of the above questions. This study is presented in the following chapter.

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V. COMPARISON OF SOAP USAGE AND 3M USAGE

A. USS CORRY.

1. Background. SOAP usage and 3M usage were expected to be very close as both represent ship usage. Since the SOAP rate and 3M rate comparison did not support this belief, further study was initiated. The primary aim of this study was to determine how complete 3M reporting is. The SOAP usage data is not assumed to be perfect, but merely a measure for comparing the 3M usage data.

A detailed manual comparison of SOAP data and 3M data for the USS CORRY (DD-817) was made with the assistance of the Norfolk SOAP team and the ship's storekeepers to determine how closely the two sets of data matched. The data was compared over the time period from 15 July 1965 through 15 July 1967. During this time period, the USS CORRY operated 12 months in the Mediterranean and 12 months stateside.

All FIIN usage on the USS CORRY for the above time period was extracted by MSO. Since the SOAP data for the USS CORRY covered all usage from the date of last overhaul (April 1964) through 15 July 1967, the 3M usage was matched manually by FIIN and date to the ship stock record cards to which all DTO requisitions (other than requisitions for not carried items) had been posted. (The ship stock record cards and DTO file are the source for SOAP usage data.) The ship stock record cards were updated to latest FIIN, however, the 3M data was not updated. An attempt was made to check both old and new FIINs on all items marked on the stock record cards as stock number changes. A further attempt was made to insure that FIINs having high 3M usage but no stock record card were valid stock numbers. No validation was made on FIINs having a 3M usage of one or two units but no stock record card.

2. Results. During the course of the study, several causes of discrepancy were discovered. These were in the area of tender issues, not carried items, and losses by inventory.

Tender issues for material required to complete a repair action for a ship are recorded in 3M under the ship accounting number of the ship for which the repair work was done. The ship accounting number of the tender is recorded as the repair activity, however, this data element is not punched on the FO (FIIN usage) card. The 3M usage for a given ship, therefore, includes all tender issues in support of the ship, while the SOAP data for the same ship does not include these issues because they are not ship issues.

On the other hand, the SOAP usage for tenders includes these issues while the 3M data does not. Thus the usage is reported by both systems but at different times and by different ships. Under the 3M system, the usage is assigned to the ship that created the demand and, therefore, may more accurately be matched with ship population.

A "not carried" item is defined as an item not allowed by the ship COSAL, load list, or by SIM (Selective Management Item) criteria. According to SIM criteria, an item may become allowed on the basis of past demand if the item has had at least two hits within six months. Usage for "not carried" items should be reported under the 3M system. These demands should also be recorded in the ship historical demand file (or some other DTO requisition file) and should be included in SOAP usage. The Norfolk SOAP team, however, does not include usage for "not carried" items, as this usage will not produce a change to the range of items allowed by the COSAL.

If the ship stock record cards are very poor, the loss by inventory quantity may be added to the actual issues to compute the SOAP usage quantity. In some cases the loss by inventory may actually reflect issues that were never recorded while in other cases it may actually reflect a loss. In the former case, the usage should also appear in the 3M data, while in the latter case it should not. Whether or not a loss by inventory quantity will be counted as usage is dependent on the condition of the ship stock record cards and the policy of the team performing the SOAP.

The 3M data and/or the SOAP data as recorded in the ship stock record cards reported usage by the USS CORRY on approximately 2700 different FIINs. Usage was reported by 3M on 92.4% of the items including 38.0% which were not reported by SOAP. Only 7.6% were reported by SOAP but not by 3M. The items not reported by both systems were grouped into the following categories:

SOAP usage only

3M usage only - tender issue

3M usage only - not carried item

3M usage only - non-COSAL/SIM item

3M usage only - COSAL item

3M usage only - other

The above breakdown for FIINs with only 3M usage was made on the basis of the source code recorded in the FO card. The accuracy of source coding is not known.

A tender issue cannot be uniquely identified from the FO card. The following source codes were assumed, for purposes of this study, to indicate a tender issue:

B - load list material issued from storeroom stock.

E - Load list material not in stock (NIS) when requested.

3 - Parts used were manufactured by a tender or another activity.

4 - Parts or material used was drawn from pre-expended materials in the ship.

A not carried (NC) item was defined as any item source coded G (NC material requisitioned or purchased).

A non-COSAL/SIM item is an item not allowed by the ship COSAL but stocked on board as a SIM item on the basis of past demand. These were defined by the following source codes:

C - Material stocked on board because of demand/usage (not on allowance list or load list) and issued from storeroom stock.

F - Material stocked on board by demand/usage which was NIS when requested.

A COSAL item is defined as any item allowed by the ship COSAL. The following codes were assumed to indicate a COSAL item:

A - Allowance list material issued from storeroom stock.

D - Allowance material NIS when requested.

All items having no source codes, or having conflicting source codes on different issues were grouped together with the items not falling in one of the above categories. It is possible that some of these items belong in one of the other categories.

The 3M usage and SOAP usage on the USS CORRY compared as follows:

FIIN match -equal quantities*		47.8%
FIIN match - unequal quantities		6.6%
FIINs with 3M usage only		38.0%
Tender issues	6.8%	
Not carried item	20.4%	
Non-COSAL/SIM item	2.6%	
COSAL item	6.6%	
Other	1.6%	
FIINs with SOAP usage only		7.6%
Quantity = 1	4.4%	
Quantity = 2	1.3%	
Quantity > 2	1.9%	
Total (2706 FIINs)		100.0%

As noted above, 54.4% of the items appeared in both reporting systems, while 38.0% appeared in only the 3M usage and 7.6% appeared in only the SOAP usage. Of the 38.0% appearing only in the 3M system,

*As this comparison was made manually, high usage items were usually considered equal if the quantities were within several uni of each other.

27.2% represented ten[illegible] issues and not carried items which were not included in the SOAP data because of a policy decision. No explanation was found for the remaining 10.8% of the items that appeared only in the 3M system, or for the 7.6% of the items that appeared only in the SOAP system.

In addition there was undoubtedly a certain amount of material used from "battle spares lockers" which was not reported under either system.

SOAP personnel felt that the USS CORRY's stock records were unusually complete and, therefore, the SOAP usage was more accurate than might be representative of the fleet. On the other hand, MSO personnel noted the USS CORRY was also one of the "better" reporting ships in the 3M system and again might not be representative of the remainder of the fleet. The study was, therefore, extended to four other ships, two operating in CRUDESLANT and two operating in CRUDESPAC, to determine if the high level of 3M reporting attained by the USS CORRY was representative of the fleet.

B. <u>Four Ship Comparison</u>.

1. <u>Background</u>. The four ships considered in this study were the USS SPRINGFIELD (CLG-7), the USS E. A. GREENE (DD-711), the USS HIGBEE (DD-806), and the USS DALE (DLG-19). The time frame covered by both the SOAP usage data and the 3M usage data was from March 1965 to March 1967 for all ships except the USS HIGBEE which covered from February 1965 to February 1967. The ships were operating in the following areas during this time period:

USS SPRINGFIELD - 24 months in the Mediterranean.

USS E. A. GREENE - 9 months in the Seventh Fleet, 3 months in North Europe, 1 month in the Caribbean, and 11 months stateside.

USS HIGBEE - 24 months in Seventh Fleet.

USS DALE - 11 months in the Seventh Fleet, 13 months stateside.

The above ships went through overhaul at different shipyards thus providing a check against drawing conclusions based on the policy of one SOAP team. The USS SPRINGFIELD was overhauled at the Boston Naval Shipyard, the USS E. A. GREENE at the Norfolk Naval Shipyard, the USS HIGBEE at the Mare Island Division of the San Francisco Bay Naval Shipyard, and the USS DALE at the Long Beach Naval Shipyard.

The usage data compared consisted of SOAP data as forwarded to NSC Oakland in the Master J-48 card and 3M FIIN usage as forwarded to MSO in the F0 or F1 card. Both sets of data were updated to latest stock number.

The original comparison was made by computer and separated the items into the following categories:

a. FIIN and usage quantity match.

b. FIIN match and usage quantity in range - The quantities were considered in range if the lower quantity was from six to ten and the other quantity was within one unit, if the lower quantity was from 11 to 30 and the other quantity was within two units, if the lower quantity was from 31 to 50 and the other quantity was within five units, or if the lower quantity was greater than 50, and the other quantity was within ten units.

c. FIIN match, 3M usage quantity high.

d. FIIN match, SOAP usage quantity high.

e. 3M usage only, tender issue - A tender issue was identified by matching the maintenance control number on the usage card with that on the maintenance action card which identifies the repair activity. If the repair activity was other than the ship itself, the usage was considered as a tender issue. Only those items for which all issues were tender issues were included in this category.

f. 3M usage only, other - this category includes all 3M only items that were not entirely tender issues.

g. SOAP usage only.

The results are shown in Figure 2, page 63. Statistics for the USS CORRY are also included for comparison purposes.

From Figure 2, the percent of items with a FIIN match and an exact quantity match or with quantities within range varied from 28% to 36% across the four ships. Approximately 48% of the items used by the USS CORRY fell in this category, thus supporting the belief that this ship was exceptionally accurate in maintaining stock records and in 3M reporting. The percent of items reported by both SOAP and 3M but with quantities not within the acceptable range varied from 6% to 8% across all five ships.

The bar charts below show the percentage breakdown of the items used by each ship. The open area represents the FIIN matches, the striped area represents the FIINs reported only by 3M, and the

Figure 2: 3M Usage Comparison

	CRUDESLANT			CRUDESPAC	
	CORRY DD-817	SPRINGFIELD CLG-7	E. A. GREENE[1] DD-711	HIGBEE DD-806	DALE DLG-19
FIIN match	54.4%	33.4%	34.1%	39.3%	44.4%
quantity match	47.8%	16.8%	16.8%	17.5%	21.0%
quantity in range		10.7%	11.1%	13.4%	15.2%
3M high	6.6%	3.0%	1.1%	1.0%	1.9%
SOAP high		2.9%	5.1%	7.4%	6.3%
3M only	38.0%	59.4%	43.1%	21.0%	14.5%
tender issue[2]	6.8%		11.7%	3.0%	1.3%
not carried	20.4%		10.9%	7.0%	4.7%
non-COSAL/SIM	2.6%		1.8%	.3%	.5%
COSAL	6.6%		10.5%	3.2%	5.9%
Other	1.6%		8.2%	7.5%	2.1%
SOAP only	7.6%	7.2%	22.8%	39.7%	41.1%
allowed items		4.6%		28.4%	
not carried		2.3%		8.8%	
Other		.3%		2.5%	
TOTAL	2706 FIINs = 100%	6516 FIINs = 100%	2859 FIINs=100%	2770 FIINs = 100%	5120 FIINs = 100%

[1]Although the USS E. A. GREENE is listed under CRUDESLANT, it spent 9 months within CRUDESPAC.

[2]Tender issues above are as determined by source code. If defined as in the computer run, tender issues represent .9% of the USS SPRINGFIELD items, 11.7% of the USS E. A. GREENE items, 3.7% of the USS HIGBEE items and 1.0% of the USS DALE items.

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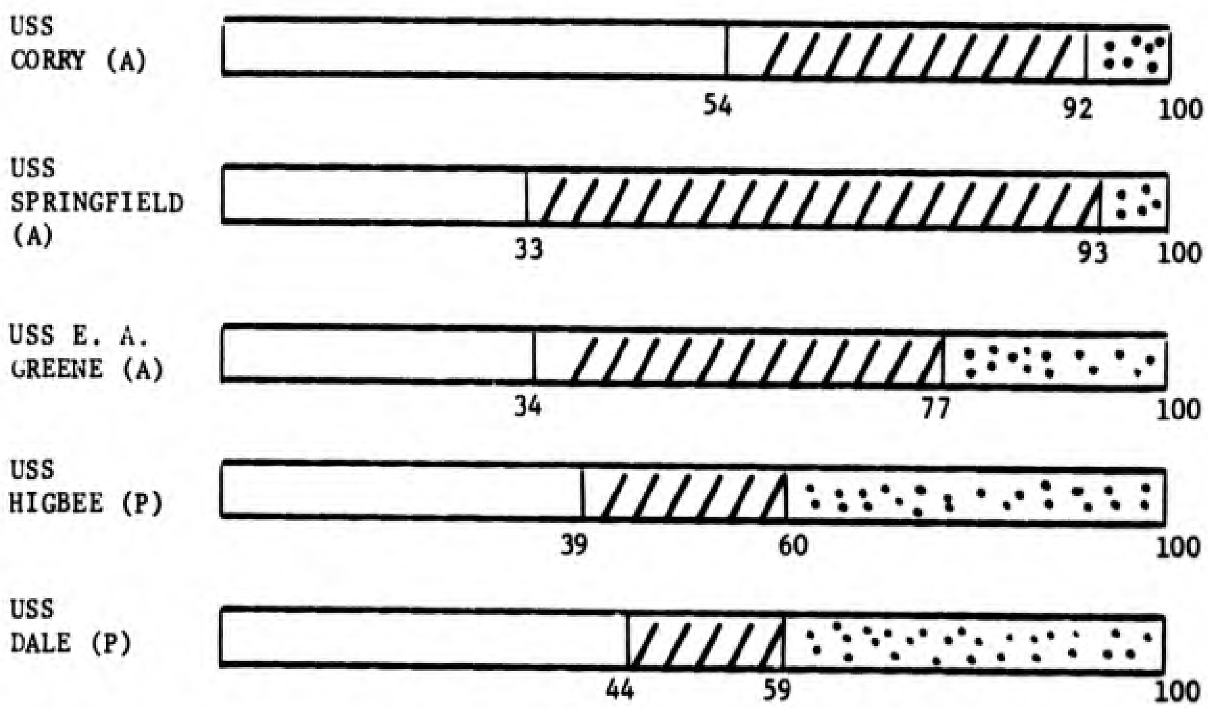
dotted area represents the FIINs reported only by SOAP.



As noted above, the percentage of items reported by the 3M system (both with and without matching SOAP reports) varied from 59% for the USS DALE up to 93% for the USS SPRINGFIELD. It is within the area of items reported by only one system that the major differences across ships appeared. The three ships in the Atlantic (A) recorded usage in the 3M system only on a high percentage of items, while the two ships in the Pacific (P) recorded usage in the SOAP system for only a high percentage of items.

As all five ships have been reporting under 3M since early 1965, it appears that 3M reporting from ships in the Pacific (Seventh Fleet) is not as complete as the reporting from ships in the Atlantic. It is further noted that the USS E. A. GREENE, which spent nine months in the Seventh Fleet had a higher percentage of SOAP only items than did either of the other two ships operating in the Atlantic.

The SOAP only items were further studied to determine if there were any common characteristics across these items. The items were separated by A/T (Allowance Type) Code into three categories:

a. Allowed items - A/T Code 1.

b. Not carried items A/T Code 4 or 8.

c. Other - A/T Code blank.

The results, shown in Figure 2, page 63, did not prove anything significant.

A manual review of the SOAP only items on the five ships revealed that the majority of the items were repair parts with a few consumable type materials scattered in. The one exception was the USS HIGBEE which contained a relatively high number of SOAP records for consumables such as mattress covers, marking ink, paper, etc. These were eliminated from the total in order to keep a valid comparison across the five ships.

No common characteristics of SOAP only items were uncovered nor was an explanation, other than incomplete 3M reporting, found for these items.

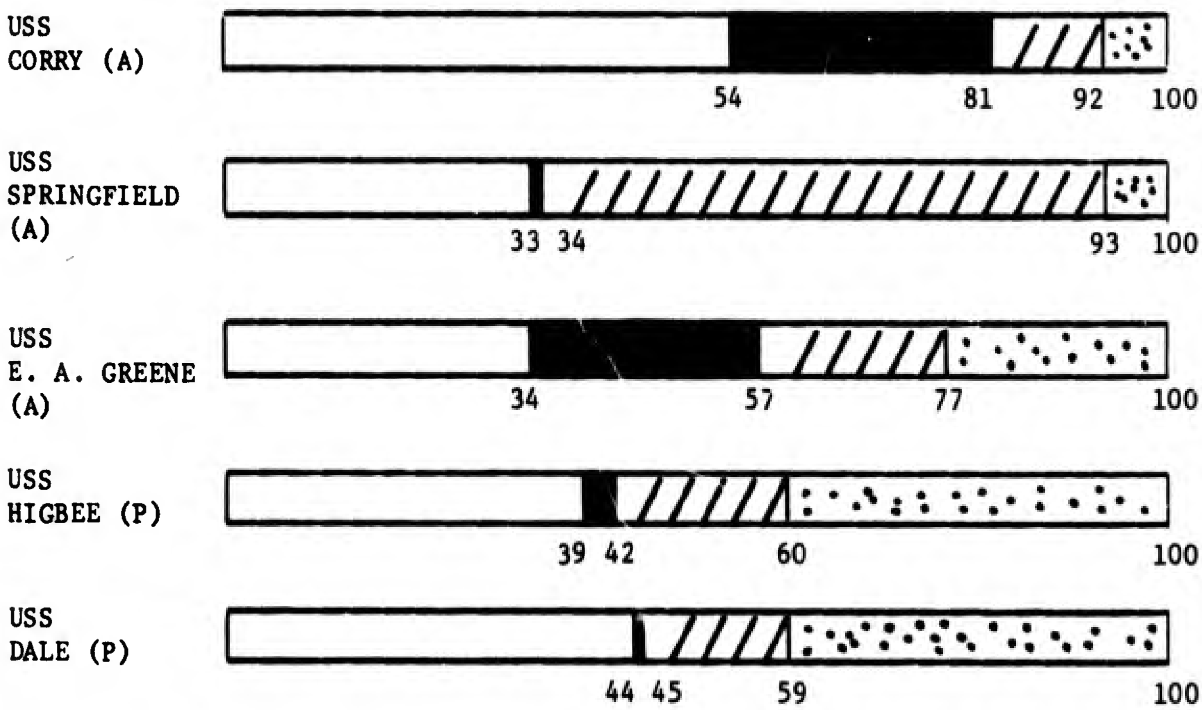
While the 3M only items represent an improvement over SOAP usage reporting, these items were also broken down into several categories to determine how many items were reported only by 3M because of SOAP policy and how many represented apparent voids in the SOAP data. These items were separated by source code, as defined earlier, into five groups - tender issues, not carried items, non-COSAL/SIM items, COSAL items and other. These results are also shown in Figure 2, page 63. It is noted that tender issues as defined earlier in the machine run and tender issues as defined by the source code are close although they are not equal.

As mentioned previously, an item used by a tender in repair of another vessel is reported as ship usage in the 3M data, but reported as tender usage in the SOAP data. The 3M only items for a given ship representing tender issues are, therefore, excluded from SOAP by policy and not because of poor reporting.

It was also noted earlier that the Norfolk SOAP team does not include not carried items as defined earlier in the SOAP data. The 3M usage on not carried items on the USS CORRY and the USS E. A. GREENE, which were overhauled at the Norfolk Naval Shipyard, did not match the SOAP usage because of this policy. The remaining SOAP teams involved in this study do not follow this policy. Thus, the not carried items on the remaining three ships (a smaller percentage than on the USS CORRY or the USS E. A. GREENE) which did not match SOAP records cannot be explained by this policy.

The bar charts below again show the percentage breakdown of the items used by each ship, but this time the 3M only items are subdivided to show those which are due to SOAP policy and those which are apparently due to incomplete SOAP usage data.

The FIIN matches are represented by the open area, the items reported only by 3M due to SOAP policy are represented by the shaded area, the items reported only by 3M apparently due to incomplete SOAP reporting are represented by the striped area, and the items reported only by SOAP apparently due to incomplete 3M reporting are represented by the dotted area.



It may be concluded from this study that the completeness of 3M reporting varies greatly by ocean, with a higher level of reporting from the ships operating in the Atlantic and a lower level of reporting from ships operating in the Pacific. Any immediate application of 3M usage data for computing usage rates must, therefore, be preceded by a careful selection of the ships to be included. Only ships with a high level of reporting should be included.

VI. RECOMMENDATIONS FOR FURTHER RESEARCH

The previous chapters have recorded the progress made by the Navy in the development of replacement factors for repair parts. Although significant progress has been made, there are still several areas deserving further research.

The revised program for computing the EDRF within UICP programs, is currently being implemented. As the EDRF has been changed from a raw average to a smoothed average, a detailed comparison and evaluation study should be made on the EDRF as computed by the two methods.

The confidence limits (weighting factors) used in the computation of the BRF are based on a general collective opinion of technical personnel. The effects of varying these limits are not yet known, although studies are currently being made in this area.

Of all the replacement factors discussed, the least effort has been directed toward the improvement of the MFRF. The major problem in computing the MFRF lies in determining families of items. Although notable progress has been made, further refinement in grouping items could significantly improve the MFRF. The MFRF might further be improved by a revision of the computational criteria. Studies are needed to test the effect of using a median value or a mode rather than the mean value, and to test the effect of using only subfamily items for which the BRF equals the EDRF or only subfamily items for which the BRF is other than a technician's estimate rather than using all items in the subfamily.

Detailed tests, as described in APPENDIX C, have been developed for determining the confidence in the MFRF. These tests can be used only when the subfamily size is large as the subfamily BRFs are generally not normally distributed. Further research is required to determine the actual distribution of the subfamily BRFs and to establish confidence intervals.

Current emphasis is directed toward the development of rates based on 3M data. Programs have been developed for computing 3M usage rates by FIIN; further effort is required to develop 3M rates by equipment application or weapon system.

APPENDIX A: CID SUBFAMILY DESIGNATORS

The first two digits of an SPCC equipment CID (Component Identification Number) identify the type of equipment as shown below. There are several codes which do not uniquely identify a type of equipment. Subfamily 00 covers all ordnance equipments, 95 and 96 cover all NAVFAC (Naval Facilities Engineering Command) equipments, and 99 is a miscellaneous group. Subfamilies defined by the above four application codes will be a conglomeration of items with similar nomenclature and varying applications.

00 Ordnance
01 Pumps
02 Boilers
03 Heat exchangers
04 Condensers
05 Turbines
06 Compressors
07 Heaters
08 Distilling plants
09 Battery chargers
10 Meters
11 Converters
12 Maintenance and repair shop equipment
13 Transformers
14 Circuit breakers
15 Controllers
16 Generators
17 Motors
18 Motor generators
19 Relays
20 Rheostats
21 Switches
22 Switchboards
23 Alarms and signalling devices - visual
24 Lighting fixtures and lamps (elect - nonelect)
25 Gyro compass equipment
26 Projection equipment
27 Interior communication equipment
28 Navigational equipment (also timepieces)
29 Injectors
30 Burners

31 Marine hardware and hull items
32 Refrigeration equipment
33 Air conditioning equipment
34 Starters
35 Wipers
36 Alarms and signalling devices - audible
37 Bearings
38 Indicators
39 Clutches
40 Fans
41 Shop equipment
42 Regulators
43 Galley equipment
44 Dehumidification equipment
45 Gages
46 Testing and measuring equipment
47 Chemical warfare equipment
48 Filters
49 Carburetors
50 Panels
51 Isolators
52 Hydraulic equipment
53 Capstans
54 Printing equipment
55 Reels and towing equipment
56 Davits
57 Cranes
58 Hoists and ammunition handling equipment
59 Elevators
60 Steering gears
61 Control equipment - constant frequency
Controls - amplifier
Controls - electrical
Controls - mechanical
Controls - rototrol
Controls - self-synchronous
62 Winches
63 Windlasses
64 Fire fighting equipment
65 Lubricators
66 Engines
67 Plumbing equipment
68 Magnetos
69 Gears
70 Governors
71 Ignition equipment
72 Minor landing craft and small boats
73 Ejectors
74 Eductors
75 Strainers
76 Purifiers

77 Traps
78 Couplir-s
79 Silencing equipment
80 Brakes
81 Blowers
82 Welding systems
83 Ship and boat propulsion components
84 Sick-bay equipment
85 Deck machinery
86 Photographic equipment
87 Underwater log equipment
88 Valves
89 Fire fighting, rescue and safety equipment
90 Rigging and rigging gear (booms, etc.)
91 Laundry equipment
92 Tanks
93 Pipe, tubing, hose, and fittings (metal and flexible)
94 ASW and minesweeping equipment
95 Automotive and construction equipment
96 Construction equipment
97 Periscopes and masts
98 Special power plant equipment
99 Miscellaneous equipment

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APPENDIX B: ELECTRONIC COMPONENTS CODE

Index Number	Description
22410000011	Hose, fabric, including assemblies
30622700011	Hose, molded, chemical, rubber
307902	Plastic products N. E. C. (Not Elsewhere Classified)
30790200011	Insulators, plastic
30790200012	Plastic items N. E. C.
30790200013	Plastic gears
30790200014	Plastic insulating items N. E. C.
322900	Glass products, except containers
32290000011	Insulators, glass
326402	Porcelain and steatite electrical products
32640200011	Porcelain and steatite insulators
32932000011	Gaskets, all types
335720	Wire, copper, base alloy, electric transmission
33572000011	Copper bus bar
335740	Transmission cable
33574000011	Telephone cable
33574000012	Coaxial cable, flexible
335780	Wire, power, insulated
33578000011	Wire, power, copper
33579200011	Shipboard cable (does not include coaxial or telephone)
34220100011	Hand tools and accessories
34520100011	Bolts, nuts, screws, rivets, washers, and other industrial fasteners ferrous and non-ferrous
34811000011	Cable, wire, iron, steel
34817100011	Wire cloth and associated products
349901	Bells, gongs, sirens and similar devices
34990100011	Bells and buzzers
354520	Gages and precision measuring tools
35452000011	Precision gages, micrometers, dial indicators and dividers

Index Number	Description
35452000012	Comparators, calipers
35452000013	Gage blocks
356101	Industrial pumps
35610100011	Pumps and attachments, excludes vacuum
35610200011	Compressors and dry vacuum pumps
3560000011	Ball and roller bearings and associated components
356401	Industrial fans and blowers
35640100011	Fans and blowers
35640100012	Fans and blower accessories
356601	Mechanical power transmission equipment
35660100011	Clutch and clutch assy's
35660100012	Couplings
35660100013	Control devices, converters, drives, decreasers
35660100014	Cams
35660100015	Mechanical transmission devices N. E. C.
35661100011	Plain bearings and bushings
356621	Metallic gears and gear drives
35662100011	Gear drives
35662100012	Gears, metallic
359903	Bellows, flexible metal hose and tubing
35990300011	Flexible metal hose and tubing
35990300012	Bellows, metal
361122	Electric and electronic test equipment
36112200011	Oscilloscopes
36112200012	R. F. Generators and measuring instruments
36112200013	Tube testers
36112200014	Inductance, resistance, capacitance measuring equipment
36112200015	Test equipment N. E. C.
36112200016	Audio oscillators
361131	Electrical measuring instruments N. E. C.
36113141000	Panel types
36113142100	Switchboard types
36113143000	Standards, portable and regular
36113144100	Electrical recording instruments direct acting, excludes potentiometric, oscillographic or light beam galvanometer
36113145200	Electrical recording instruments controlling and/or recording instrument self-balancing potentiometric types

Index Number	Description
36113146000	Electrical indicating instruments N. E. C. (includes light beam galvanometer, non-automatic null measuring devices)
36113149000	Electrical indicating and recording devices sub-assy's and parts u/w or p.o (does not include jeweled bearings)
361301	Low voltage distribution equipment (under 1200V)
36130100011	Circuit breakers
36130100013	Switch boards
361331	Fuses and fuse equipment under 2300V
36133100010	Fuses and fuse links
36133100011	Fuse holders
362101	Motor generating sets and other rotating equipment
36210100011	Motor generator sets
36210100012	Dynamotors
36210100013	Actuators, electric
36210300011	Motors, special aircraft
362104	Synchro's and servos
36210400011	Synchro's
36210400012	Servo devices
36210400013	Synchro and servo sub-assy's and parts
36210400014	Motors, sub-fractional thru 1/100 H.P.
362110	Fractional horsepower motors, excludes special aircraft motors, synchronous motors
36211000011	Motors, D.C. fractional H.P.
36211000012	Motors, shaded pole, A.C. fractional H.P.
36211000013	Motors, standard A.C. fractional H.P.
36211000014	Motors, universal
362121	Integral H.P. Motors and generators under 2,000KW
36212100011	Generators A.C.
36212100012	Generators D.C.
36212100013	Motors, A.C. polyphase induction
36212100014	Motors, A.C. single phase
36212100015	Motors, A.C. synchronous
36212100016	Motors, D.C.
362140	Prime mover generator sets (except turbo driven)
36214100011	Diesel engine driven
36214000012	Gasoline engine driven
362160	Parts and supplies for M.G. and M.G. sets

Index Number	Description
36216000011	Parts and supplies for motor generators
36216000012	Parts and supplies for motor generator sets
362320	Welding wire and rods
36232000011	Electrodes
362930	Other industrial electrical products N. E. C.
36293000011	Solenoid, electrical
364100	Electric lamps (bulbs)
36410000011	Dial lamps
36410000012	Lamps, incandescent other than dial
36410000013	Lamps, glow, electric
364301	Current carrying wiring devices except connectors and protective devices
36430100011	Light indicators and assy's (includes lamp holders)
36430100012	Terminal blocks
36430100013	Controllers
364302	Connectors, Army Navy type
36430291200	Cylyndrical multi-contact
36430291310	Rack and panel multi-contact
364303	Connectors, transmission and distribution, except AN types
36430391000	Connectors, misc.
36430391100	Connectors, coaxial
36430391400	Connectors, fusion sealed (except coaxial)
36430391500	Connectors, printed circuit
364420	Electrical conduit
36442000011	Rigid and flexible
36442000012	Fittings
366100	Telephone and telegraph equipment
36610000011	Telegraph keys
36610000012	Telephones
36610000013	Teletype assy's and parts
36610000014	Cryptological equipment
36610000015	Telegraph equipment
36610000016	Facsimilie equipment
366211	Transmitters, radio communication
36621100011	Airborne
36621100012	Marine
36621100013	Transmitters/receivers
36621100014	Ground

Index Number	Description
366220	Broadcast equipment
36622000011	Television equipment
366231	Intercommunication equipment
36623100011	Equipment assy's and parts
366241	Navigational aids, electronic
36624100011	Radar transmitters, marine
36624100013	Radar receivers, marine
36624100015	Radar transmitters, airborne
36624100017	Radar receivers, airborne
36624100019	Radiac equipment
36624100021	Navigational compasses
366242	Electronic systems equipment, military
36624200011	Countermeasures
36624200012	Telemetry
36625100011	Missile guidance equipment
366261	Sonar and related devices
36626100011	Sonar equipment
36626100013	Bathythermographs, sub-assy's and parts
367100	Electron tubes, receiving types except cathode ray tubes
36710071110	Subminiature, gas and vacuum, military reliable
36710071190	Subminiature, gas and vacuum other than military reliable
36710071310	Miniature, gas and vacuum includes baseless larger than T6 1/2, compactron, military reliable
36710071390	Miniature, gas and vacuum includes baseless larger than T6 1/2, compactron other than military reliable
36710071410	Standard glass and vacuum, military reliable
36710071490	Standard glass and vacuum other than military reliable
36710071500	Ceramic tubes, includes nuvistors
36710071900	Acorn, ballast, lock-in and metal
367200	Cathode ray tubes, picture type
36720072100	Cathode ray tubes, black and white all sizes
36720072200	Cathode ray tubes, color, all sizes
367302	Transmitting and special purpose tubes
36730273111	High vacuum diodes
36730273120	Power transmitting and special purpose triode and multi-grid external anode tubes

Index Number	Description
36730273140	Power transmitting and special purpose rocket and pencil types
36730273200	Klystrons
36730273300	Magnetrons
36730273500	Traveling wave tubes
36730273800	Light sensing, light emitting and storage tubes
36730273900	Special purpose, miscellaneous
367910	Transistors, crystal diodes and similar solid state devices
36791074100	Semiconductor diodes, germanium
36791074200	Semiconductor diodes, silicon
36791074500	Semiconductor devices, N.E.C.
36791074570	Semiconductor devices, light sensitive
36791074900	Diodes and dry disc rectifiers, other materials
36791076100	Transistors, germanium
36791076200	Transistors, silicon
36791076900	Transistors, materials other than germanium and silicon
367920	Capacitors, electronic applications
36792011100	Capacitor, fixed, paper, dielectric, non-metal case
36792011600	Capacitor, fixed, paper dielectric, metal case
36792012100	Capacitor, fixed film dielectric, non-metal case
36792012200	Capacitor, fixed, film dielectric, metal case
36792012500	Capacitor, fixed, combination of film and paper dielectric
36792013100	Capacitor, fixed, metallized paper or film dielectric non-metal case
36792014110	Capacitor, fixed, tantalum electrolytic foil
36792014330	Capacitor, fixed, tantalum liquid electrolyte sintered slug and wire
36792014340	Capacitor, fixed, tantalum dry electrolyte, sintered or solid slug
36792015110	Capacitor, fixed, mica dielectric
36792015200	Capacitor, variable, mica dielectric
36792016110	Capacitor, fixed, ceramic dielectric temperature compensating
36792016120	Capacitor, fixed, ceramic dielectric general purpose
36792016200	Capacitor, variable, ceramic dielectric
36792016300	Capacitor, fixed, glass dielectric
36792016400	Capacitor, variable, glass dielectric
36792016500	Capacitor, fixed, vitreous enamel dielectric
36792017000	Capacitor, variable, air
36792018000	Capacitor, fixed, air
36792019000	Capacitor, fixed and variable N. E. C.
367930	Resistors, electronic applications

Index Number	Description
36793021110	Resistors, fixed, composition
36793023100	Resistors, fixed, deposited carbon and boro-carbon
36793023300	Resistors, fixed, metal film
36793024000	Resistors, variable non-wire wound
36793025000	Resistors, fixed, wire wound
36793026000	Resistors, variable, wire wound
36793029000	Resistors, miscellaneous
367940	Transformers, coils, reactors, electronic applications
36794031000	Transformers and reactors, MIL-T-27, except toroidal
36794032000	Transformers and reactors, MIL-T-27, toroidal
36794033000	Transformers and reactors, non-MIL, excludes toroidal
36794034000	Transformers and reactors non-MIL toroidal
36794035000	R. F. coils and transformers
36795100011	Filters and networks
367952	Relays and switches, electronic applications
36795251000	Relays, clapper, rotary, plunger or solenoid (except telephone)
36795251310	Relays, telephone type
36795251410	Relays, crystal control type, sealed
36795252000	Relays, miscellaneous
36795255000	Switches
367953	Transducers and related products
36795368100	Quartz crystals hermetically sealed
36795368200	Quartz crystals unsealed
36795369000	Instrument transducers all types
36795369002	Transducers, N. E. C.
36795369003	Hydrophones and related sonar listening devices
36795369004	Quartz crystal associated hardware
367954	Electronic printed circuits, printed circuits boards and printed electronic sub-assy's
36795485000	Complex circuits
367957	Electronic components and sub-assy's N. E. C.
36795700011	Dehydrators, dehumidifiers and accessories u/w antennas and transmission lines
36795700012	Hardware, electronic
36795700013	Antenna, assemblies and parts
36795700014	Coaxial cable, flexible
36795700015	Coaxial cable, flexible, fittings
36795700016	Coaxial cable, rigid
36795700017	Coaxial cable, rigid, fittings
36795700018	Waveguides
36795700019	Waveguide fittings

Index Number	Description
36795700020	Microwave components and accessories
36795700021	Power supplies, N. E. C.
36795700022	Sockets, electronic
36795700023	Tube clamps, chimneys and associated devices
36795700024	Panels, cabinets, racks, chassis and similar devices
36795700025	Delay lines
36795700026	Knobs, escutcheons, dial assy's and similar devices N. E. C.
36795700027	Recording and reproducing equipment assy's and parts
36795700028	Ferrite and related devices
36795700029	Counter and counter assy's
36795700030	Charts, recording paper and similar devices N.E.C.
36795700031	Radomes
36795700032	Valves
36795700033	Computer equipment, assy's and parts
36795700034	Infr-red equipment - non-industrial
36795700035	Antenna fittings, masts and associated hardware N.E.C.
36910000011	Storage batteries
36920100011	Dry cells
36930100011	X-ray tubes and x-ray equipment, assy's and parts
372912	Aircraft parts, man carrying, military
37291200011	Instruments, flight
381123	Navigational instruments except aircraft
38112300011	Gyroscopes, except aircraft
381124	Laboratory apparatus and scientific instruments
38112400011	Meteorological equipment, sub-assy's and parts
382111	Aircraft instruments
38211100011	Aircraft instruments, except flight
382134	Industrial process instruments
38213400011	Guages, pressure and vacuum
38213400012	Thermometers
38213400013	Temperature instruments, except thermometers and Calorimeters
38213400014	Instruments N. E. C.
386102	Motion picture theatre, studio, laboratory and still photography
38610200011	Motion picture projectors and accessories
387100	Watches, clocks, timers

Index Number	Description
38710000011	Timers, electric
38710000012	Timers, mechanical

Gaskets, all types (includes packing material)

Prefix code - 329320-00011

12th and 13th digit indicate material

01. Monel (nickel alloy)
02. Aluminum
03. Synthetic rubber
04. Aluminum mesh (neopreme rubber - impregnated)
05. Teflon coated
06. Carbon steel
07. Steel
08. Copper
09. Stainless steel
10. Teflon (solid)
11. Corrugated metal-asbestos
12. Brass
13. Asbestos
14. Plastic
15. Rubber/stainless steel
16. Fiberglass
17. Cloth (airplane)
18. Compound
19. Paper
20. Manganese
21. Graphite

Fans and Blowers

Prefix code - 356401-00011

12th digit indicates type of unit	1. Single with motor 2. Double with motor 3. Single without motor 4. Double without motor 5. Belt drive with motor 9. Other
13th digit indicates type of unit	1. Fan, axial 2. Blower, tube axial 3. Blower, vane axial 4. Blower, multi-stage axial 5. Blower, centrifugal (radial) 6. Blower, packaged, panel mounting 7. Impeller or rotor only 9. Other
14th digit indicates size	1. Up to 4" outer housing dia. or rotor size 2. Over 4" to 8" outer housing dia. or rotor size 3. Over 8" outer housing dia. or rotor size 4. Up to 5" dia. propeller 5. Over 5" to 10" dia. propeller 6. Over 10" diameter propeller 9. Other
15th digit indicates output (free air) each unit in cubic feet per minute	1. Up to 100 CFM 2. 101 to 250 CFM 3. 251 to 600 CFM 4. 601 to 1,000 CFM 5. 1,001 to 1,600 CFM 6. 1,601 to 1,800 CFM 7. 1,801 and over 9. Other
16th digit indicates nominal voltage and frequency with horsepower if with motor	1. 115 V AC 60 cycles, fractional H. P. 2. 115 V AC 60 cycles, 1 H. P. and over 3. 115 V AC 400 cycles, fractional H. P. 4. 115 V AC 400 cycles, 1 H. P. and over 5. Other AC, fractional H. P.

6. Other AC, 1 H. P. and over
7. Other DC, fractional H. P.
8. Other DC, 1 H. P. and over
9. Other

Synchro

Prefix code - 362104-00011

12th digit indicates degree of accuracy	1. Precision 9. Other
13th digit indicates type	1. Synchro, non-MIL 2. Synchro, MIL 3. Resolver, non-MIL 4. Resolver, MIL 5. Induction potentiometer 9. Other
14th digit indicates frequency	1. DC 2. 60 cps 3. 400 cps 9. Other
15th and 16th digit indicates a frame size in tenths of an inch	Example: Frame size 15 will be coded as "15"

Capacitor, Fixed, Air Dielectric

Prefix code - 367920-18000

12th digit indicates working voltage	1. Thru 150 2. Over 150 thru 300 3. Over 300 thru 500 4. Over 500 thru 1,000 5. Over 1,000 thru 3,000 6. Over 3,000 thru 6,000 7. Over 6,000 thru 10,000 8. Over 10,000 thru 20,000 9. Over 20,000
13th digit indicates maximum capacity in picofarads	1. Thru 15 2. Over 15 thru 50 3. Over 50 thru 150 4. Over 150 thru 250 5. Over 250 thru 500 6. Over 500 thru 750 7. Over 750 thru 1,000 8. Over 1,000 thru 3,000 9. Over 3,000
14th digit indicates number of sections	1. Single 2. Part of dual unit 3. Part of triple unit 4. Part of quadruple unit 5. Part of quintuple unit 6. Part of sextuple unit 9. Other

Switches

Prefix code - 367952-55000

12th and 13th digit indicate type

01. Standard snap or toggle action
02. Linear motion, butt contact
03. Leaf type, cantilever contact spring, plain
04. Leaf type, cantilever contact spring with bellows or diaphragm actuator
05. Mercury contact
06. Knife blade (excludes antenna)
07. Rotary drum and cam actuated contact
08. Rotary dial or face plate including decade
09. Rotary high frequency
10. Slide type, high frequency
11. Sensitive
12. Pressure
13. Antenna
14. Coaxial
15. Waveguide
16. Push, switch
17. Rotary, snap action
18. Thermostatic switch
19.
20. Switch assembly
21. Switch, relay

99. Other

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APPENDIX C: MFRF STATISTICAL TESTS

1. MFRF Confidence Interval. Statistical methods[1] can be used to determine how close the MFRF is to the unknown true mean replacement factor μ. Although the approach is more accurate for large sample sizes, it may be applied with limitations for small sample sizes.

In order to compute the MFRF confidence interval, the distribution of the MFRF must be determined. If the number of items in the subfamily (n) is large, the following theorem may be applied:

> Theorem 1: Central-limit theorem. If a population (subfamily item BRFs) has a finite standard deviation σ and mean μ, then the distribution of the sample mean (MFRF) approaches the normal distribution with mean μ and standard deviation $\sigma_{\bar{x}} = \sigma/\sqrt{n}$ as the sample size n increases.

If the subfamily item BRFs are normally distributed, the theorem below may be applied:

> Theorem 2: If a population (subfamily item BRFs) is normally distributed with mean μ and standard deviation σ and a random sample of size n is drawn, then the sample mean (MFRF) will be normally distributed with mean μ and standard deviation $\sigma_{\bar{x}} = \sigma/\sqrt{n}$.

It is noted that Theorem 2 is conditional on the normality of the subfamily item BRFs. A sample study made on the MFRFs for H cog items revealed that this condition usually does not exist. This topic is discussed in detail in Chapter II, page 23.

If either of the above two conditions applies, the MFRF will be normally distributed with mean μ and standard deviation $\sigma/\sqrt{n}$. The

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[1]Theorems and approach are discussed in Hoel, Paul G., "Introduction to Mathematical Statistics", pp 138-148.

following probability statement can, therefore, be set up and evaluated:

$$\Pr\{MFRF - t(\sigma/\sqrt{n}) \leq \mu \leq MFRF + t(\sigma/\sqrt{n})\} = \alpha$$

Where

α = confidence level

t = standard normal t value for a two-sided test with a confidence level of α if $n > 30$.

t = student's t value for a two-sided test with a confidence level of α and (n-1) degrees of freedom if $n \leq 30$.

σ = true standard deviation - approximated by the sample standard deviation s

$$s = \sqrt{\frac{\sum_{i=1}^{n} (BRF_i - MFRF)^2}{n-1}}$$

n = number of items in subfamily

The closeness of the upper and lower limits of the confidence interval reveal how closely the MFRF approximates the true mean family replacement factor.

The consistency of the MFRF from one run to the next is determined by comparing the standard error of the mean ($\sigma_{\bar{x}} = \sigma/\sqrt{n}$) for each run. The smaller the value of $\sigma_{\bar{x}}$, the smaller the range of values falling in the confidence interval for μ; and, therefore, the more closely grouped the successive values of the MFRF are expected to be for a given subfamily. Thus a downward trend in $\sigma_{\bar{x}}$ normally indicates the MFRF is becoming more representative of the subfamily, while an upward trend indicates a less reliable MFRF.

If there is an upward trend, one may desire to determine if the MFRF values from the two runs are significantly different. Assuming that the subfamily MFRF is normally distributed, the following theorem applies:

> Theorem 3: If the sample means x_1 and x_2 (in this case two MFRF values for a given subfamily), are normally distributed, then the difference of the means if normally distributed with a mean of $\mu_1 - \mu_2$ and a standard deviation of $\sqrt{\sigma^2_{\bar{x}_1} + \sigma^2_{\bar{x}_2}} = \sqrt{\sigma_1^2/n_1 + \sigma_2^2/n_2}$

Thus the following statistic may be formed:

$$t = \frac{(MFRF_1 - MFRF_2) - (\mu_1 - \mu_2)}{\sqrt{\sigma_1^2/n_1 + \sigma_2^2/n_2}}$$

Using this statistic, the following procedure is used to determine if the difference between the two MFRFs is significant. It is initially assumed that there is no significant difference between the two MFRFs and, therefore, $\mu_1 - \mu_2 = 0$. The t value is computed and the absolute value of t is compared to the table t value for a two-sided test at the desired confidence level. The standard normal t value is used for large samples, while the student's t value with $(n_1 + n_2 - 2)$ degrees of freedom is used for small samples. If the computed t value is less than or equal to the table value, the assumed hypothesis is correct and there is no significant difference between the two MFRFs. If the computed t value is greater than the table value, the assumed hypothesis is false and there is a significant difference between the two MFRFs at the specified confidence level, i.e. if a 95% confidence level were selected, there would be a 95% probability of significant difference between the two MFRFs.

If the computation reveals a significant difference, it is likely (although not necessarily true) that items are not being assigned to the proper subfamilies. Such subfamilies should be manually reviewed for corrective action.

It was noted above that this approach is most valid when the sample size, i.e. the number of the items in the subfamily is large. It may also be used for small sample sizes when the sampling distribution of the sample mean is known to be normal or closely approximated by the normal, as in the case mentioned in Theorem 2. However, there is still a problem in determining how closely the true standard deviation σ is approximated by the sample deviations. As this factor is seldom known, it is desirable to form reasonably large subfamilies.

2. BRF Dispersion. It may further be desired to determine how close the actual experienced BRF for a new item will be to the MFRF used as an estimate. This can be easily determined if the BRF distribution for the subfamilies is normal - a condition that was seldom met in past experience. If this condition is met and it is assumed that the MFRF = μ, (a valid assumption if the confidence limits determined above are close), the following confidence interval can be set up.

$$\Pr \{MFRF - t\sigma \leq BRF \leq MFRF + t\sigma\} = \alpha$$

Where

α = desired confidence level

t = standard normal t value for a two-sided test with a confidence level of α if $n > 30$

t = student's t value for a two-sided test with a confidence level of α and (n-1) degrees of freedom if $n \leq 30$

For example, if $\alpha = .95$ then the experienced BRF for an individual item will fall within $\pm$ 1.96 standard deviations from the MFRF in 95 out of 100 cases.

If the subfamily MFRF for any two runs remains approximately the same, it may be significant to determine the dispersion of the subfamily BRFs from one run to the next. This may be done by comparing the standard deviation s for each run. The smaller the value of s, the smaller the range of values falling in the confidence interval for the BRF. An upward trend in s, while the MFRF remains constant, produces a wider confidence interval for the BRF.

In the latter case, one may wish to determine if the difference between the two standard deviations is significant. The distribution of the standard deviation when the sample size n is large is given by the following theorem[1]:

> Theorem 4: If the sample size is large, the sample standard deviation is approximately normally distributed with a mean approximated by σ and a standard deviation approximated by $\sigma/\sqrt{2n}$ or $s/\sqrt{2n}$.

Therefore, by Theorem 3, the difference of the two standard deviations $(s_1 - s_2)$ is normally distributed with a mean of $\sigma_1 - \sigma_2$ and a standard deviation of $\sqrt{\sigma_{s_1}^2 + \sigma_{s_2}^2} = \sqrt{s_1^2/2n_1 + s_2^2/2n_2}$. Thus the following statistic may be formed.

$$t = \frac{(s_1 - s_2) - (\sigma_1 - \sigma_2)}{\sqrt{s_1^2/2n_1 + s_2^2/2n_2}}$$

[1] Hald, A., "Statistical Theory with Engineering Applications", p.300.

The test for determining if the two standard deviations are significantly different is similar to the test for determining if two MFRFs are significantly different. It is initially assumed that there is no significant difference between the two standard deviations and therefore $\sigma_1 - \sigma_2 = 0$. Since this test is applied only when there is an upward trend in the standard deviation, a one-sided test of significance is used. The t value is computed and the absolute value of t is compared to the standard normal t value for a one-sided test at the desired confidence level. If the computed t value is less than or equal to the table value, the assumed hypothesis is correct and the upward trend in the standard deviations is not significant.

If the computed t value is greater than the table value, the assumed hypothesis is false and the difference between the two standard deviations is significant. Hence, the dispersion of item BRFs about the MFRF is becoming significantly larger and the MFRFs assigned to new items coming into the subfamily are becoming less and less representative based on the history for similar items in similar service.

As noted previously, the tests for determining the BRF dispersion are valid only if the BRF distribution for the subfamily is normal. The significant difference test is further dependent on a large sample size.

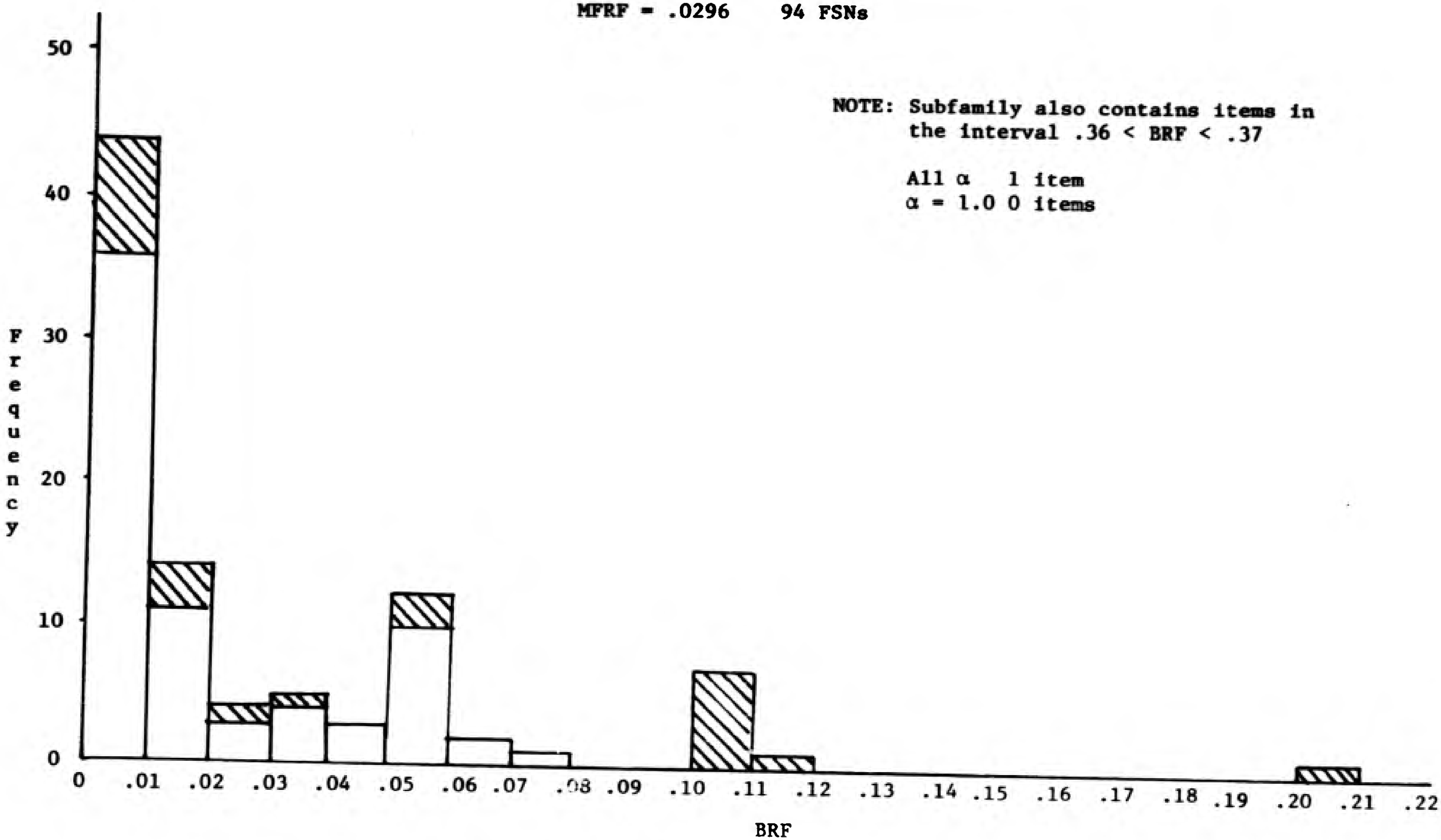
APPENDIX D: SUBFAMILY DISTRIBUTIONS

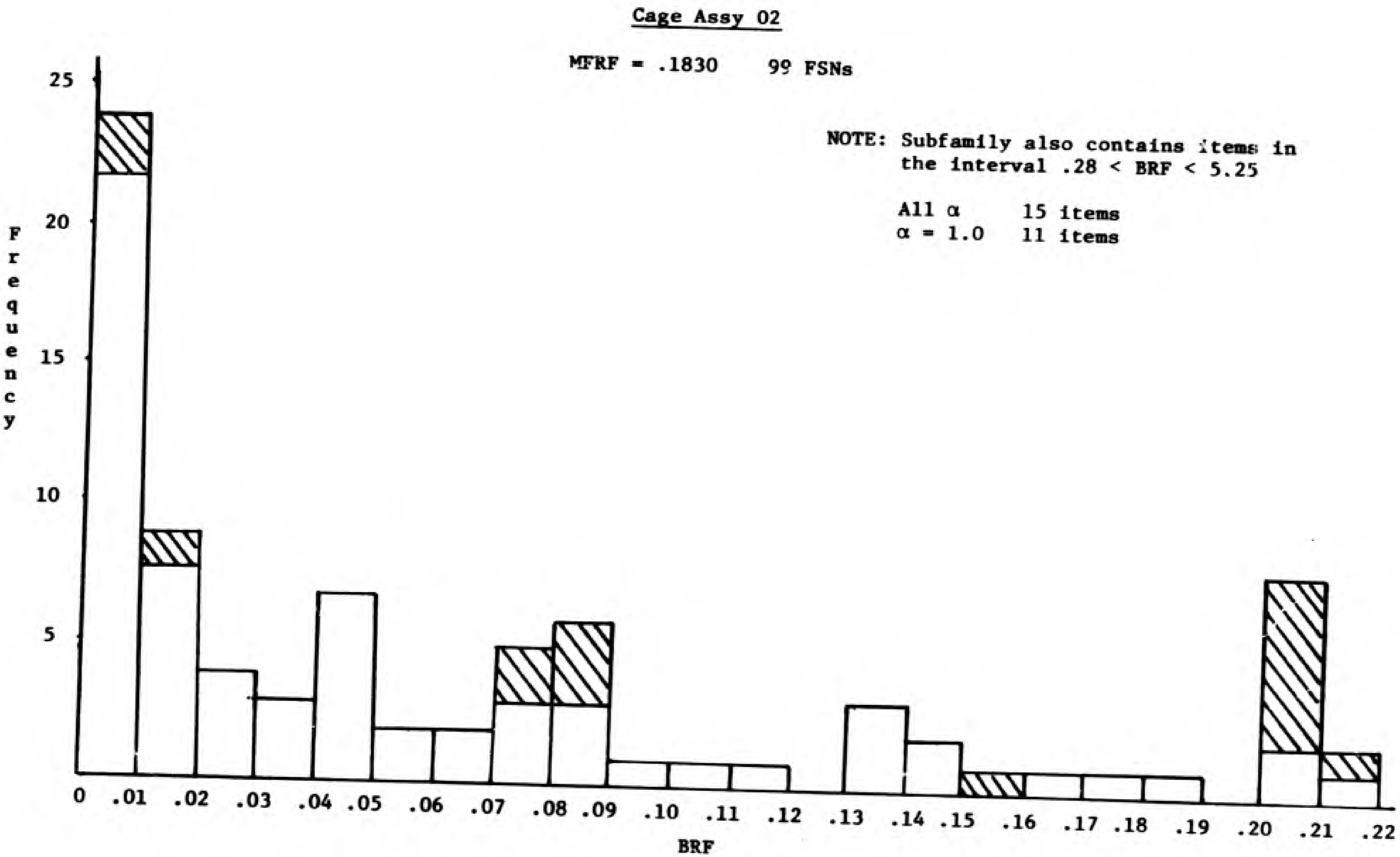
The charts on the following pages represent the BRF frequency distributions for several H cog subfamilies. The shaded portions represent those items for which the BRF was other than a pure EDRF, i.e., $\alpha \neq 1.0$, while the unshaded portions represent those items for which the BRF was a pure EDRF, i.e. $\alpha = 1.0$.

Subfamily ABRASIVE TIP 41 is included as it was the only subfamily sampled that had a normal distribution. Unfortunately, information pertaining to the MFRF, the number of items with a full confidence BRF ($\alpha = 1.0$) and the number of items with a less than full confidence BRF is no longer available.

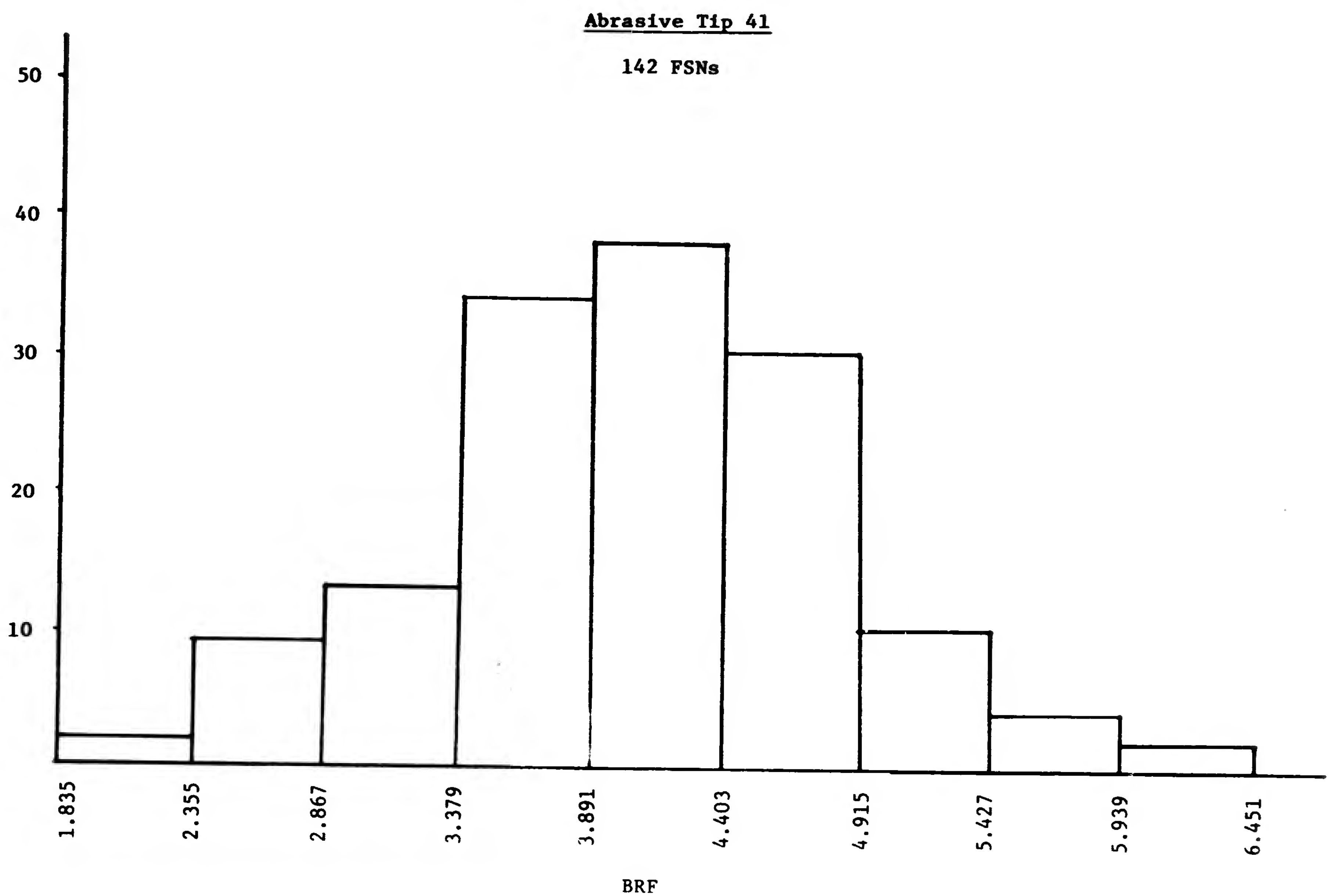
Casing 01

MFRF = .0296   94 FSNs

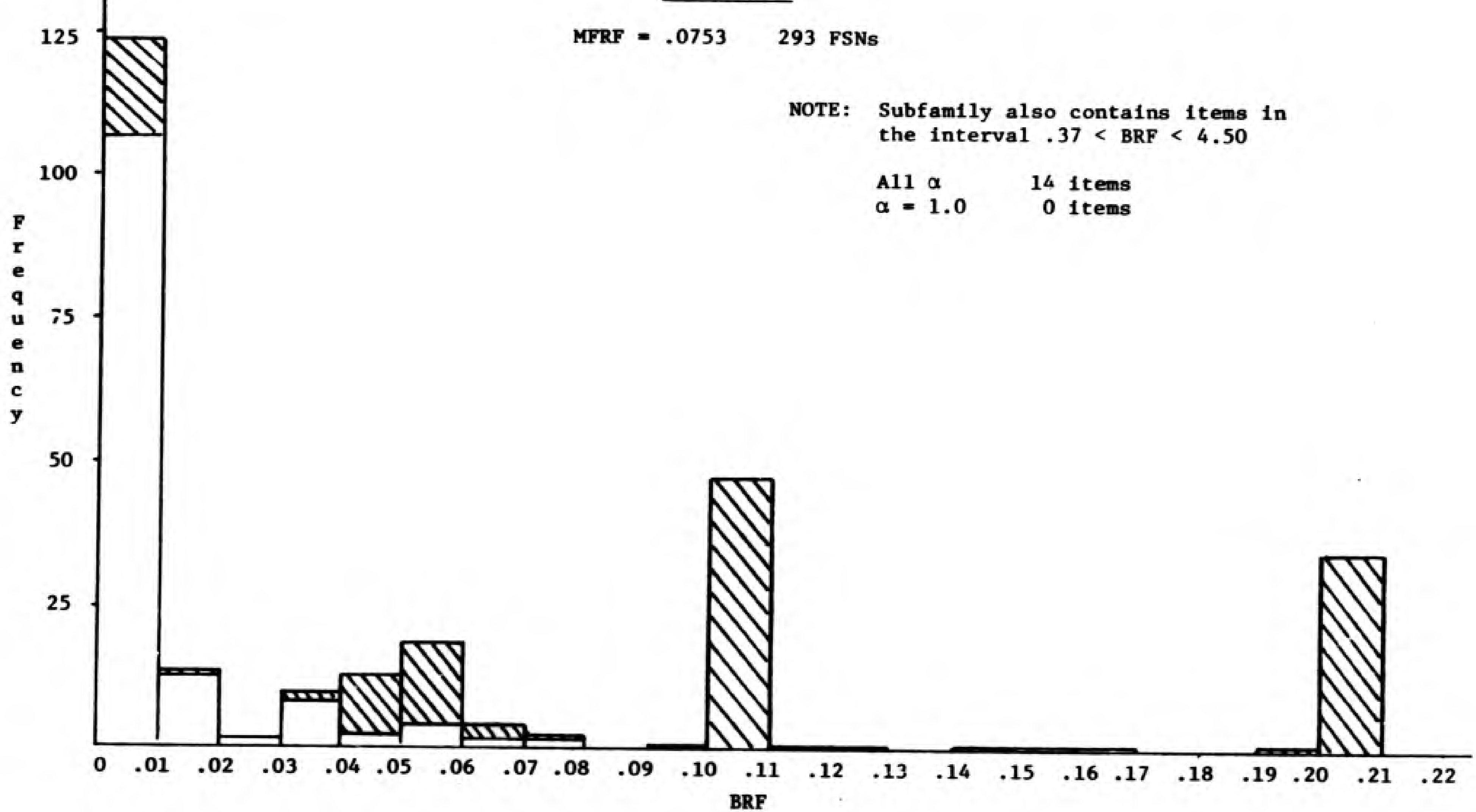


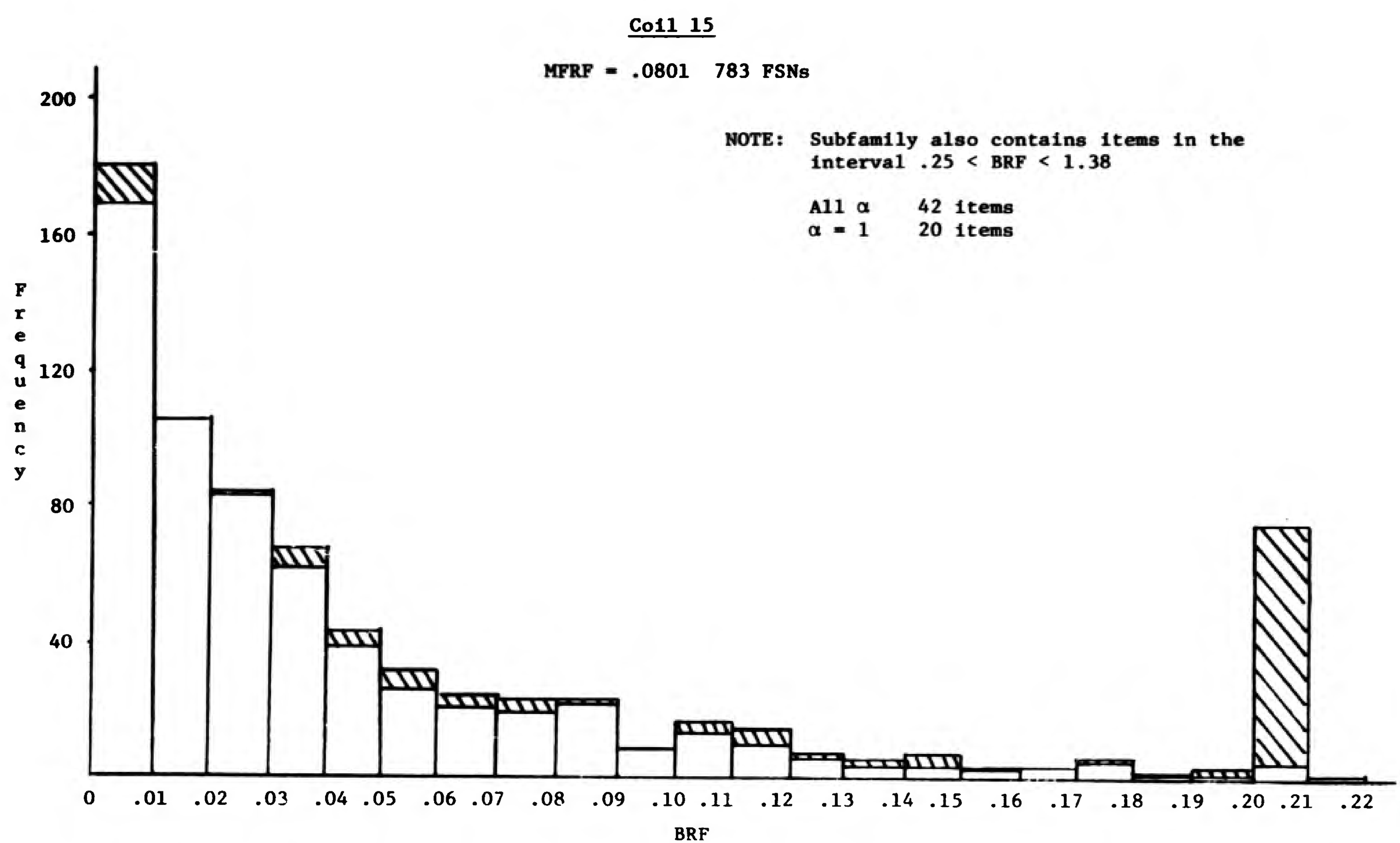


Cage Assy 02
MFRF = .1830 99 FSNs
NOTE: Subfamily also contains items in the interval .28 < BRF < 5.25
All α 15 items
α = 1.0 11 items
Frequency
25
20
15
10
5
0 .01 .02 .03 .04 .05 .06 .07 .08 .09 .10 .11 .12 .13 .14 .15 .16 .17 .18 .19 .20 .21 .22
BRF


Abrasive Tip 41
142 FSNs
Frequency
50
40
30
20
10
1.835
2.355
2.867
3.379
3.891
4.403
4.915
5.427
5.939
6.451
BRF

Circuit 14


MFRF = .0753 293 FSNs
NOTE: Subfamily also contains items in the interval .37 < BRF < 4.50
All α 14 items
α = 1.0 0 items
Frequency
125
100
75
50
25
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
.11
.12
.13
.14
.15
.16
.17
.18
.19
.20
.21
.22
BRF


Coil 15
MFRF = .0801 783 FSNs
NOTE: Subfamily also contains items in the interval .25 < BRF < 1.38
All α 42 items
α = 1 20 items
Frequency
200
160
120
80
40
0 .01 .02 .03 .04 .05 .06 .07 .08 .09 .10 .11 .12 .13 .14 .15 .16 .17 .18 .19 .20 .21 .22
BRF

APPENDIX E. SYSTEM/3M, SOAP/3M AND SYSTEM/SOAP GRAPHS

The charts on the following pages show data plots of the rates in each of the six samples:

9N cog System/3M rates

H cog System/3M rates

9N cog SOAP/3M rates

H cog SOAP/3M rates

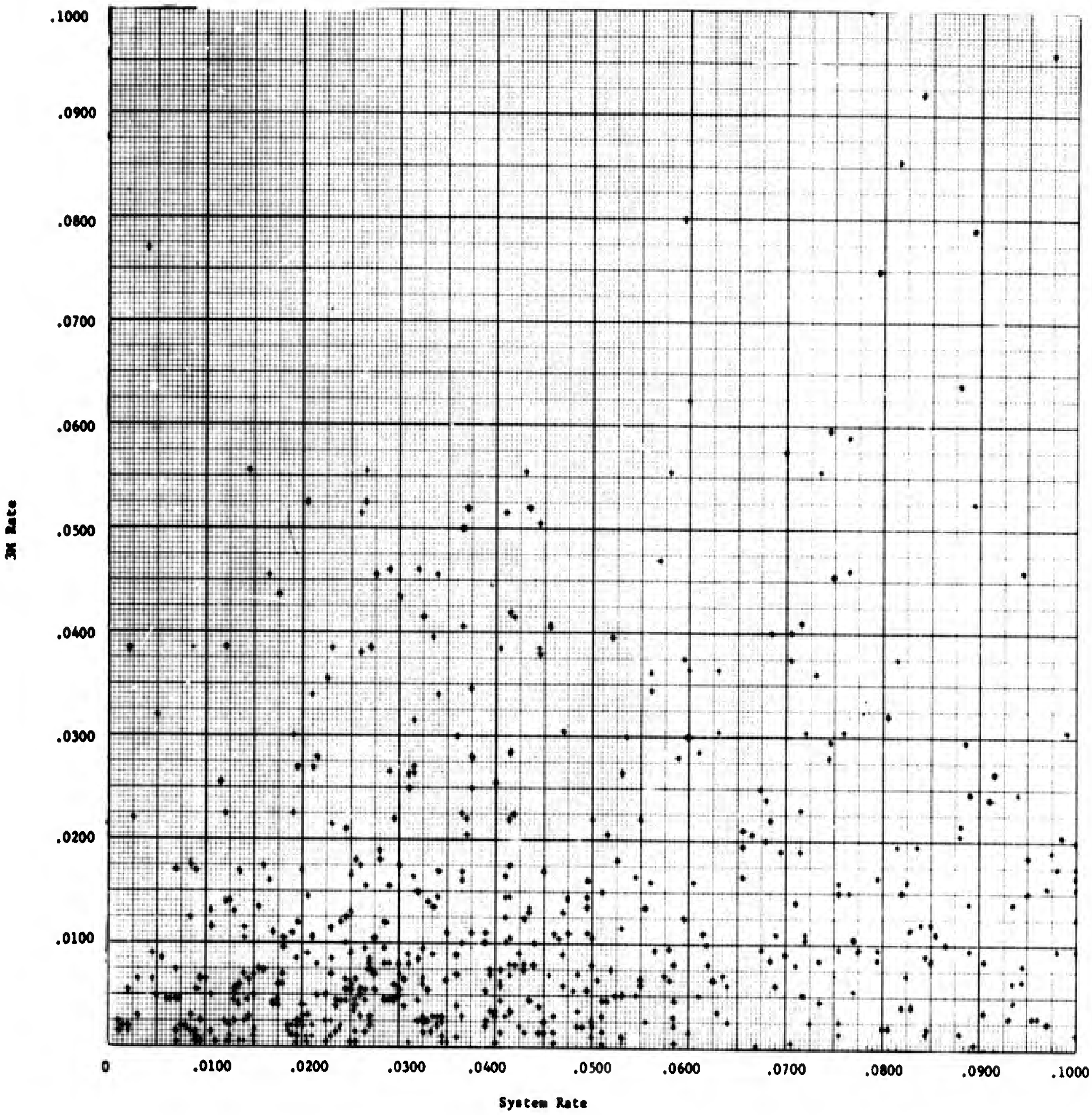
9N cog System/SOAP rates

H cog System/SOAP rates

The rates in each sample were plotted on two separate graphs - the first covering all items having both rates less than .1000 and the second covering all remaining items.

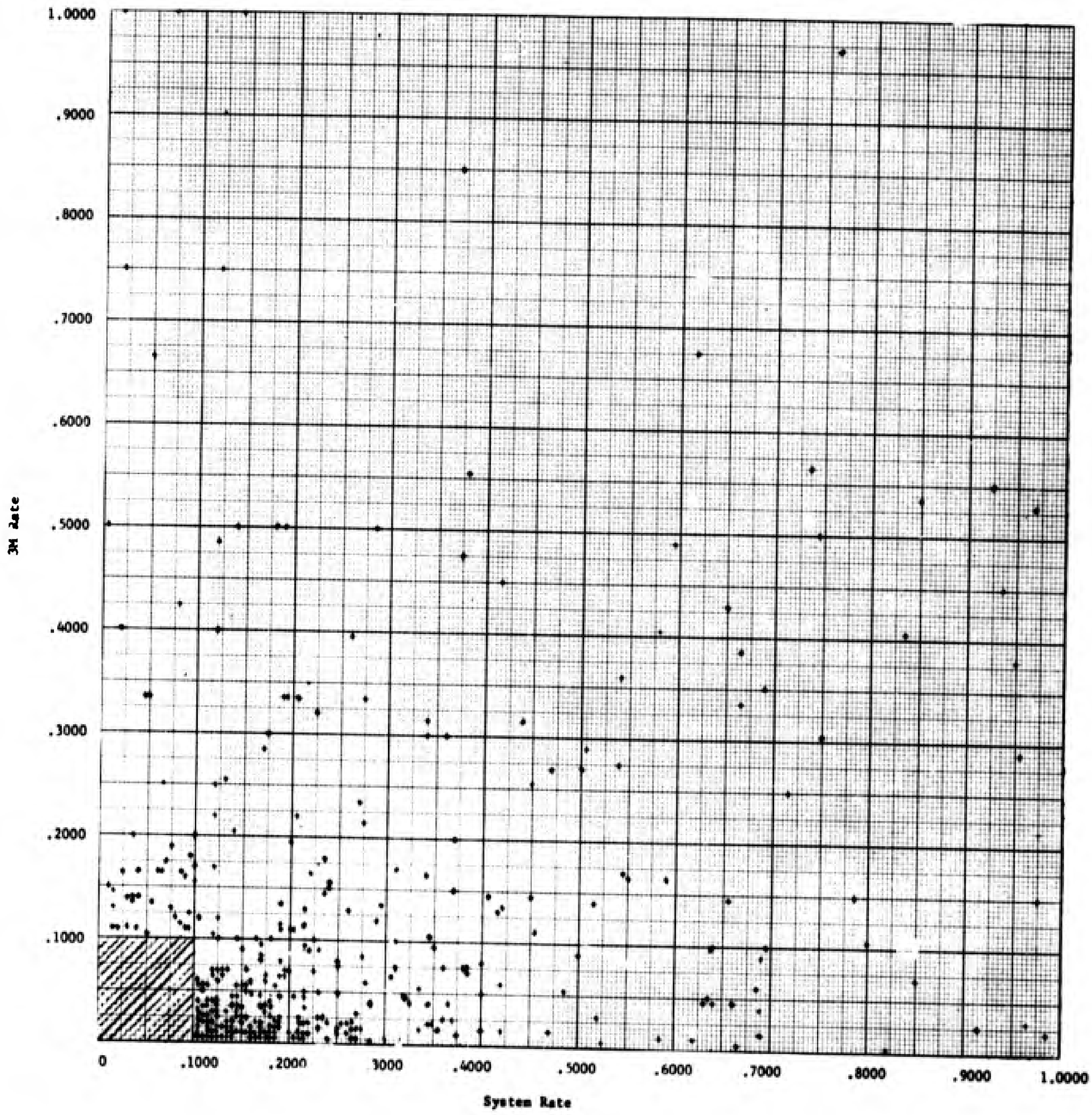
9N Cog System/3M Rates

0 < Rate ≤ .1



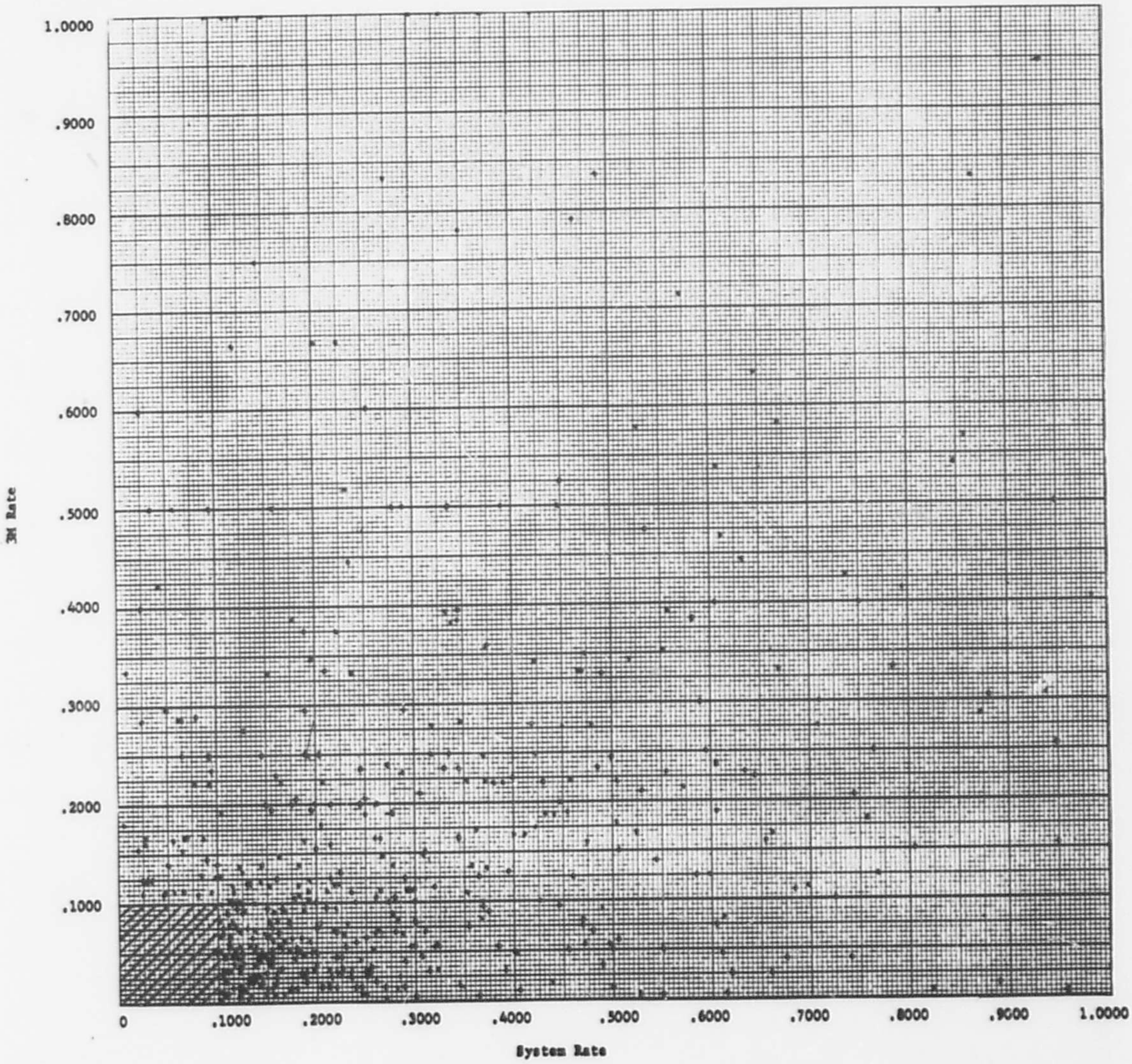
9N Cog System/3M Rates

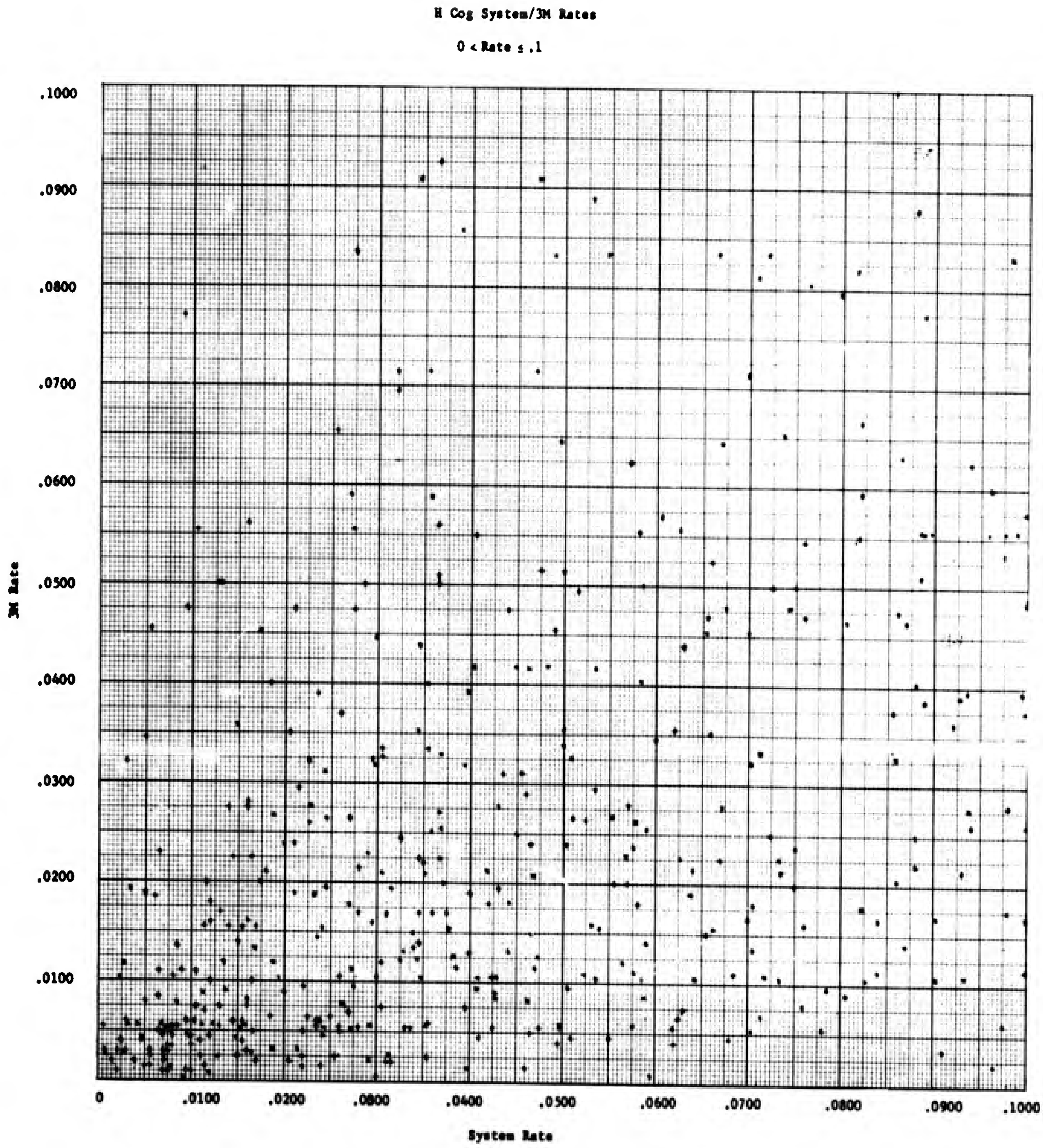
.1 < Rate ≤ 1.0



H Cog System/3M Rates

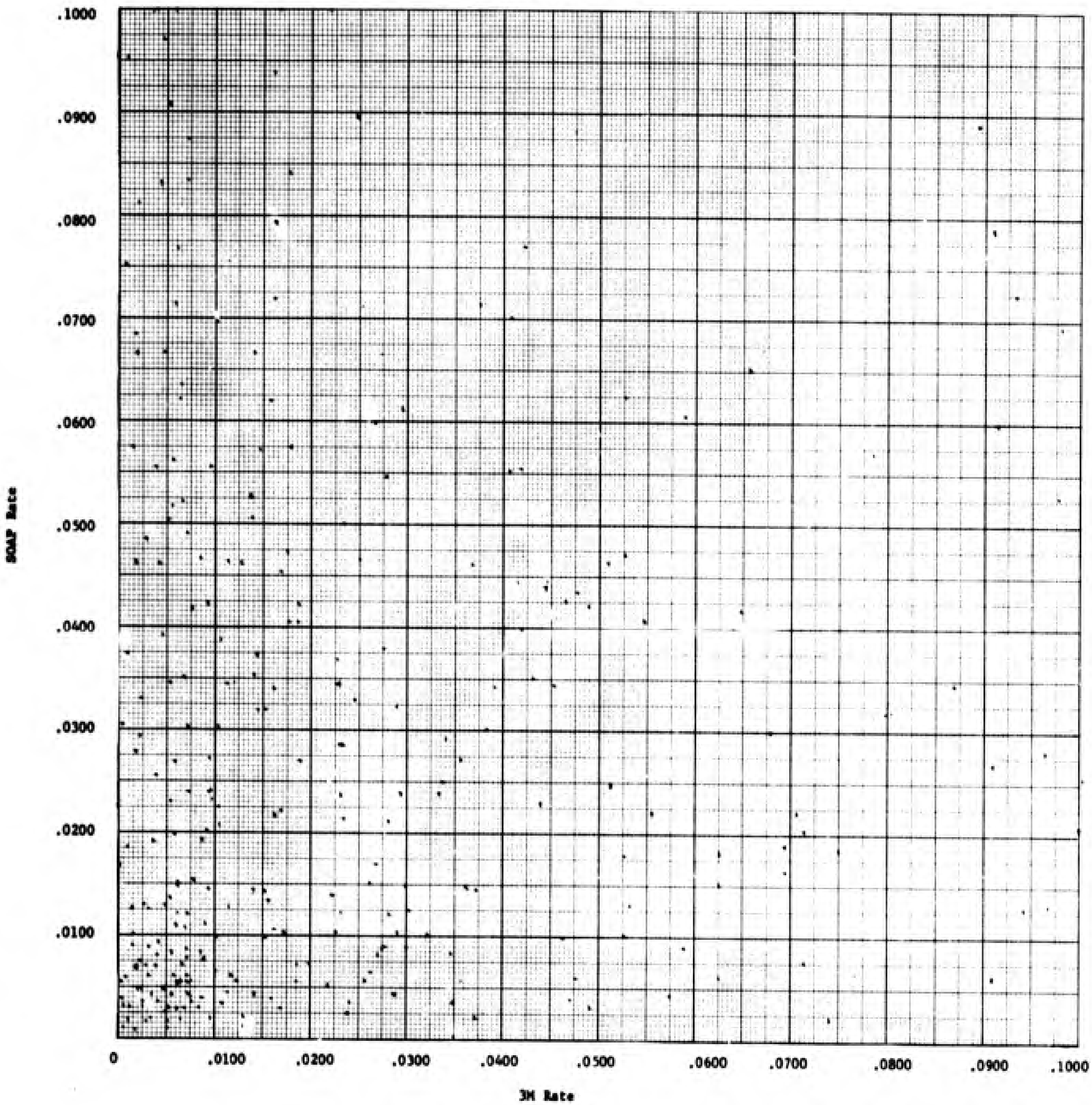
.1 < Rate ≤ 1.0




H Cog System/3M Rates
0 < Rate ≤ .1
3M Rate
.1000
.0900
.0800
.0700
.0600
.0500
.0400
.0300
.0200
.0100
0
.0100
.0200
.0300
.0400
.0500
.0600
.0700
.0800
.0900
.1000
System Rate

9N Cog SOAP/3M Rates

0 < Rate ≤ .1



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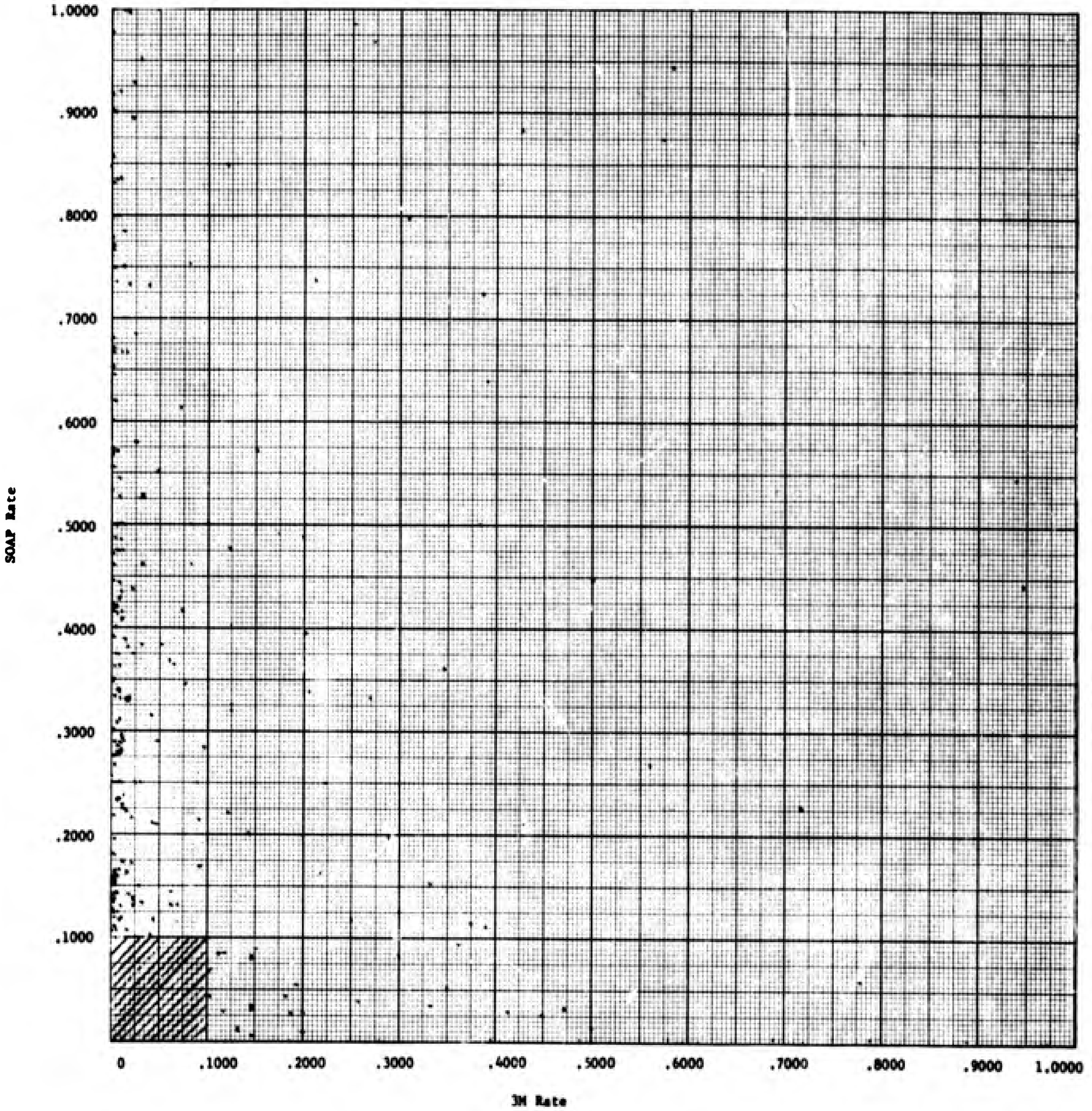
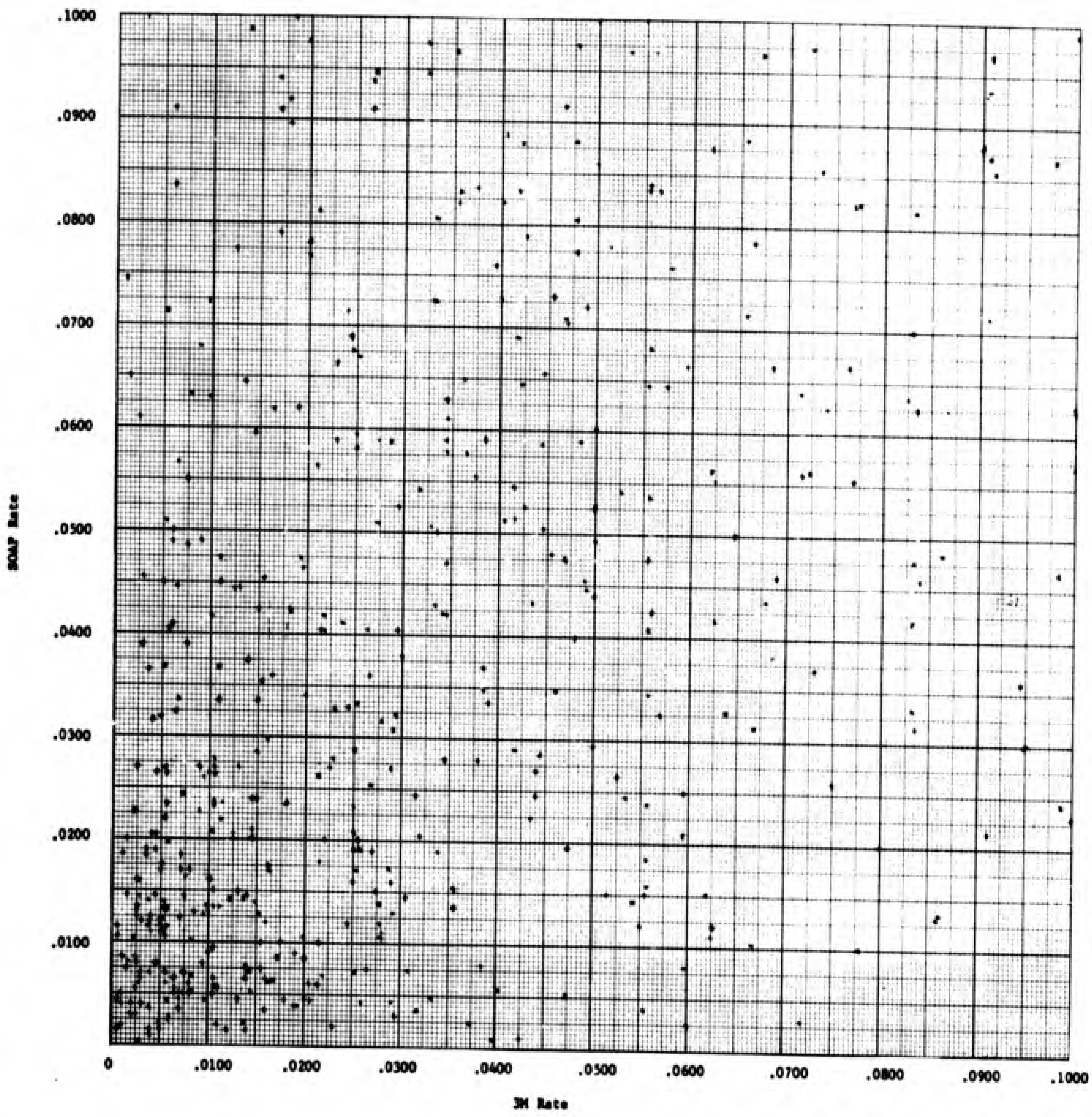
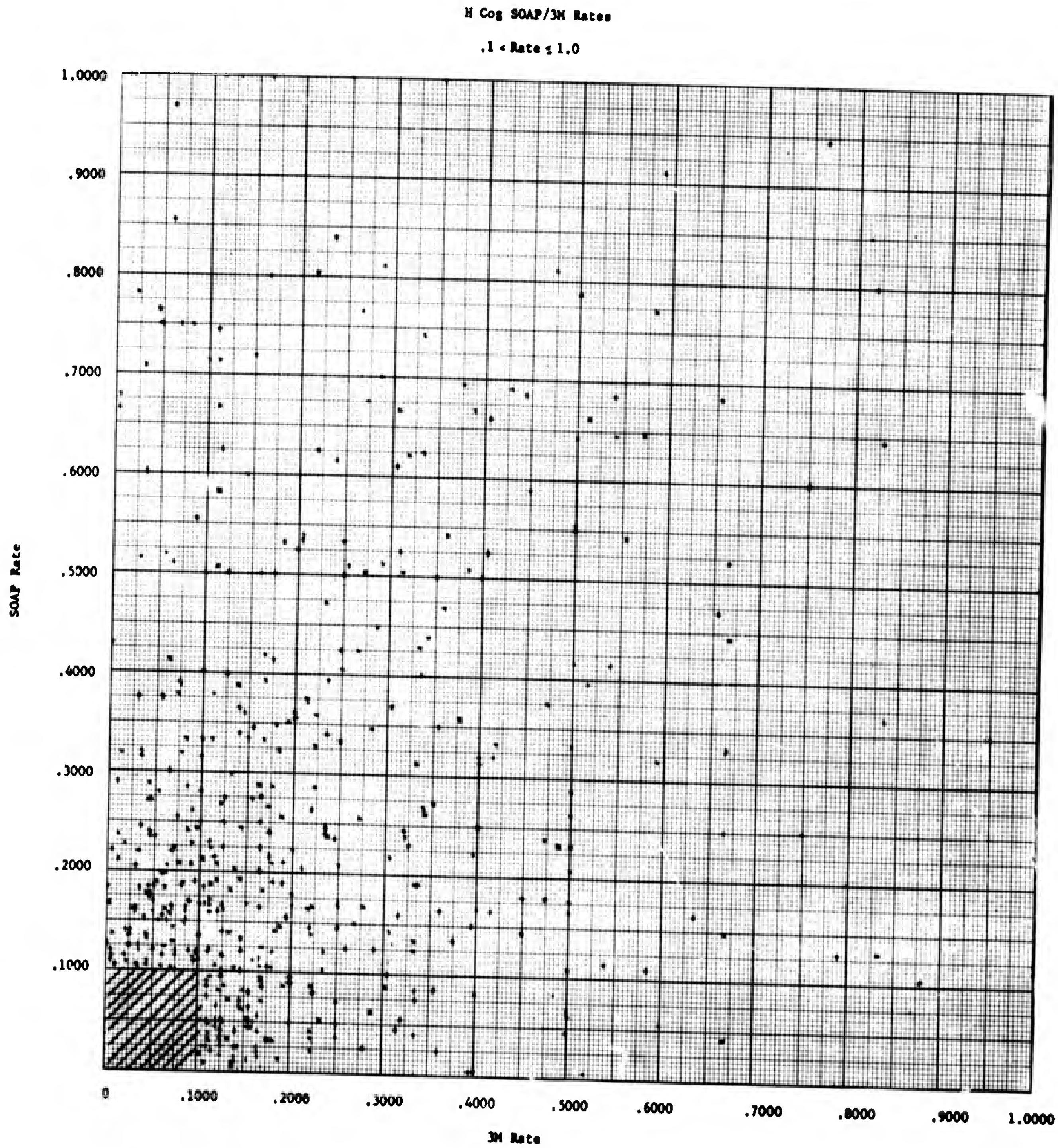


H Cog SOAP/3M Rates

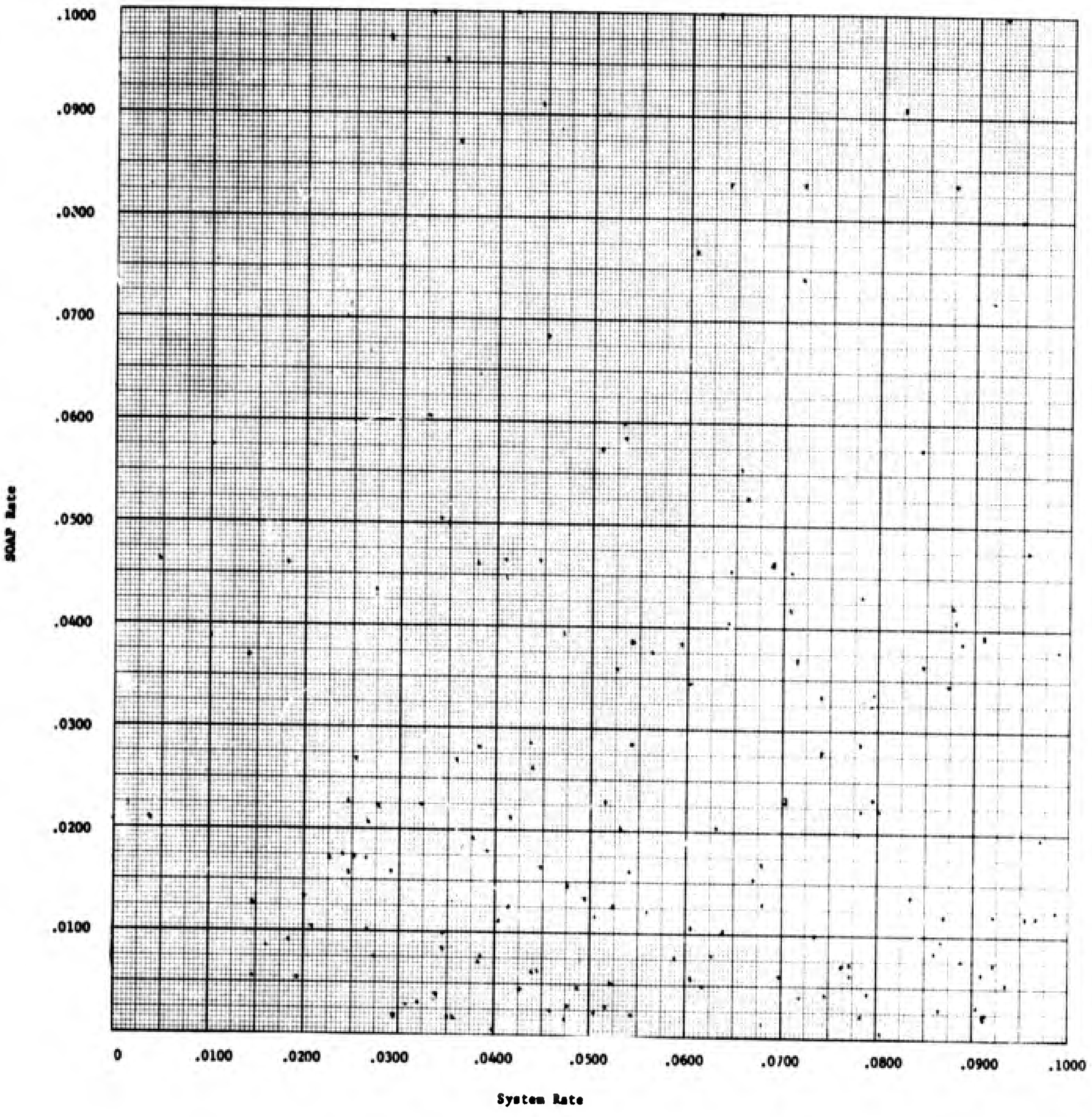
$0 < \text{Rate} \leq .1$




H Cog SOAP/3M Rates
.1 < Rate ≤ 1.0
SOAP Rate
1.0000
.9000
.8000
.7000
.6000
.5000
.4000
.3000
.2000
.1000
0
.1000
.2000
.3000
.4000
.5000
.6000
.7000
.8000
.9000
1.0000
3M Rate

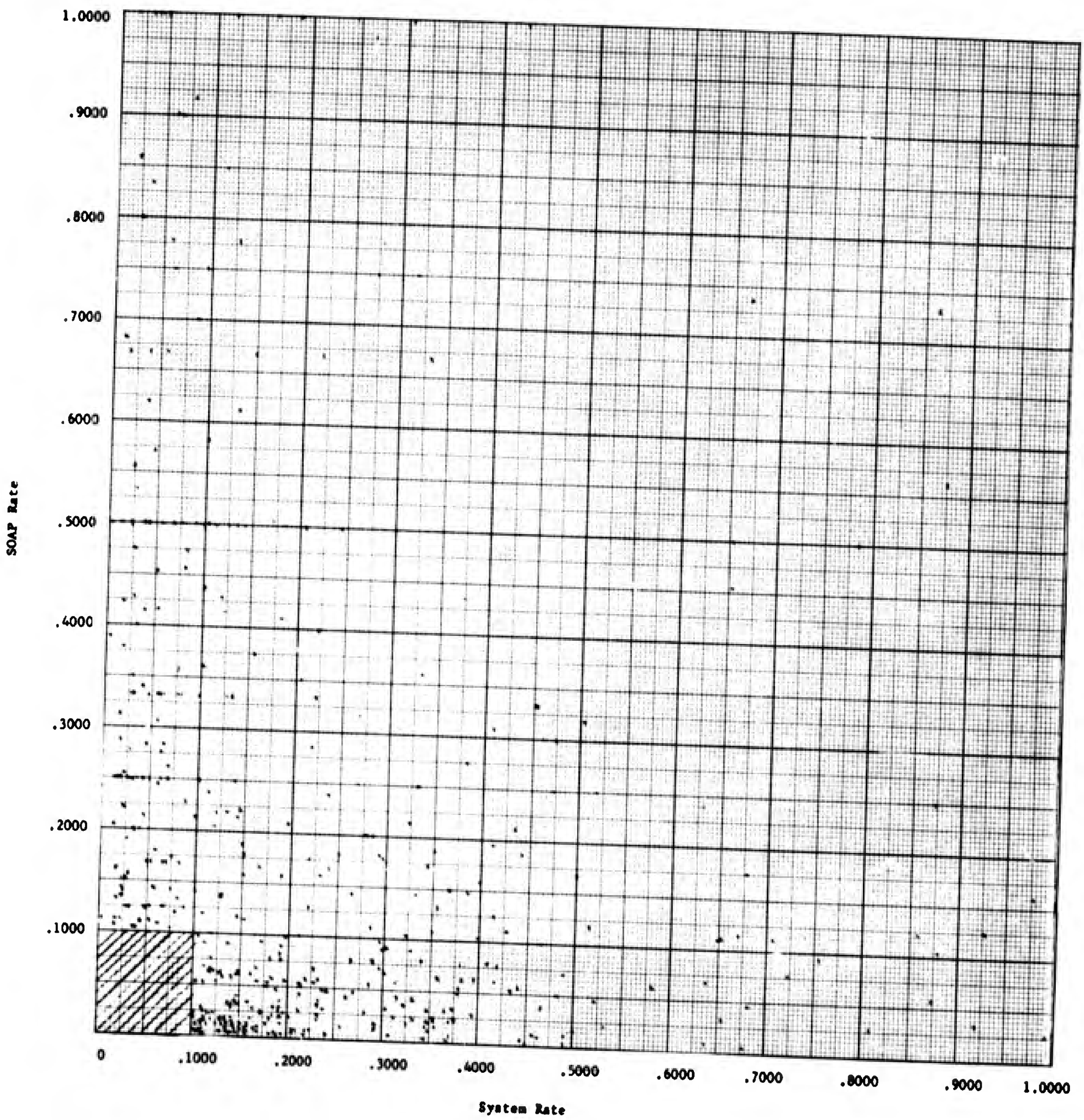
9N Cog System/SOAP Rates

0 < Rate ≤ .1



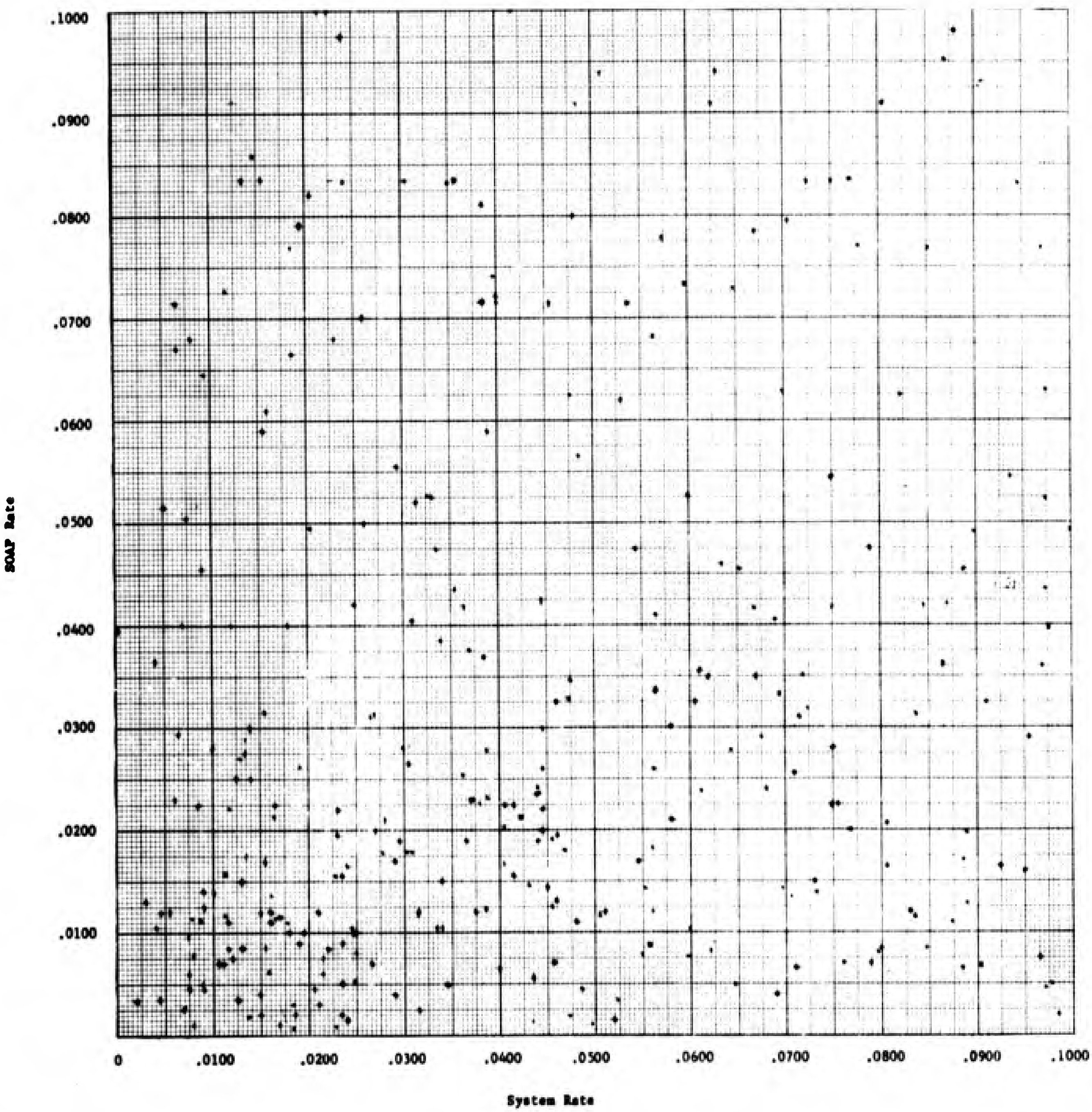
9N Cog System/SOAP Rates

.1 < Rate ≤ 1.0



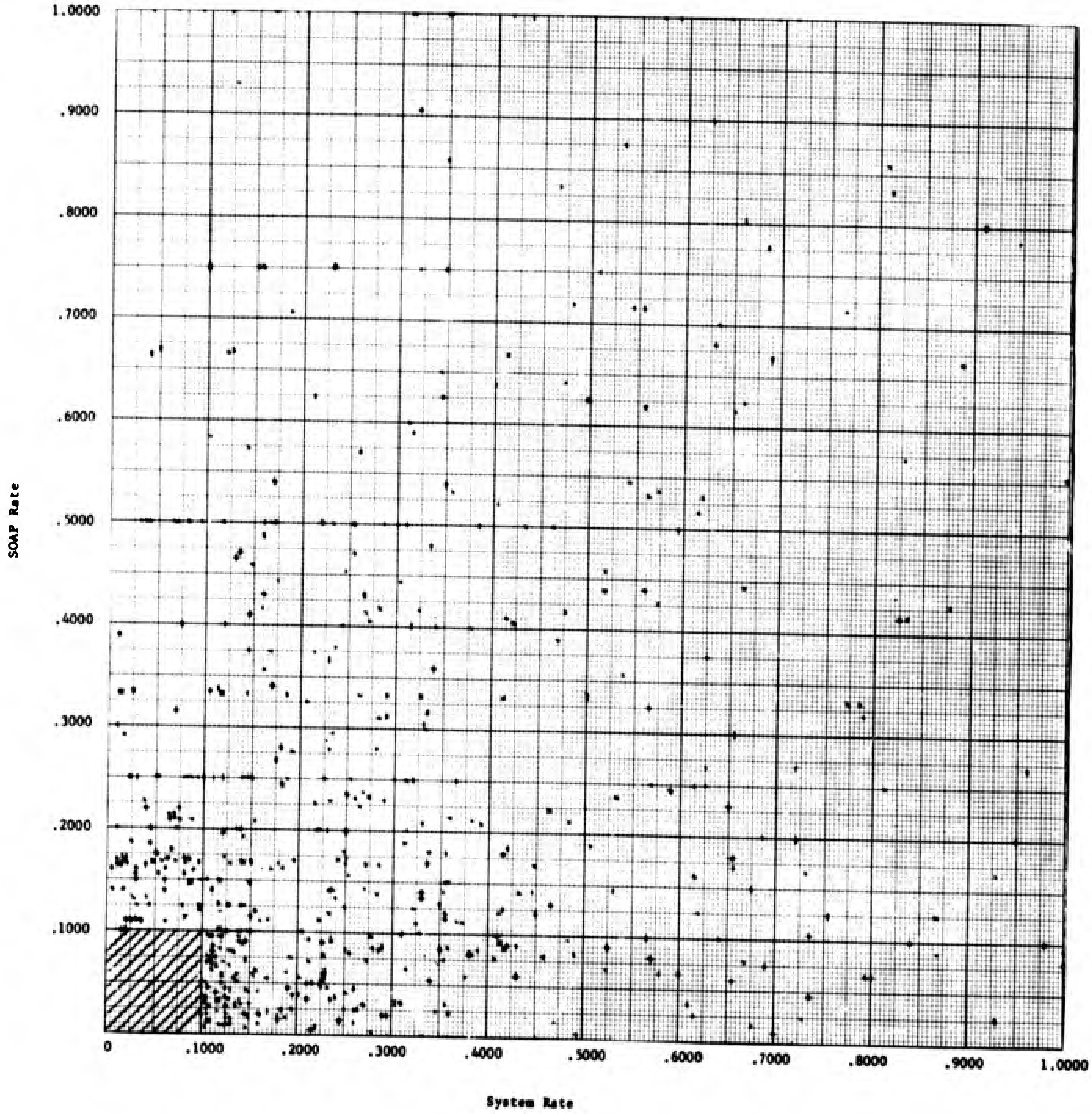
H Cog System/SOAP Rates

0<Rate ≤ .1



H Cog System/SOAP Rates

.1 < Rate ≤ 1.0



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APPENDIX F: NONPARAMETRIC TESTS

Nonparametric tests compare distributions without specifying the form of the distributions. The only assumptions made are that the paired observations (and hence their differences) are independent, and that each observation for system, SOAP, or 3M comes from the same continuous probability distribution.

1. Sign Test. The sign test examines the hypothesis that two samples of data do not differ by examining the distribution of the differences of the paired observations. If the two samples do not differ, the median (middle value) of the differences should be zero and the number of positive and negative signs should follow a binomial distribution with $p = 0.5$, i.e. the number of positive differences should not differ significantly from the number of negative differences. Tables of confidence limits based on the binomial probability distribution are available for determining if the number of positive and negative differences are significantly different (see Natrella: Table A-33; Bowker and Lieberman: Table 7.4).

a. Application. The sign test is applied as follows:

(1) Compute the number of positive differences and the number of negative differences, discarding zero differences.

(2) Compute: n = total number of nonzero differences.

r = number of times the less frequent sign occurs.

(3) Find the critical value (R) of r.

(a) Use tables of critical value for given confidence level and n (see Natrella: Table A-33; Bowker and Lieberman: Table 7.4).

(b) If n is not given in the tables, compute a critical value R as follows:

R = nearest integer less than A-kb

Where

A = median approximated by $\frac{n-1}{2}$

b = range measure approximated by $\sqrt{n-1}$

k = 1.2879, 0.9800, or 0.8224 for the 1%, 5%, or 10% significance levels (two-sided) respectively

(4) If $r > R$, accept hypothesis that there is no significant difference between the two samples. If $r \leq R$, reject the hypothesis that there is no significant difference between the two samples.

b. Example. The sign test is applied below to the H cog sample of system rates and 3M rates. The sample consisted of 1000 items (n = 1000) and the differences (system EDRF - 3M EDRF) were positive for 856 items and negative for 144 items (r = 144). Given the above, determine if there is a significant difference between the two samples at the 1% level of significance.

Compute the critical value (R) of r as follows:

R = nearest integer less than A-kb

$$A\text{-}kb = \frac{n-1}{2} - 1.2879\sqrt{n-1}$$

$$= \frac{1000-1}{2} - 1.2879\sqrt{1000-1}$$

$= 499.5 - 40.7 = 458.8$

Therefore R = 458.

Since r(144) is less than R(458), it is concluded that there is a significant difference between the two samples.

2. Wilcoxon Signed-Rank Test. This test is a modification of the sign test, but is more sensitive than the sign test because the magnitude as well as the sign of the difference is taken into account. The procedure tests the same hypothesis as the sign test, but uses a different approach. If the two samples do not differ, the sum of the positive ranks should approximately equal numerically the sum of the negative ranks.

a. Application. The Wilcoxon signed-rank test is applied as follows:

(1) Compute the paired differences.

(2) Rank the differences without regard to sign. The smallest differences will be assigned rank 1, the next smallest will be assigned rank 2, etc. Ties in the differences will be assigned average ranks; for example, if the smallest value occurs twice, each will be assigned rank $\frac{1+2}{2} = 1.5$. If this value occurred three times, the rank would be $\frac{1+2+3}{3} = 2$.

(3) Give the sign of the original difference to the corresponding rank.

(4) Compute T, the smaller of the positive or negative rank sums.

(5) Find the critical value of T.

(a) Use tables of critical values for given confidence level and n (see Natrella: Table A-34; Bowker and Lieberman: Table 7.5).

(b) For n > 25, T is approximately normally distributed, and the critical value ($T\alpha$) may be computed as follows:

$$T\alpha = \mu - t_{1-\alpha/2}\sigma$$

Where

μ = mean = $\frac{n(n+1)}{4}$

σ = standard deviation = $\sqrt{\frac{n(2n+1)(n+1)}{24}}$

t = standard normal variate

α = significance level

n = sample size

(6) If $T > T\alpha$ accept the hypothesis that there is no significant difference between the two samples. If $T \leq T\alpha$, reject the hypothesis.

b. Example. The Wilcoxon signed-rank test is applied below to the H cog sample of system rates and 3M rates. The sample consisted of 1000 items (n = 1000). The differences (system EDRF - 3M EDRF) were ranked low to high, and the sign of the difference was assigned to the rank. The sum of the positive ranks was 399,314 while the sum of negative ranks was 101,186. Thus T = 101,186. Given the above, determine if there is a significant difference between the two samples at the 1% level of significance (α = .01).

Compute the critical value ($T\alpha$) of T as follows:

$$T\alpha = \frac{n(n+1)}{4} - t_{1-\alpha/2}\sqrt{\frac{n(2n+1)(n+1)}{24}}$$

$$= \frac{1000(1000+1)}{4} - 2.576\sqrt{\frac{1000(2000+1)(1000+1)}{24}}$$

$$= 250,250 - 23,533 = 226,717$$

Therefore $T\alpha = 226,717$.

Since T (101,186) is less than $T\alpha$ (226,717), it is concluded that there is a significant difference between the two samples.

APPENDIX G: REFERENCES

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13. ABSTRACT

The report records the progress in developing usage rates for application at the various echelons in the Navy Supply System. They are needed to accurately determine the repair parts to be carried by the individual ship, aboard the supporting tenders, and ashore. Historically back-up parts requirements were based on replacement factors estimated by engineers or technicians. Usage rates are based on data available at the various echelons. The study compares the various rates developed, applies statistical tests, and suggests additional research to improve the accuracy of current usage rates.