NAVY POSITIVE DISPLACEMENT PUMP STANDARDIZATION STUDY

by

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(ABSTRACT)

A quantitative deficiency exists as defined by the Naval Ships Logistics Center whereby half of the 200,000 supported hull, mechanical and electrical Applied Parts Lists, (or APLs) representing installed equipment, have a population of 5 or less. A 5% yearly growth indicates support costs will be in excess of $300M. With pumps being the largest supported equipment area, a rationale exists for exploring life-cycle cost savings for a standard Navy positive displacement pump. A systems engineering approach for selection and demonstration of life-cycle cost savings of two proposed Navy positive displacement pump cases modeled against status quo is presented at the concept level leading to an optimum. The approach begins with a literature search, followed by data and cost figures derived from current and projected fleet profiles of Naval Ships Logistics Center and Ship Parts Control Center maintained data bases and cost models with a rule-book developed herein for consideration of mission needs with regard to time. FY92 program results indicate: 2200 different positive displacement designs were installed aboard 540 ships; identification of 3-pump group regions; regions bounded by 0-250 psi and 0-460 gpm account for 64% percent of all pump APLs; $84.1M potential acquisition savings is proposed for summation of those pumps in the 64% range over a 20-year time span. From the FY92 data, two of the best possibilities are selected and modeled over a 35-year life cycle. A payback period for a proposed 50 and 200 gpm design is 7 and 11 years for baseline dollars and 7 and 13 years with 5% discounting. A 50 gpm concept is selected based on shortest payback time and logistics based ranking factors. For academic purposes, a potential for standardization exists.

DEDICATION

To my family, friends and co-workers who have made this possible.

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I'm grateful to those individuals and organizations that have provided information and assistance allowing for this paper's technical content. I would like to thank my committee chair person, Professor Blanchard, and committee members, Norman Eiss and James Hanrahan whom have provided good feedback in assembling this effort. I would like to recognize Jim Hanrahan for his excellent flying skills and who was able to provide air transportation to VPI&SU for the Defense.

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I would like to thank CDNSWC for allowing public release of information used herein that is suitable for commercial use. It should be noted that events have prompted limited information for public disclosure with some information omitted and stated, modified or assumed. The author requests that this paper or any portion thereof shall be cited or used with written consent.

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ABBREVIATIONS

ABV	Annual Buy Value
ANSI	American National Standards Institute
APL	Applied Parts List
ARU	Annual Replacement Usage
ASF	Acquisition Savings Factor
ASME	American Society of Mechanical Engineers
ASNE	American Society OF Naval Engineers
C	Total Cost
C_R	Cost of Research and Development
C_{DB}	Cost for Design
C_{TE}	Cost of Test and Qualification
C_{PP}	Cost of Production and Procurement
C_O	Cost of Logistics and Maintenance
CC	Commodity Class
CCF	Component Characteristics File
CCP	Composite Centrifugal Pump
CDNSWC	Carderock Detachment of the Naval Surface Warfare Center
CM	Cost of NSN/APL Maintenance
CP	Cost of Provisioning
DTRC	David Taylor Research Center
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
F.O.	Fuel Oil
g	Gravitational Constant
GPM, gpm	Gallons per Minute
HEDRS	Hull Mechanical and Electrical Equipment Data Research System
Hg	Mercury
ILS	Integrated Logistics Support
IMP	Institute of Modern Procedures
k	Thousand
KHz	Kilohertz
LAN	Local Area Network
MARAD	Maritime Administration
M	Millions
MS	Maintenance Savings
mV/g	Millivolt/gravity constant
MTBF	Mean time between failure
MTBM	Mean time between maintenance
N	Number
NAVSEA	Naval Sea Systems Command
NEMA	National Electrical Manufacturers Association
NOAA	National Oceanographic Atmospheric Administration
NSLC	Naval Ships Logistic Center
NSN	National Stock Number
OSHA	Occupational, Safety and Health Administration

PAS	Potential Acquisition Savings
PESS	Potential Economic Savings for Standardization
PBV	Projected Buy Value
PSI,psi	Pounds per Square Inch
PDP	Positive displacement pump or "Displacement"
Ph	Phase
PPR	Planned Program Requirements
RFI	Radio Frequency Interference
ROI	Return on Investment
RP	Repair Parts Costs
RPS	Repair Parts Savings Factor
SAC	Service Application Code
SAE	Society of Automotive Engineers
SBA	Standardization Benefits Analysis
SCSC	Standardization Candidate Selection Criteria
SPCC	Ship Parts Control Center
SPDPS	Standard Positive Displacement Pumping System
TPIS	Total Potential ILS Savings
TRP	Total Repair Costs
UNREP	Underway Replenishment
USN	United States Navy
V	Volts

I. INTRODUCTORY SECTION

A. OBJECTIVE

1. <u>Background- Definition of Problem:</u> A quantitative deficiency exists as defined by the Naval Ships Logistics Center whereby half of the 200,000 supported hull, mechanical and electrical Applied Parts Lists, (APLs) representing installed equipment have populations of 5 or less. Of the 200,000 APLs, 18% have a single population. A 5% yearly growth indicates support costs will be in excess of $300M. With pumps being the largest supported area, a rationale exists for exploring life-cycle cost savings through the standardization of a Navy positive displacement pump. Results of a literature search presented herein indicate that standardization programs have historically produced cost savings while improving system performance. As an example, there were 638 applied parts lists reductions and $78M savings based on previous standardization programs of 2-inch and under valves, fire pumps and heating, ventilation and cooling equipment. Results from FY92 program efforts indicate there were 2200 different supported positive displacement pump designs installed on 540 ships. Projections presented herein show that even with fleet down-sizing, pump procurement is a future requirement and there will be proliferation if a status quo policy is maintained based on previous history. Results from the FY92 program

efforts presented herein indicate that for a particular positive displacement pump case study $84.1M potential savings can be realized based primarily on acquisition cost savings over a 20-year period.

2. Navy Standard Positive Displacement Pump Objective:

The determination of an optimum positive displacement pump case for a new proposed design effort involving standardization is this study's objective; whereby, two of the best standard positive displacement pump candidates are determined from the possibilities leading to a demonstration of life-cycle cost savings that makes use of a systems engineering approach.

B. THE CASE FOR STANDARDIZING

Development of a new standardized design stems from a rationale whereby, lowered acquisition, operation and support costs are achieved without compromising performance. Historically, performance improvements result from standardization programs where an improved standardized product enhances total ship system capabilities. Improving subsystems performance parameters typically involves higher efficiencies, lighter weight, reductions in quantities (resulting from improved reliability potentially leading to the elimination of redundant systems), spare parts, longer mean time between failures, lower maintenance and shorter down times all translating to longer ship mission capabilities with improved operating envelopes and reduced manning at lowered costs.

For this study, the term status quo refers to the present method for obtaining positive displacement pumps. The status quo is an evolutionary form not involving competitive bulk procurement of standard positive displacement pumps; and where documentation, engineering data, and design drawings are not Navy owned.

Programs implementing standardization may gain benefits over evolutionary forms but not without potentially compromising solutions. Compromise may result from standardization due to: (1) Early end-of-life usefulness whereby new processes, technology, global climate, and/or design may antiquate a standardized design; (2) Limiting system utilization whereby available standardized components may reduce performance, envelope and/or operation; and (3) Limiting selection by relying on standard designs, thus hindering introduction of new designs that potentially have low acquisition costs.

Table 1, Standardization Philosophical Considerations is derived from references 1 through 5 and provides a synopsis of philosophies and omits political considerations. For the purposes of this study it is assumed that past histories define status quo and that although standardization compromises may exist, it is assumed that considerations presented in Table 1, are either in favor of, or do not affect proposed standardized designs.

An alternative to the development of standardized components include standard modules or interface requirement where strict form, fit and functional specifications allow interchangeability between vendor A and vendor B. Form, fit and functional specifications provide stepping stones to good systems design (i.e. modularity) and improved logistic support but maintain proliferation possibilities on component and piece part levels. A simplistic example of a household application having discard-upon-end-use, with no documentation requirements and employs standard modules is the common light-bulb, whereby there are variations in cost and operating life, but has many sources of supply.

The definition of standardization in this paper's original context (circa 1990) infers a new design whereby the Navy has ownership of production design drawings and

TABLE 1, STANDARDIZATION PHILOSOPHICAL CONSIDERATIONS

FOR	AGAINST
Life-Cycle Cost Savings	Eliminates jobs in areas of savings
Improves reliability and availability	Limits selections reducing choices, performance and design optimization.
Reduces downtime	Reduces/eliminates new designs
Ownership of design, data and drawings	Vendor/producer objections
Allows competitive procurement in bulk being less affected by consumer markets	New process or technology may make standardized designs obsolete
Promotes and maintains new technologies based on actual needs.	Standardized designs may not have lowest acquisition costs
Consumer economics dictate through supply, demand and maximum achieved market value	Commitments are long-term and not required for off-the-shelf items.
Enhances mission capabilities with less manning	Design development efforts required or procurement of existing designs
Lengthy ship life-cycle times requires supplier consistency	Creates redistribution of wealth

supporting engineering data. Having complete Navy control over hull, mechanical and electrical component or system design, and material makeup over time positively affects logistics management similar to Navy ship hull design ownership. Cases where there are limited designs, manufacturers and/or production volumes, may indicate Navy ownership not to appear cost-worthy based on acquisition savings alone; however, long term logistics savings may potentially be realized if availability becomes difficult. If availability were to becomes a problem in a down-sized fleet, other issues such as logistically maintaining the correct infrastructure to cope with global climate might become independent of consumer markets. The importance of achieving this study's objective of cost effective standardization has been emphasized with regard to other programs from the top down by Vice Admiral Kenneth Malley, USN, Commander, Naval Sea Systems Command, in his address " Affordability Through Commonality" at the 1992 ASNE Day Presidents Club Luncheon: " We Absolutely cannot afford to continue to introduce large numbers of unique components into the Navy or commercial sector. The infrastructure costs will kill us"[1].

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[1] Naval Engineers Journal, May 1993, page 167.

A time base allowing for the evaluation of life-cycle cost savings for a new standardized Navy positive displacement pump is determined by considering the larger system within which the pump operates. An ideal and convenient time base is assumed for a Navy standard pump life-cycle that equals a ship life-cycle for purposes of maximizing standardization benefits. Examining present ship life-cycles provides a maximum pump life-cycle time increment as an optimum reference point. Present naval ship acquisition processes involve phases spanning long periods of time as depicted by reference 6, <u>Naval Ship System's Class Notes</u>. Trends indicate new class lead ship development times span 10 years from concept to delivery. With 30-year ship service lives and class building lasting 30 years, a window of time exists spanning 55 to 70 years from subsystem development inception to end of service life. During these time spans hull, mechanical and electrical components and system suppliers may potentially change ownership, go out of business, or change models making the objective of achieving life-cycle cost savings through implementing standardized components logistically desirable yet difficult to model based on acquisition savings alone. Figure 1 provides a hypothetical Generic Time-line, depicting the "Long Life of a Naval Ship". For this study's purpose a 35-year pump life cycle is assumed.

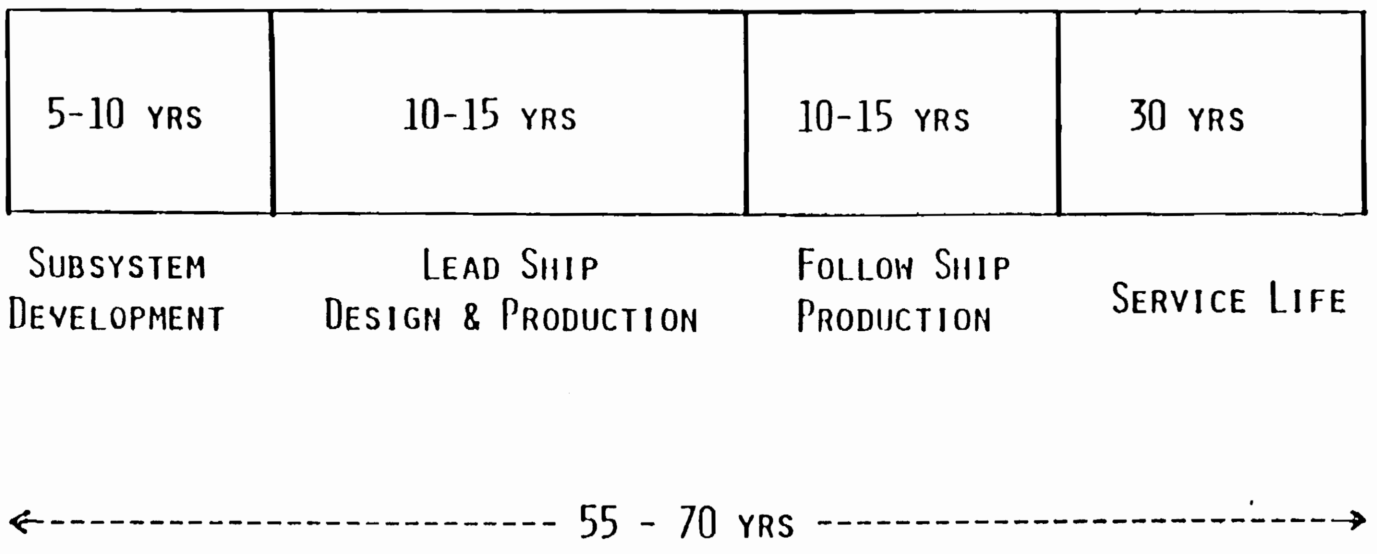

FIGURE 1, LONG LIFE OF A NAVAL SHIP

C. PUMPS

1. <u>Introduction:</u> Wide ranging variations in pump architecture and application require some background in components and systems to visualize a potential for life-cycle cost savings. Results from data developed herein indicate variations covered by five major types, eight major specification areas, and 2200 different supported designs. Since there are many different pump types with each having design variations, there are overlapping possibilities in selection and implementation. Appendix A, provides a technical treatment of pump definition and nomenclature where descriptions are derived from references 7 through 13.

2. <u>Mission Profiles:</u> Four generic positive displacement pump systems mission profiles exist: (1) Single speed operation where the pump is motor driven at constant speed, (i.e. on or off); (2) Multispeed operation where the pump is motor driven by a two or more speed motor, (usually varying flow); (3) Varying speed where the pump is attached to equipment or motor of variable speed, (i.e. attached to machinery); and, (4) Variable volume operation where pump internal mechanisms provide varying flow in response to system demand, (i.e. motion control applications). For practical purposes equipment used in profiles one, two and three could ideally have similar

geometries with profile four's positive displacement pumps possibly having commonality with design internals. Positive displacement pump speed variation alters flow rate but not system operating pressures as depicted in Figures 2, 3, 4, and 5.

Profile 1 shown in Figure 2 has application to emptying or filling requiring operation to be either on or off. Pumps operating in these modes are usually transfer pumps handling fluids such as fuels, lubricating oils, bilgewater and wastewater. Typical examples are operations which pump fuel oil from deep ballast tanks to service tanks.

Profile 2 shown in Figure 3 has application to multiple discrete speeds. Examples include fuel oil service and transfer where fuel consumption related to ship speed determines demand flow rate and pump speeds.

Profile 3 shown in Figure 4 has application to infinitely varying speeds or a necessity to be attached to a prime mover. Examples are lubricating oil pumps attached to rotating machinery where the pump is submerged within a sump supplying oil under pressure to a bearing journal with demand in pressure and flow set within design machinery parameters.

Profile 4 shown in Figure 5 has application to infinitely varying flow and/or pressure. Examples are high pressure hydraulic pumps used in steering gear and winching applications that pump oil under varying pressure and/or flow in response to servo control.

The amount of usage or duration and number of stops and starts defines pump requirements as required by the ship. A ship as a system is profiled to derive usage requirements. Common to profiles 1 through 4 is a generic speed time profile as provided in reference 6 and reproduced as Figure 6 where two profiles exist, for war-time and peace-time. Pump usage is directly related to the ship's operating profiles with an example being increased fuel and oil feed rates with increased ship velocity. Performance specifications are derived from these profiles.

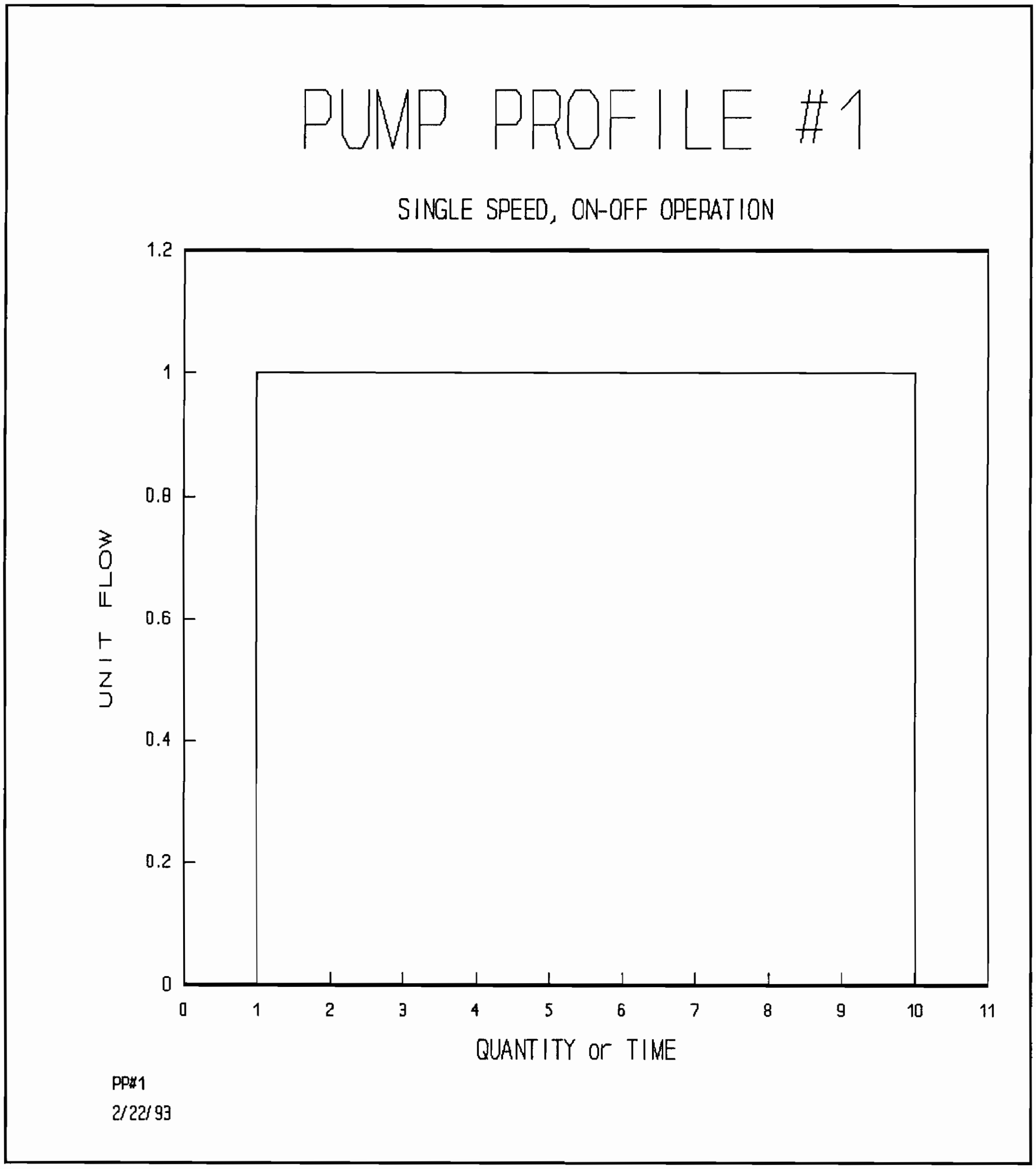

FIGURE 2, HYPOTHETICAL MISSION PROFILE #1: SINGLE SPEED OPERATION

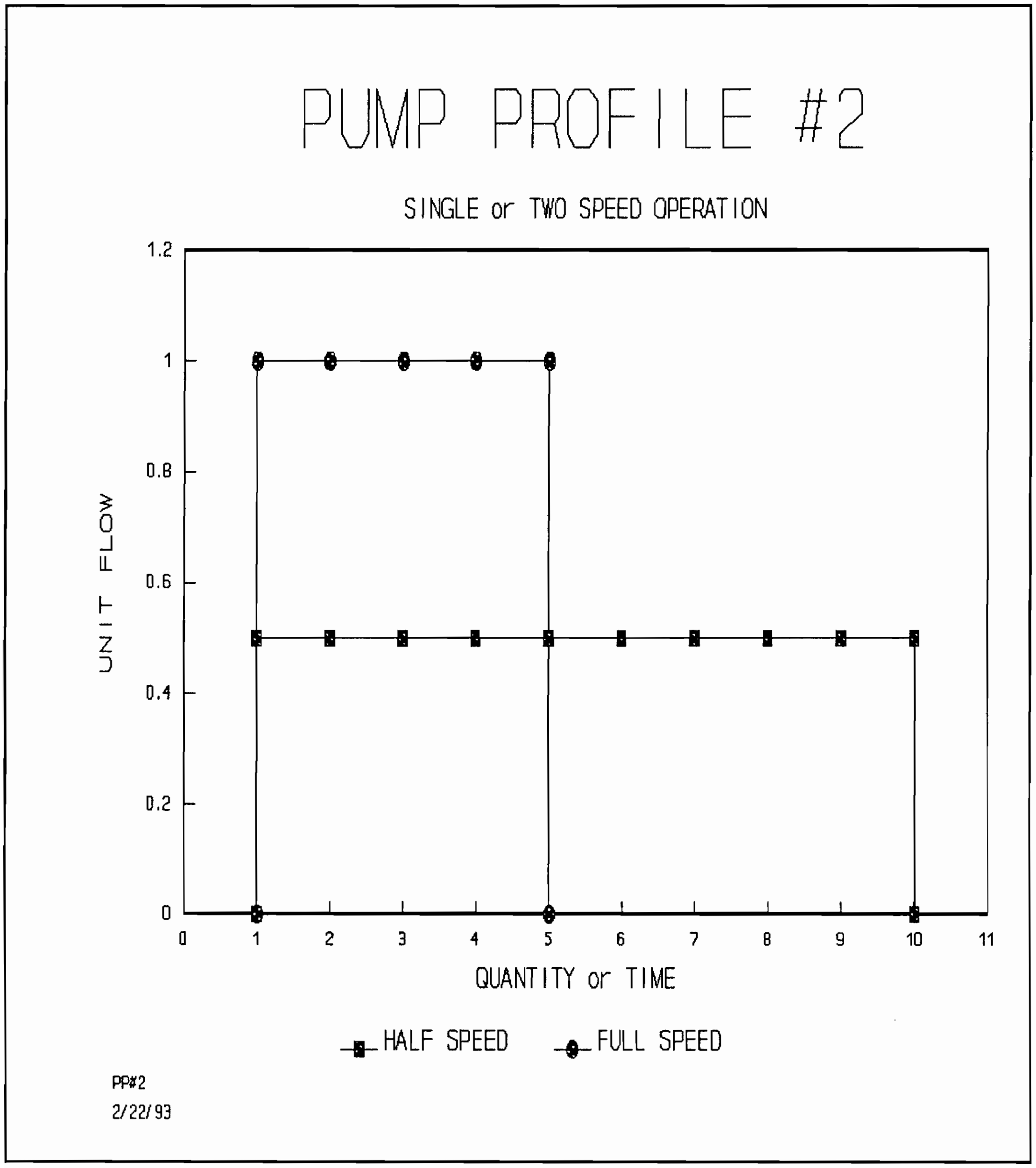

FIGURE 3, HYPOTHETICAL MISSION PROFILE #2: MULTIPLE SPEED OPERATION

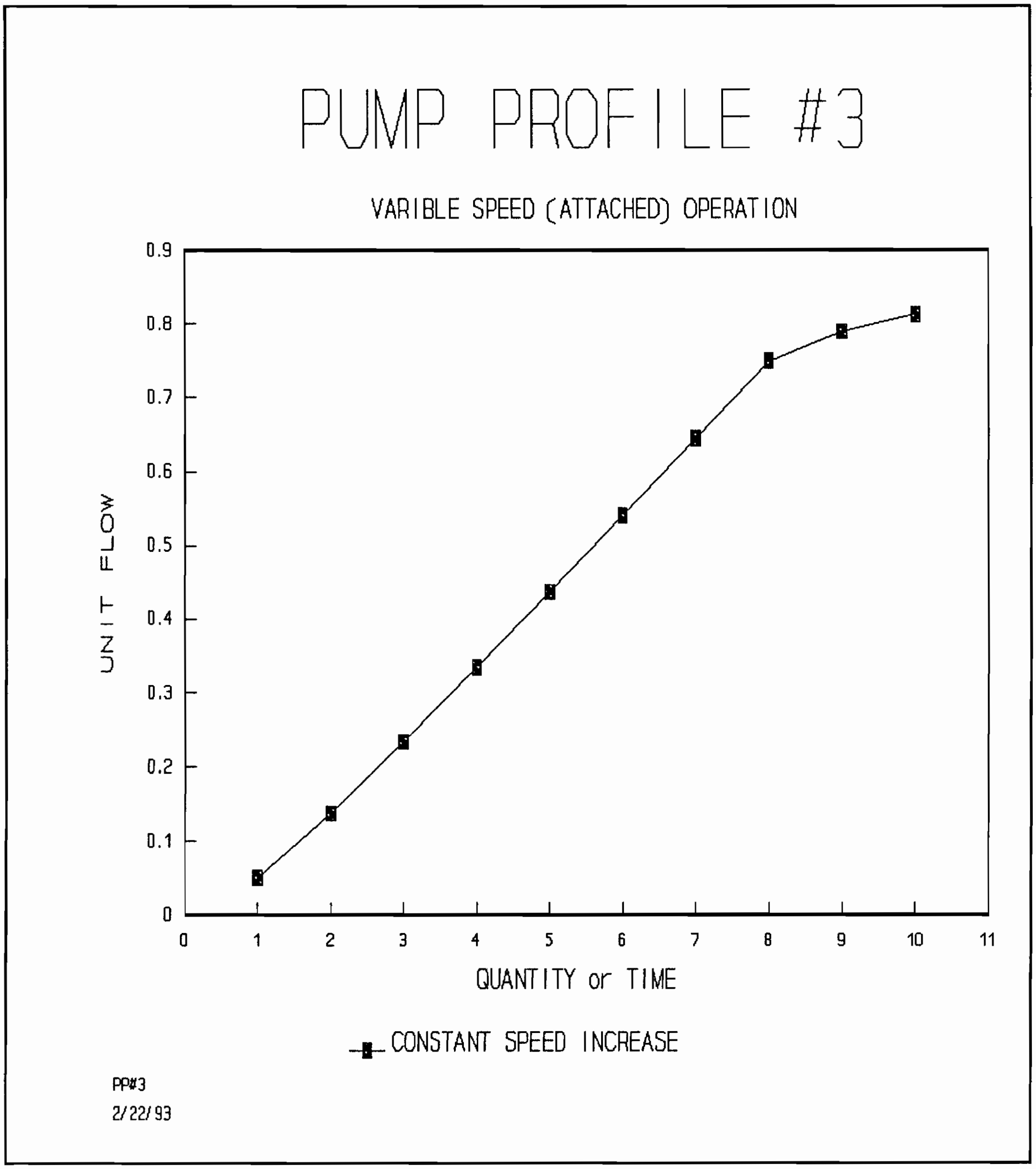

FIGURE 4, HYPOTHETICAL MISSION PROFILE #3: VARYING SPEED OPERATION

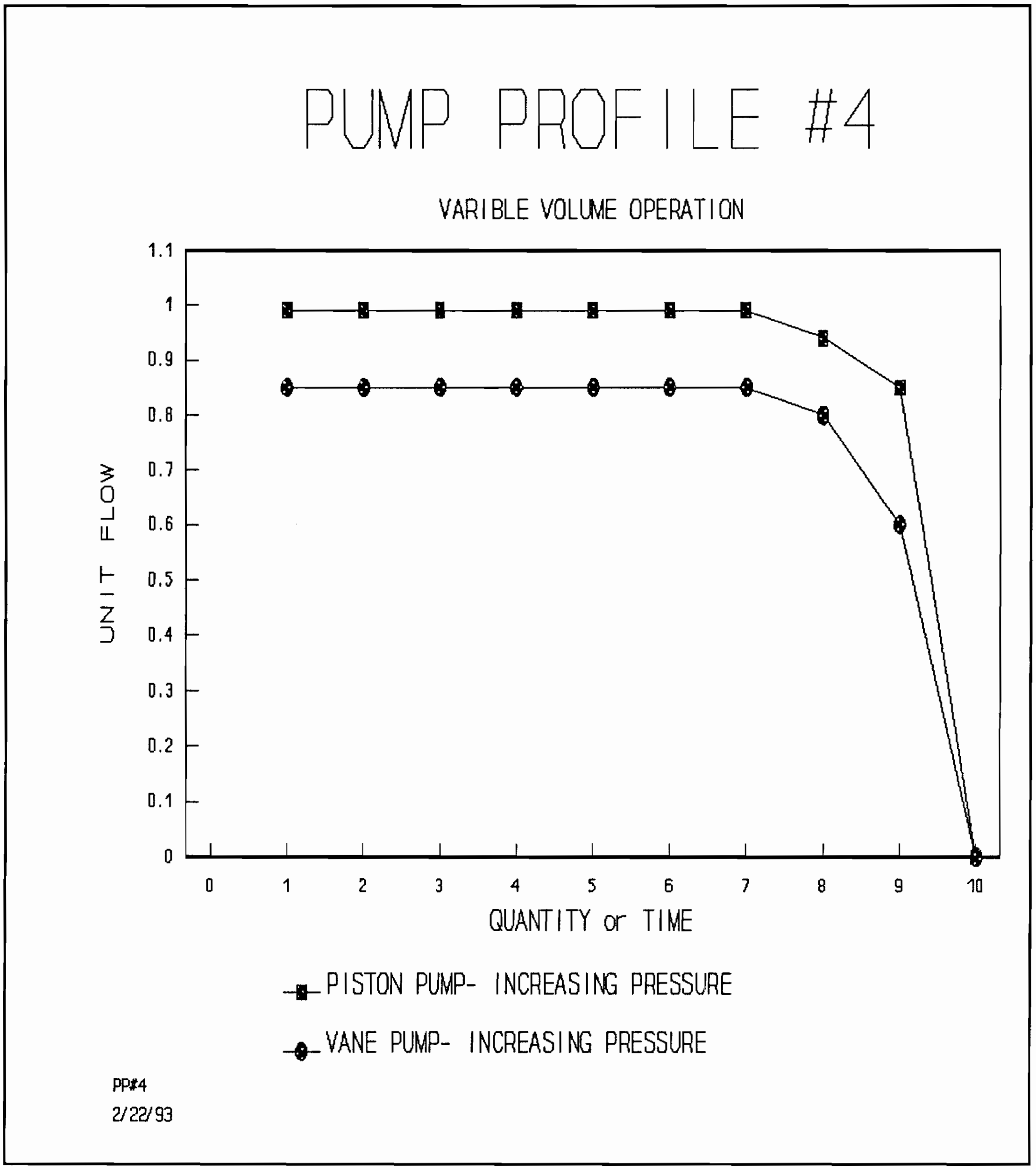

FIGURE 5, HYPOTHETICAL MISSION PROFILE #4:

VARIABLE VOLUME OPERATION

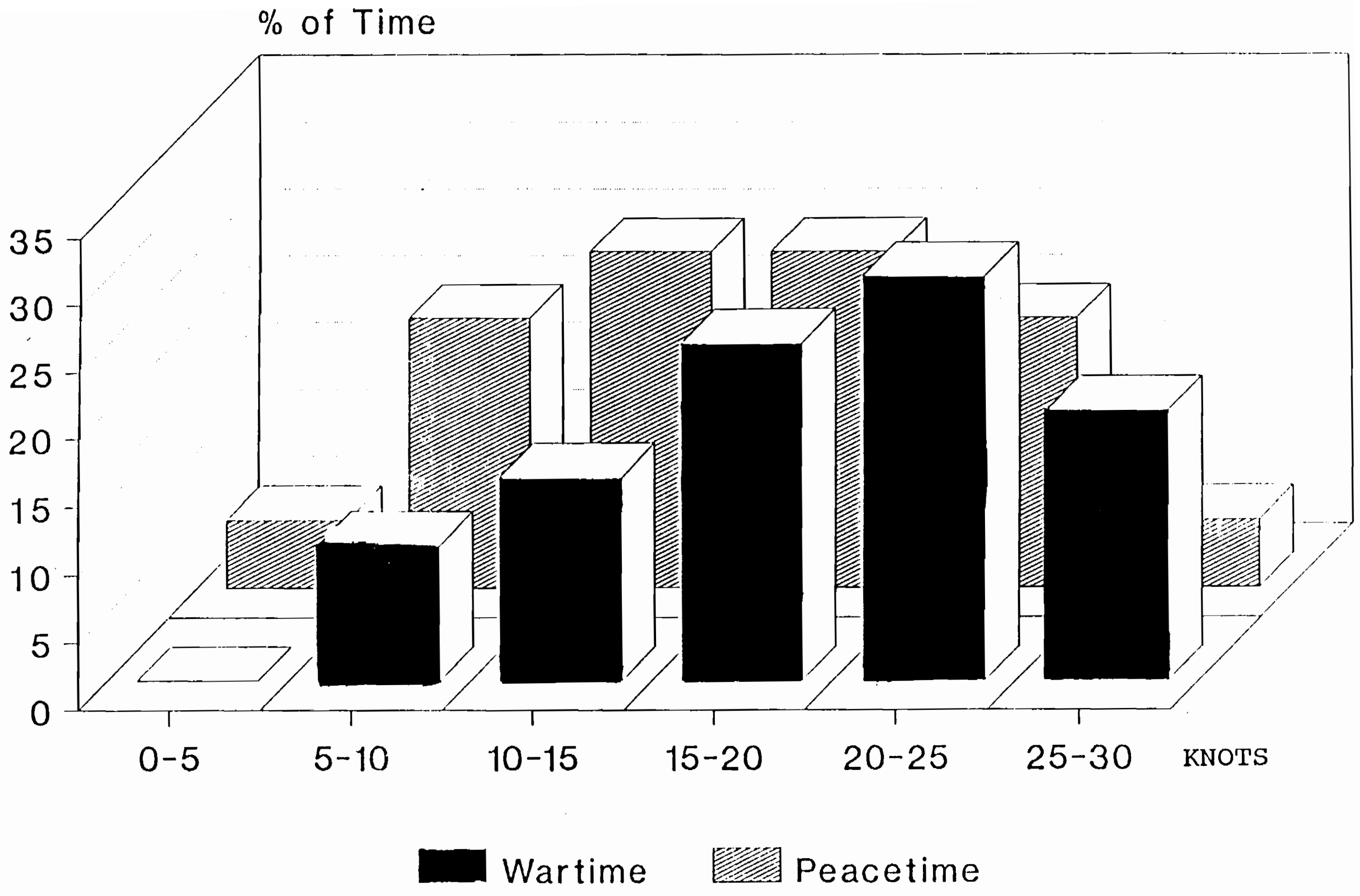

FIGURE 6, SPEED TIME PROFILE

II. REVIEW OF LITERATURE

A. STANDARDIZATION STUDIES

1. Introduction: A precedent for life-cycle cost savings through standardization and lessons learned from previous pump developments results from a literature search. Findings are highlighted as either qualitative and/or quantitative terms in Table 2.

TABLE 2, REVIEW OF STANDARDIZATION STUDIES LITERATURE SUMMARY

TECHNOLOGY AREA	QUALITATIVE	QUANTITATIVE
NSLC STUDY	YES	YES
UNREP STUDY	YES	YES
CCP STUDY	YES	YES
PDP STUDIES	NO	YES
CERAMIC VANE PUMP	NO	YES
INDUSTRY STUDIES	YES	YES
SINGLE SCREW	NO	YES

2. Naval Ships Logistic Center Studies: Navy standardization programs showing success measured in life-cycle cost savings with improved performance includes:(1) Two inch and under valves; (2) Titanium fire pump; (3) P-250 fire pumps; and, (4) Shipboard air conditioning.

Based on reference 4 statistics, \$78M savings were achieved from reducing 638 applied parts lists in (1) through (4). Measures of the degree of non-standardization are indicated whereby 50% of 200,000 hull, mechanical and electrical Applied Parts Lists or APLs have populations of 5 or less. Of the 200,000 APLs, 18% have a single population. If proliferation continues, then a projected 5% yearly growth will create \$300M in maintenance costs. Maintaining a large number of nonstandard designs negatively impacts fleet operational readiness creating "an unacceptable burden"[2]. Equipment statistics maintained by Ships Parts Control Center indicate roughly 68% represent new construction, 20% represent modernization with the remaining resulting from repairs and maintenance actions[3]

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[2] " HM&E Standardization Overview", Standardization of Hull, Mechanical and Electrical Equipments on Ships, NSLC Memorandum., (4120/22510/PROMO), Enclosure 3.

[3] "Telephone conversation with Dick Jones", CDNSWC/NSLC, 7/7/92.

3. Underway Replenishment at Sea Program Studies: Successes with the Navy's Under Way Replenishment at Sea programs were realized only through standardization programs. Reference 5 provides chronological events leading to standardized deck gear, (i.e. winches), indicating histories and systems engineering methodologies for success. In rough numbers highlights indicate, 15 years since the beginning of program inception, 29 out of 52 ships have been standardized. Experience indicates reliability increases, ranging from a factor of two to twenty, depending on winch complexity. Prior to standardization 1,142 winches required 138 technical manuals, however only 19 were required for standardized winches. For 1,142 nonstandardized performance specification design winches, over 500 applied parts lists and 21,000 national stock numbers were required; however, with the 1,312 standardized design winches, only 153 applied parts lists containing 4,450 national stock numbers are required. Under Way Replenishment At Sea Programs success results from demonstrated long term commitments, and systems engineering implementation with standardization philosophies.

4. Navy Composite Centrifugal Pump Program: A standard family of Navy composite centrifugal pumps is being pursued as presented during the American Society of Naval Engineers day in 1993 and described in reference 15. Considerations in developing standard composite centrifugal pumps are primarily twofold: (1) Reducing logistics burdens through design standardization to a useful maximum; and, (2) Technology insertion of proven new composite materials with advanced sealing. The standard composite centrifugal pump program is nearing development completion with units to be available and standardization payoffs realized. Units are slated for both new shipbuilding and back-fit applications. A most immediate payback will be an estimated 25% cost savings realized during acquisition through competitive bulk procurement.

B. POSITIVE DISPLACEMENT PUMP STUDIES

1. Introduction: To achieve the goal of life-cycle cost savings through the selection of a positive displacement pump involving a new standardized design effort, a knowledge base is developed defining mission needs and functional requirements. Previous studies dating from 1979 indicate standard positive displacement pump potentials as improved and standardized machines with developments leading to prototypes. Standardization motivation evolved from experiences: (1) Changing from existing Navy heavy bunker fuel oils (F.O.) to a more refined lighter fuel oil termed Marine Diesel or No. 2 Distillate; and, (2) Implementation of modern day seawater ballast compensated ship architectures.

Problems using new distillate fuels result from fluid characteristics having less lubricity and solvent-like properties as compared to older heavy oils. Fluid properties, such as lowered viscosity, promote thinner film thickness between the pump's moving components thus accelerating wear and making fluid sealing within pressure-sealing envelopes more difficult. As pump components wear, lowered suction capabilities and volumetric efficiencies result. The solvent-like nature of modern marine naval distillates allows contamination to be more easily dissolved into solution. Pump designs operating shipboard during an era of fuel changeovers were prone to failures resulting from contamination and lowered viscosity effects. As a result, the object of life-cycle cost savings through standardization of a new positive displacement pump design addresses failure modes, and mandates corrosion contaminant and tolerant fluid sealing geometries.

Sea water compensated ships are typical of modern Naval ship system architectures where combination fuel oil and ballast tanks are located in deep bottom sections. Operations consist of fuel oil usage from tanks and same tank replenishment with seawater over time thus maintaining near constant ship stability. A mechanical fluid network consisting of pumps, piping, filters and purifiers capable of removing seawater and contamination reliably is required for seawater compensation. Efforts to promote possible non-compensating systems have been looked into recently. A non-seawater compensated ship architecture has been addressed by Levedahl[4] in a rounded-tumble-home-freeboard platform design not requiring a network of mechanical fluid compensation features. Although the possibility of non-compensating systems exists due to ecological rationale, the

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[4] "A Capable, Affordable 21st Century Destroyer", Levedahl, William J. PH.D, Naval Engineers Journal, May 1993, page 221.

future for Naval combatant's pump utilization requirements appears to be status quo. Advantages of compensating systems exceed non-compensating systems for fossil fueled ships requiring high endurance capability. For this reason it appears that near traditional architecture in tank location will dominate.

2. Ceramic Vane Pump: Efforts to develop new standard pump machinery are described within reference 15. NAVSEA contracts dating from the late 1970's promoted improved standardized designs utilizing hard corrosion resistant ceramic pump parts in standardized and interchangeable design formats, culminating in successful demonstrators for fuel oil services. The pump design was geared towards Navy steam fired ships typical of that era, but fleet implementation was never realized. Design philosophy revolved around vane pump interchangeable cam rings with each cam ring corresponding to a discrete displacement. One drawback of such a design philosophy deals with larger physical size and interface when applied to smaller systems at a lower flow and/or pressure.

3. Industry Studies: Reference 16 provides data base development and overview of Naval Combatant major services and systems including fuel oil, auxiliary fuel transfer and

JP-5 systems concluding with selection of several standardization candidates and categories. Highlights indicate recommendations for immediate use and back-fit but does clearly state: **"recommended that Navy-owned standard rotary sliding vane pumps be developed for fuel system applications."**

Reference 17 findings provide standardization philosophy by pump types, services and within manufacturer lines; however, the study does not address standardization in a systems engineering context relative to a new standardized design. Selections are based upon current populations and physical engineering considerations such as form, fit and function. Minimal considerations are directed towards systems engineering aspects such as reliability, maintenance, advanced technology, cost, logistics support and time considerations. An excellent attempt to identify standard fluid systems is reproduced from reference 17 and is provided as Table 3, Current Standard Fluid Classification System that identifies four fluid categories for various service characteristics: "Clean Fluids with Salt Water"; "Clean Fluids Without Saltwater"; "Dirty Fluids"; and, "Special Applications." These classifications show good insight to Navy pumping

TABLE 3, CURRENT PROPOSED FLUID CLASSIFICATION SYSTEM (ref 17)

Clean fluid with Salt Water	Clean Fluids Without Saltwater	Dirty Fluids	Special Applications
JP 5 Defueling JP 5 Transfer Gasoline De-fueling Oily Salt Water Transfer Plumbing and Drainage Cooling Sea Water Pump	JP 5 Booster JP 5 Service Fuel Oil Service Lube Oil Service Lube Oil System Aviation	JP 5 Tank Stripping Fuel Oil Stripping Fuel Oil Tank Drain Lube Oil Transfer Fuel Oil Transfer Cargo Oil Transfer Contaminated Oil Transfer Pollution Control- Oil Abatement Waste Oil Dirty Oil Bilge System Bilge and Ballast Contaminated Water Waste Collecting Tank Drain	Fire Fighting - AFFF Fire Fighting - Fog Foam Booster Fire Fighting- Proportioner

system needs that couple to hardware requirements; but simplification presented herein, as shown in Table 4 provides better clarity.

Improvements in existing commercial designs, (not standardized in this report's context), in severe service applications are highlighted in reference 18 dating from 1979. Results indicate harder contaminant and corrosion resistant materials utilization could increase pump life-cycles beyond existing and will provide a greater reliability. Throughout time, these improvements and others have been implemented, as depicted in reference 16's tabulations of pump types.

4. Navy Standard Single Screw Pump: Navy programs indicated in reference 17 were aimed at developing a Standard Navy Single Screw Pump. Program plans philosophy was geared toward a standard Navy-owned design alleviating proliferation. Prototype development led to a successful 5000 hr demonstration, but implementation was not realized.

TABLE 4, REDUCED PROPOSED STANDARD FLUID CLASSIFICATION SYSTEM

CONTAMINATED CORROSIVE FLUIDS CLASS A	CLEAN FLUIDS WITH LUBRICITY CLASS B
Any fluid media containing fluid mixtures or particulate matter to be filtered. Abrasion, corrosion, poor lubricity or unpredictable viscosity are typical fluid properties.	Fluids that have been purified or filtered and have predictable fluid properties to include a measure of lubricity and corrosion protection.
Columns 1 & 3 of Table 3.	Columns 2 & 4 of Table 3.

III. MATERIALS AND METHODS

A. INTRODUCTION

This study's background, materials and methods are based upon availability, allocation of resources, existing infrastructure and time concerns. Where data, processes and/or methods are modified, it may be stated as, hypothetical, proposed and/or assumed. Methods and materials use the following: (1) Data Base Development-Definition of Navy standard positive displacement pumping needs through current and projected data base development via Naval Ships Logistic center and Ships Parts Control Center current master data bases crossed with projected ship force sizes with a rule-book developed herein that describes a method for determining Navy needs beyond what is generically described in Phase I of the Standardization Candidate Selection Criteria; (2) Standardization Candidate Selection Criteria, where cost benefits are provided for identified groups of pump Applied Parts Lists; (3) Reliability and maintainability considerations, where reliability and maintenance estimates for pump Applied Parts List groups cost savings are realized by materials and design improvements; (4) Proposed standard Design "A" modeled against Design "B" on an equivalent basis with regard to status quo; and, (5) Selection based on life-cycle cost savings and naval ship systems ranking factors.

B. STANDARDIZATION CANDIDATE SELECTION CRITERIA

An algorithm developed by Naval Ships Logistic Center provides a conservative estimate for potential acquisition savings for the implementation of hull, mechanical and electrical equipment standardization.[21] Standardization Candidate Selection Criteria's philosophy is modified as presented herein to include more detail. Additional detail includes a better method for definition of mission need, includes operation and maintenance costs, and further cost reductions due to elimination of supported equipment.

Four phases comprise the Standardization Candidate Selection Criteria. Phase I, Equipment Nominations identifying procedures recommending equipment stratification into functionally similar groups. Phase II, Economic Analysis providing potential acquisition savings based on Phase I groupings. Phase III, Design Selection Analysis determining optimum methods for achieving design standardization. Phase IV, Analysis ranking those groupings having passed phases I-III. Although all four phases are defined, departure from a literal definition, additions and modifications are provided herein adding to the "Systems Engineering" context. Phase I equipment nominations follows from a rule-book for grouping like equipment, developed herein. Pumps are generically grouped by a functional analysis template developed herein. By definition, the Standard Candidate Selection Criteria requires pump data hierarchically segregated by Commodity Class, Lead Allowance Parts lists, Applied Parts Lists and National Stock Numbers. Within each of these is nomenclature descriptive of form, fit, function and application. Standardization Benefits Analysis is preferred for this study due to many positive displacement pump types as described in generic terms within Appendix "A". Standardization Benefits Analysis groups Applied Parts Lists having similar characteristics and contains a model for estimating integrated logistics costs associated with proliferation. Augmenting Phase I is a rule-book described herein that forms a preprocessor aimed at Standardization Benefits Analysis (defining "similar characteristics"). Ignoring applied parts lists to manufacturer ratio during Phase I results from assuming Navy ownership through standardization.

Phase II, Economic Analysis requires obtaining all national stock numbers for each applied parts lists and other related weapon systems file data comprising the national stock number salient characteristics, unit price, planned program requirements, quarterly demand average number of parts per applied parts list, acquisition method code and acquisition method suffix code. Calculating acquisition savings projections requires intermediate steps as defined:

Annual Replacement Usage (ARU) = Planned Program Requirements (PPR) + [(Quarterly Demand-(Quarterly Carcass Return Average * Survival Rate)) *4]

Annual Buy Value (ABV) = Annual Replacement Usage (ARU) * Replacement Price

Total Projected Buy Value (PBV) = ABV*TIME

Potential Acquisition Savings (PAS) = Total PBV * ASF

Time values are user-defined and a goal of a 5-year payback time is promoted as in reference 22. Payback time are results that are determined within the assumed 35-year life-cycle.

Acquisition Savings Factor (ASF) = 25%, a default value that provides a conservative estimate.

Nine variables are identified that comprise Integrated Logistics Support Costs (as defined by this algorithm, and are assumed as costs associated with a management function): (1) Cost of Provisioning Technical Documentation, CPTD; (2) Cost of Provisioning, CP; (3) Cost of NSN/APL Maintenance, CM, (not to be confused with repair maintenance costs); (4) Cost of Training, CT; (5) Cost of Technical Manuals, CTM; (6) Cost of Installation Drawing Changes, CIDC; (7) Cost of Configuration Control, CCC; (8) Cost of Testing, CT; and, (9) Cost of Planned Maintenance, CPM. Determining Standard Candidate Selection Criteria potential Integrated Logistics Support costs includes only CP and CM values, since not all values are known thus yielding a conservative estimate. The Integrated Logistics Support algorithm (where it is assumed that costs are associated with the management function) is as follows:

P = Number of different parts per applied parts list

CP = 450 + 131.25*P

Total CP = CP * L, where L is a projected number of years for APL introductions, for the desired life-cycle.

CM = $448*(.25*P*APR)*[(1/2)*1*(L+1)], where APR is the Average annual proliferation rate. Note: (1/2)*L*(L+1) is a progression factor representing annual incremental increases in national stock numbers for L years. Total Potential ILS Savings or TPIS = Total CP + CM.

Repair parts cost are similarly found where:

RP = Repair Parts Cost from data base

RPS = Repair Parts Cost Savings = RP*ASF

TRPS = Total Repair Parts Cost Savings = RP*ASF*L

Since Phase II only considers applied parts lists proliferation, additional savings are realized due to applied parts lists reductions. According to Cooper[5] annualized estimations following CM rationale follows: Yearly APL Reduction Savings = (L/t)*[448*P*.25*(No. of APLs)]*(.5*L/20), where the time-increment is: (1) t = 20 years for FY92 program efforts, (2) t = the ship or pump life-cycle assumed as 35 years; and, (3) t = 5 years for a desired payback goal.

Standardization Candidate Selection Criteria's Phase III, Design Selection establishing evaluation criteria provides methods for selecting standard designs. The Acquisition Method Code and Acquisition Method Suffix Code indicates if drawings and rights are determined as Navy possessions. Other indicators such as Engineering Support Codes define current levels of support, where A is fully supported, B is obsolete with repair parts only and C is Obsolete. From a logistics viewpoint, indicators such as maintenance costs, repair histories, availabilities and fleet comments provide a reasonable basis for accepting existing designs. Methods for developing standard designs include: Purchasing data and rights, Bailment, Reverse

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[5] "A quote by NSLC's Terry Hibbard as presented by Lynn Cooper for FY92 program review"

engineering, Sole source procurement and developing new designs. Feasibility of each approach requires cost estimating assuming that options exist. For this study's purpose two of the best possible standardized candidates are determined and evaluated for life-cycle cost savings:

(1). Proposed Design "A",

(2). Proposed Design "B" both are

projected against status quo projected proliferation effects. Standardization Candidate Selection Criteria's Phase IV, Group Rankings prioritizes standardization efforts where economic and design factors provide figures of merit. Subjective factors include improved maintenance and reliability.

Processes for realizing cost savings are identified, using the Standardization Candidate Selection Criteria comprised of ILS cost savings (as defined by this algorithm), APL reductions, and PAS. These savings are cumulative over the life-cycle. In other words, what is saved in one year is also saved in following years for a given time frame

or life-cycle.

C. DATA BASE DEVELOPMENT

Positive displacement pump data provided from Naval Ships Logistic Center and Ships Parts Control Center maintained data bases allow several different ways of analyzing positive displacement pumps in terms of the life-cycle. A current data base content provides salient pump characteristics showing an overall current fleet quantity beyond what is depicted within individual technical manuals and drawings. Similar to this data base are positive displacement pump salient characteristics supplied in the Hull, Mechanical and Electrical Data Base Research System, (HEDRS) data base. These are: (1) CAGE; (2) NAVCOM PLAN; (3) MFG DWG; (4) MFR ID; (5) EQUIP SPEC; (6) NSN; (7) NONE LISTED; (8) ENVELOPE DIMENSIONS; (9) INTERFACE REQUIREMENTS; (10) TYPE; (11) CAPACITY; (12) INTAKE; (13) INTAKE CONNECTION TYPE; (14) DISCHARGE; (15) DISCHARGE CONNECTION TYPE; (16) SUCTION LIFT; (17) TOTAL DYNAMIC HEAD; (18) ROTATION; (19) MOUNTING; (20) TYPE DRIVE; (21) POWER RATING; (22) SPEED; (23) MEDIA; (24) MATERIAL; (25) NOISE; AND, (26) SUCTION. Utilizing published Naval Ships Logistic Center HEDRS data on optical disk allows discrete sorts with cross referencing; however, larger application specific files from a master file were required due to the way data is stored and retrieved. Several master data files were requested indicative of current fleet quantities; but shortly after receiving the above data, downsizing was announced at all Navy levels prompting requests for a Naval Ships Logistic future oriented data base descriptive of when standardized pumps would be introduced fleet-wide or a year-2000 estimate. This was deemed necessary since life-cycle cost savings are this study's objective and the life-cycle begins at development stages. Visualizing future oriented fleet data base development considers ship phase outs, new building, and proliferation effects. Published numbers indicate approximately 100 ship short term reductions and long term phase outs, with new introductions totalling 197 ships[6]. Projecting fleet or mission needs is relevant, but accurately projecting within the current global climate is difficult. Causal model techniques were used to emphasize this concept, but determination of actual ship and ensuing pump quantities was performed through an Institute of Modern Procedures algorithm external to this study. Future projections characteristic of current trends are modeled with future projections with and without the effect of proliferation. Modeling processes for visualizing

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[6] Maritime News and Engineering Reporter.

downsizing effects is presented in ; "Systems Approach To Positive Displacement Pump Standardization", term paper for ENGR 5104, 20 April 1992.

Ship Parts Control Centers data bases comprising present money values and Naval Ships Logistics Center's future quantities projection allow net present worth analysis of proposed alternatives and pragmatic selections based on future Navy pumping needs; i.e when pumps are deployed operationally throughout the fleet. Candidate design scenarios are then based on future needs (not necessarily present savings) that are then justified through economic analysis on an equivalent basis.

D. RULE-BOOK FOR DATABASE DEVELOPMENT

A rule-book for enhancing the Standardization Candidate Selection Criteria's Phase I methods beyond those stated considerations is deemed necessary to accommodate the systems engineering approach where relevant factors are considered: (1) time, (2) cost of money; and, (3) mission needs. Investigating relevant systems parameters and component characteristics provides a technical basis allowing a means for differentiating possibilities in a time base. Additional technical preprocessing ensures meaningful results, better describing the mission need with regard to life-cycle cost savings directed towards the infusion of new technology resulting from product development and/or acquisitions over the life-cycle. Since the life-cycle begins in the research and development stage, considerations are paid to developmental, design, production and logistics costs for a new design as relating to time.

Identified in standardized language within the Standardization Selection Criteria, reference 22 Phase I equipment nominations are rational means for initiating standardization studies. Applying sound and practical engineering judgements regarding component characteristics for standardization is simply stated; however, positive displacement pump system complexities demand further definition as could be the case with other systems and component standardization efforts. For this study, data characterization and recognition determine to a large part what standardization potentials exist. A rule-book is shown in Table 5 that lists cursory and general positive displacement generic salient characteristics with functional specification requirements. Using Table 6, a template for data is possible assuming a maximum of generic requirements, thus completing Standardization Candidate Selection Criteria Phase I, equipment nominations.

TABLE 5, RULE BOOK FOR DATABASE DEVELOPMENT

(1) DEVELOP SYSTEM FUNCTIONAL SPECIFICATIONS IN BROADEST OF TERMS ALLOWING TRENDS IN DATA TO BE REVEALED. THE GREATEST POTENTIAL FOR MAXIMIZING APL GROUPINGS IS THUS FORMED. SEGREGATE DATA USING FUNCTIONAL OR RELEVANT SPECIFICATIONS USING NATURAL TRENDS.

(2) DETERMINE WHEN STANDARDIZED COMPONENTS WILL ENTER FLEET OPERATION AND DEVELOP APPLICABLE DATA BASES DESCRIPTIVE OF MISSION NEED FOR APPLICABLE TIME FRAMES.

(3) DEVELOP DATA BASE FOR CURRENT FLEET COSTS.

TABLE 6, RULE-BOOK TEMPLATE

DATA CHARACTERISTIC	FUNCTIONAL OR RELEVANT SPECIFICATION
DISCHARGE/ENVELOPE PRESSURE (1)	ANSI B16.5, PIPE FLANGES AND FLANGED FITTINGS. SHIP CLASS PUMP TABLES FROM SHIPBUILDING SPECIFICATIONS.
SUCTION PRESSURE (1)	SHIP CLASS PUMP TABLES FROM SHIPBUILDING SPECIFICATION. PUMP SPECIFICATIONS.
FLOW (1)	GENERAL SPECIFICATIONS FOR SHIPS OF THE UNITED STATES NAVY. SHIP CLASS PUMP TABLES FROM SHIPBUILDING SPECIFICATION.
MECHANICAL INTERFACE (1)	ANSI B16.5, PIPE FLANGES AND FLANGED FITTINGS. SAE SHAFTING AND MOUNTING.
TYPE (1)	PUMP TYPES AS DEFINED IN HEDRS DATA BASE AND SPECIFICATIONS.
DRIVER (1) (2) (3)	DRIVER TYPE AS DEFINED IN HEDRS DATA BASE. HORSEPOWER REQUIREMENTS AS PER HYDRAULIC INSTITUTE STANDARDS OR RELEVANT SPECIFICATION.

NOTE (1): Additional specifications define these requirements. See references 7 and 11 through 13.

NOTE (2): Mil-M-176060E "Military Specification, Motors, 60-Hertz, Alternating Current, Integral-Horsepower, Shipboard Use.

NOTE (3): For other motor specification requirement references See references 7 and 11 through 13.

E. RELIABILITY AND MAINTENANCE CONSIDERATIONS

Standardization Candidate Selection Criteria is not automated for maintenance repair man-hours costs, (but is automated for maintenance of applied parts lists and national stock number software costs), and does not provide maintenance man-hours costs. The Standardization Candidate Selection Criteria does however consider parts consumption and return core values with maintenance costs and reliability impact noted as key indicators for ranking external to automation processes.

A study emanating from CDNSWC's logistic group makes use of a 3M data base that provides a 5-year historical reliability and maintainability analysis. Extrapolating reliability and maintainability cost is provided over an entire projected life-cycle. Reliability and maintainability data includes information as supplied in Table 7:

TABLE 7, RELIABILITY AND MAINTAINABILITY DATA

(1) Fleet impact from the past five years
(2) Flow range
(3) Applied parts lists
(4) Equipment Population
(5) Nomenclature
(7) Corrective Maintenance man-hours, MMHR
(8) Corrective Maintenance Actions, MA
(9) Corrective Man hour cost, MHRC
(10) Parts Cost, PC
(11) Total Repair/replacement cost, Cost/Design

Cost savings from improved designs and materials result from an increasing reliability, reduced maintenance man-hours and parts costs. Factors for assessing improvements are based upon case history estimate where improvements have been made. These factors correspond to an estimated 40% improvement in reliability based on case histories, estimates of like materials, and design improvements. Maintenance man-hour costs are $15/hr.

F. ECONOMIC EVALUATION

For the purposes of this study, two of the best possible design configurations are determined and a demonstration of life-cycle cost analysis is used to determine an optimum selection: Proposed Standard Design "A",; vs, Proposed Standard Design "B" with regard to status quo where there are proliferation effects.

Evaluating the two possible designs on an equivalent basis follows criteria presented within chapter 8, reference 1. Table 8, states those assumptions used in performing the economic evaluation. Money costs are estimated at 5%, based on a 10-year treasury note. Life-cycle cost analysis estimates are comprised of costs associated with tasks identified at the concept level in the Systems Engineering Acquisition Management Plan, Table 9.

TABLE 8, MONEY COSTS AND TIME FACTORS SUMMARY

INTEREST RATE	5%
SHIP OPERATING LIFE	30 YEARS
DESIRED PAY BACK GOAL	5 YEARS
INVESTMENT TIME	5 YEARS

TABLE 15, SYSTEMS ENGINEERING ACQUISITION MANAGEMENT PLAN

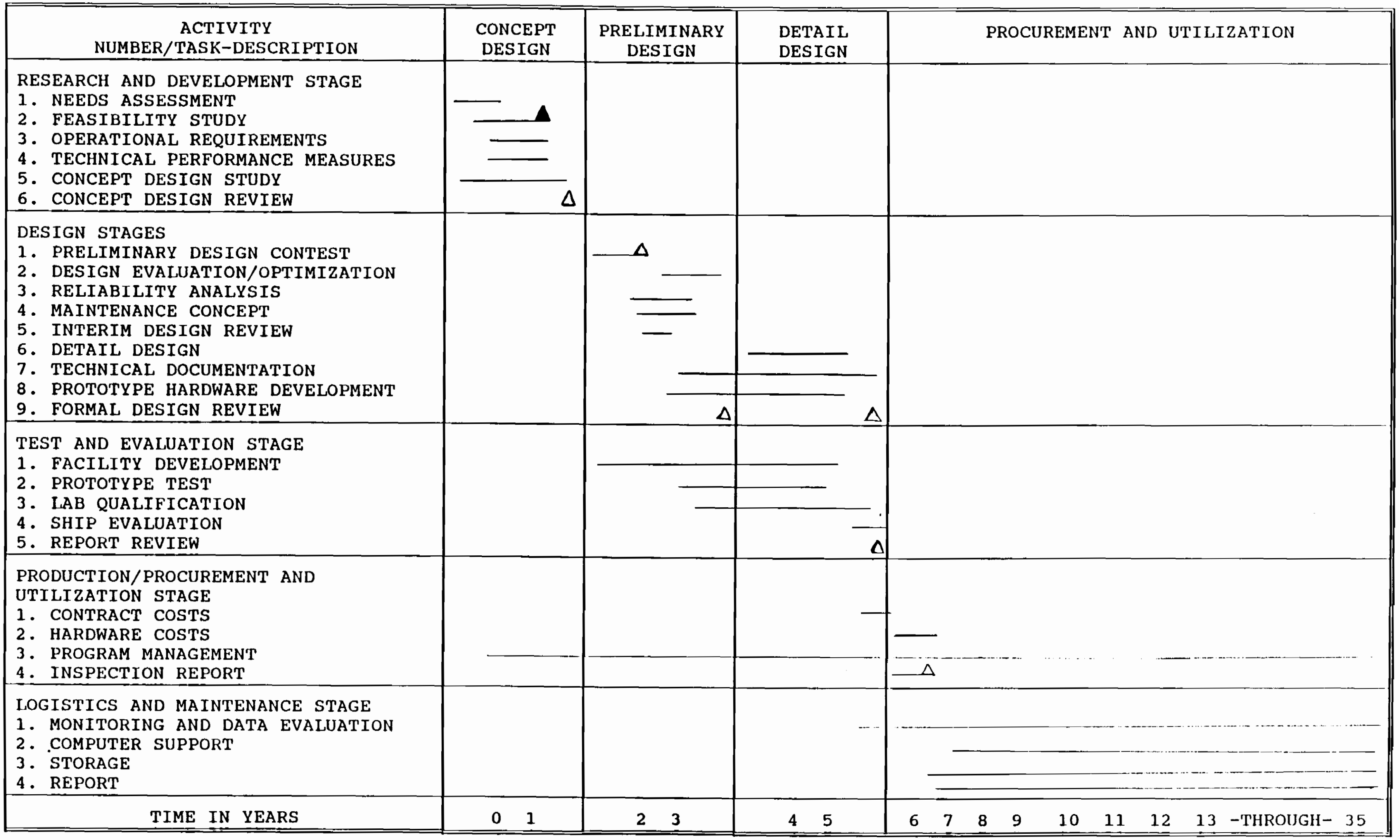


Table 10, Cost Breakdown Structure with description identifies major cost categories with description for use at the concept level in identifying costs associated with the tasks as shown in Table 9 for developing a new standardized design and for comparison with status quo. Methods used for identifying costs categories results from: (1) availability of data describing the status quo; (2) cost for estimation of a new system with respect to availability of status quo cost figures and with regard to reference 1, appendix C. Only the most significant and available costs are identified at the concept level.

Table 11, Economic Evaluation Formula Summary provides detail assumptions and considerations used throughout the life cycle in cost estimating. Output from this table allows for a tabulation of data plotted as the cost stream over a 35-year life-cycle to show when a payback time is achieved. Baseline present year dollars and discounted dollars are tabulated. Considerations in developing Table 11, use those factors listed in Tables 9 and 10. New standardized designs will require up front investing costs in the areas of Research and Development, Design, and Test and Qualification; whereas, the status quo costs in areas of Research and Development, and Design are not required. Costs for status quo Test and Evaluation are estimated over the life-cycle by a percent of estimated production cost. A means for estimating baseline status quo costs are derived from the cost benefits study provided as in Standardization Selection Criteria. Since the principle values for determining cost savings is a 25% acquisition savings factor, actual status quo Production and Procurement costs are estimated as:

(1) Status quo actual estimated cost = (Cost Savings)/.25

Then for standardized designs;

(2) Standardized actual estimated cost = .75*(Status quo).

Since new proposed standardized pumps will require a one time bulk competitive purchase, Production and Procurement costs are modeled as such at the end of year-5; whereas status quo designs costs are an incremental yearly purchase.

Status quo Logistics and Maintenance costs are estimated from Reliability and Maintenance costs and occurs throughout the life cycle. Method for achieving an estimate assumes that available data describing status quo is incomplete by a factor of two. Estimating costs for the new standardized design assumes that improvement in design leads to a reduction in Logistics and Maintenance costs by a factor of 2 and 2.5 respectively for Design "A" and Design "B" (Where this is elaborated upon in the results section).

TABLE 11, ECONOMIC EVALUATION FORMULA SUMMARY

MAJOR ITEM DESCRIPTION	YEAR (0-5)	(5-7)	(7-30)
RESEARCH AND DEVELOPMENT			
DESIGN "A"	INCREMENTAL	NONE	NONE
DESIGN "B"	ESTIMATES	NONE	NONE
STATUS-QUO "A"	NONE	NONE	NONE
STATUS QUO "B"	NONE	NONE	NONE
DESIGN COSTS			
DESIGN "A"	INCREMENTAL	NONE	NONE
DESIGN "B"	ESTIMATE	NONE	NONE
STATUS-QUO "A"	NONE	NONE	NONE
STATUS QUO "B"	NONE	NONE	NONE
TEST AND QUALIFICATION			
DESIGN "A"	∝ R & D COST	NONE	NONE
DESIGN "B"	∝ R & D COST	NONE	NONE
STATUS-QUO "A"	ESTIMATE	ESTIMATE	ESTIMATE
STATUS QUO "B"	ESTIMATE	ESTIMATE	ESTIMATE
PRODUCTION AND PROCUREMENT			
DESIGN "A"	.75*"A"	NONE	NONE
DESIGN "B"	.75*"B"	NONE	NONE
STATUS-QUO "A"	"A" ∝ DATA	"A" ∝ DATA	"A" ∝ DATA
STATUS QUO "B"	"B" ∝ DATA	"B" ∝ DATA	"B" ∝ DATA
LOGISTICS AND MAINTENANCE			
DESIGN "A"	("A"/2)	("A"/2)	("A"/2)
DESIGN "B"	("B"/2.5)	("B"/2.5)	("B"/2.5)
STATUS-QUO "A"	2*(DATA)="A"	2*(DATA)="A"	2*(DATA)="A"
STATUS QUO "B"	2*(DATA)="B"	2*(DATA)="B"	2*(DATA)="B"
YEARLY SUMMATION	SUMMATION	SUMMATION	SUMMATION

TABLE 10, COST BREAKDOWN STRUCTURE WITH DESCRIPTION

MAJOR COST ITEM	DEFINITION OF COST
RESEARCH AND DEVELOPMENT C_R	Feasibility studies to determine standardization potentials, basic research in pump design and materials, engineering design, documentation, prototype and program management.
DESIGN COSTS C_{DB}	Detail design efforts where pump definition and development occurs. Elements include system design, mechanical, structural, electronic engineering, logistics, producability, standardization, reliability, maintainability engineering. Navy owned technical data, documentation, and drawings are produced as a result of this stage.
TEST AND QUALIFICATION C_{TE}	Qualification of new equipment. Costs include interface requirements, test facilities and operator time for evaluations, inspection and reports.
PRODUCTION AND PROCUREMENT C_{PP}	Acquisition of hardware, packaging, shipment, and storage. Program management costs for contracting efforts.
LOGISTICS AND MAINTENANCE C_0	Labor and travel associated with monitoring components over the life-cycle and providing logistics management for implementation and phase out of old to new designs.

TOTAL COST = $C = C_R + C_{DE} + C_{TE} + C_{PP} + C_O$

G. EVALUATION SUMMARY

Logistic support analysis criteria as presented in chapter 6 of reference 2 in conjunction with preceding sections allows for an evaluation based on naval ship systems factors. Table 12, defines major evaluation parameters with subjective qualitative weighing factors. Base rates are determined indicative of the degree of compatibility with meeting desired goals ranging from 1 to 10. Scores are obtained by multiplying weighing factors by base ratings. The highest total score represents a best choice based upon total model content to include cost-make up with final scores ranging between 1 and 100. Rationale for determining weighing factors stems from both Naval Ship Systems Design Philosophy-Weighing Factors and cost benefits analysis. Risk or probability is identified within each evaluation parameter that modifies best cost data with desirable operational system requirements allowing for a selection based on all concerns.

TABLE 12, NAVAL SHIP SYSTEMS DESIGN PHILOSOPHY-WEIGHING FACTORS

1	COMBAT CAPABILITY	10
2	ACQUISITION COST	10
3	SHIP DISPLACEMENT	5
4	ENERGY CONSERVATION	5
5	MANNING REDUCTION	5
6	OPERABILITY	5
7	PASSIVE SURVIVABILITY	5
8	BLOCK UPGRADE/FUTURE GROWTH	5
9	HABITABILITY	2.5
10	APPEARANCE	2.5
11	MINIMUM RISK	2.5
12	STANDARDIZATION	2.5

IV. RESULTS

A. INTRODUCTION

Evaluation of the data allows for a selection of two of the best candidates. These candidates are then modeled against status quo to determine an optimum selection.

B. STATISTICS FROM THE RULE-BOOK

Results indicate : (1) Table 13, Approximately 2200 applied parts lists, and 36,000 pumps installed aboard 540 ships as of 1992; (2) Figure 7, The scatter plot of pressure vs flow shows a numerical plotted for each supported design point indicating a potential for both overlap and redundancy at many points with discrete pump regions indicated by color banding and by pressure are Hydraulics (10,00-2000 psi), Lube oil (400+ gpm), fuel oil phase-out (around 1000 psi) and a broad area (below 250 psi and 450 gpm), fuel and misc services; (3) Figure 7, 64% of all pumps fall within 250 psi and 400 gpm or the region depicted in yellow; (4) Figure 8, Twelve discrete pump sizes are possible based on standard pipe and flange sizes ranging from 1/8" to 3 1/2"; however, six line sizes appear to be an optimum based on practical input from cognizant sources; (5) Figure 9, Projected population based on future needs for discrete flow ranges indicates that a mission need exists in the 50 gpm flow range; (6) Figure 10, All flow ranges have projected proliferation based on present average rate for discrete flow ranges and further confirms that a 50 gpm flow range is a best candidate for selection based on future needs; and, (7) Figure 11, Minimum specification suction requirements of 10" Hg. as depicted with Figure 12 showing over 8 specifications requirements defines technical performance specifications.

TABLE 13, DATA BASE SALIENT CHARACTERISTICS

SHIPS	QUANTITY
AD	7
AE	12
AFDB	2
AFDL	2
AFDM	4
AFS	7
AGF	2
AO	5
AOE	6
AOR	7
AR	2
RD	3
ARDM	5
ARS	11
AS	12
ASR	6
ATF	2
ATS	3
BB	4
CG	45
CGN	9
CV	8
CVN	7
DD	31
DDG	22
FF	40
FFG	51
FFT	8
LCC	2
LHA	5
LHD	4
LKA	5
LPD	14
LPH	7
LSD	13
LST	20
MCM	9
MHC	2
MSO	15
PCH	1
PG	8
PHM	6
TAE	1
TAF	1
TAFS	3
TAG	1
TAGM	3
TAGOR	3
TAGOS	22
TAH	2
TAK	3
TAKR	3
TAO	26
TAOT	9
TARC	3
TAFT	7
TOTALS	540

TOTAL PUMP APLS=2200

PUMP APLS HAVING PRESSURE AND FLOW DATA=1640

PUMP APLS HAVING SUCTION DATA=15

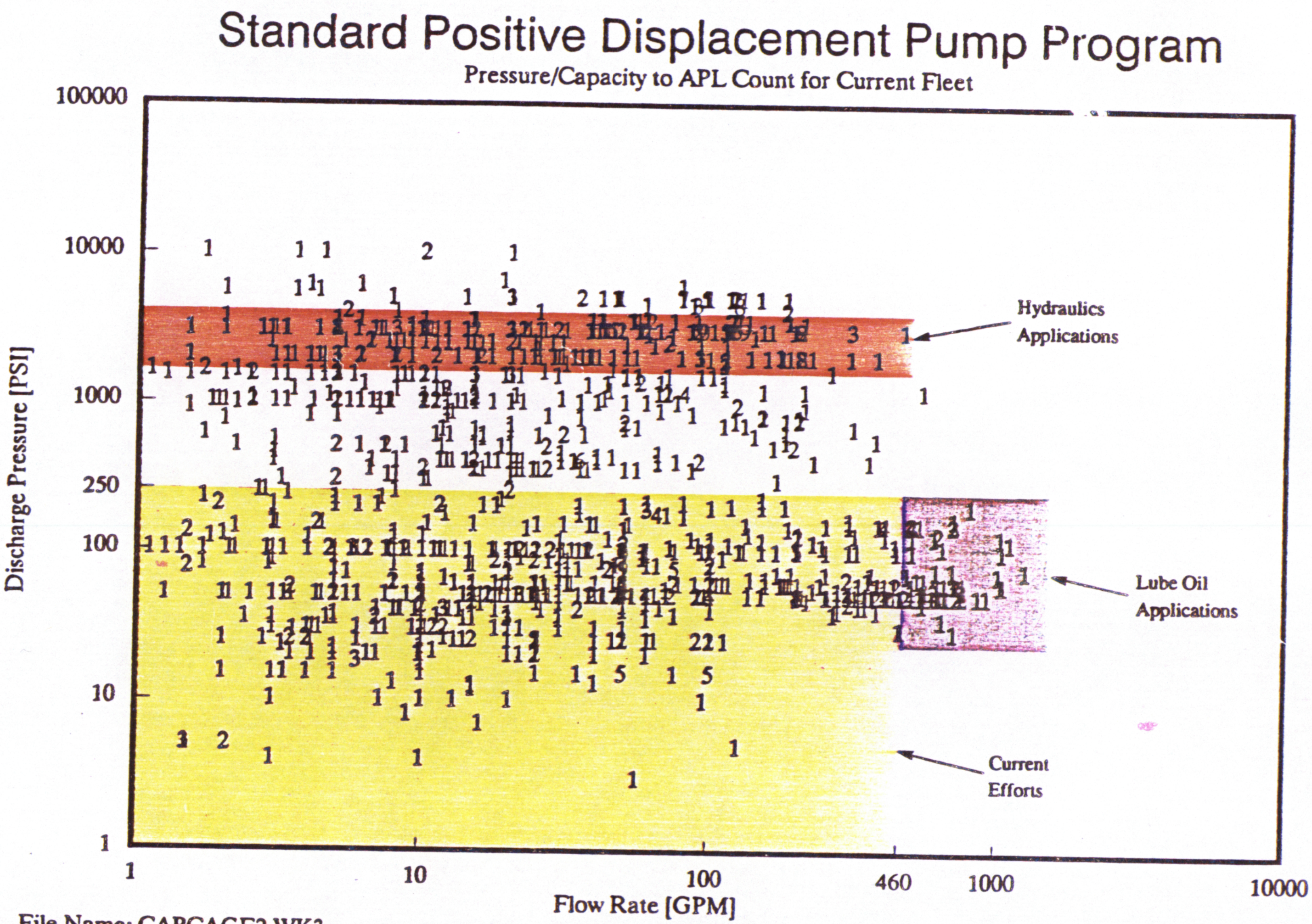
BASED ON 1640 APLS THERE ARE 25918 PD PUMPS INSTALLED FLEETWIDE

FUTURISTIC DATA BASE:

450 SHIP NAVY

200 SHIP NEW BUILDING IN THE NEXT TEN YEARS

NAVY NEEDS WHEN PUMP FAMILIES ARE INCORPORATED



File Name: CAPCAGE2.WK3
Graph Name: P-G-01

FIGURE 7, SCATTER PLOT

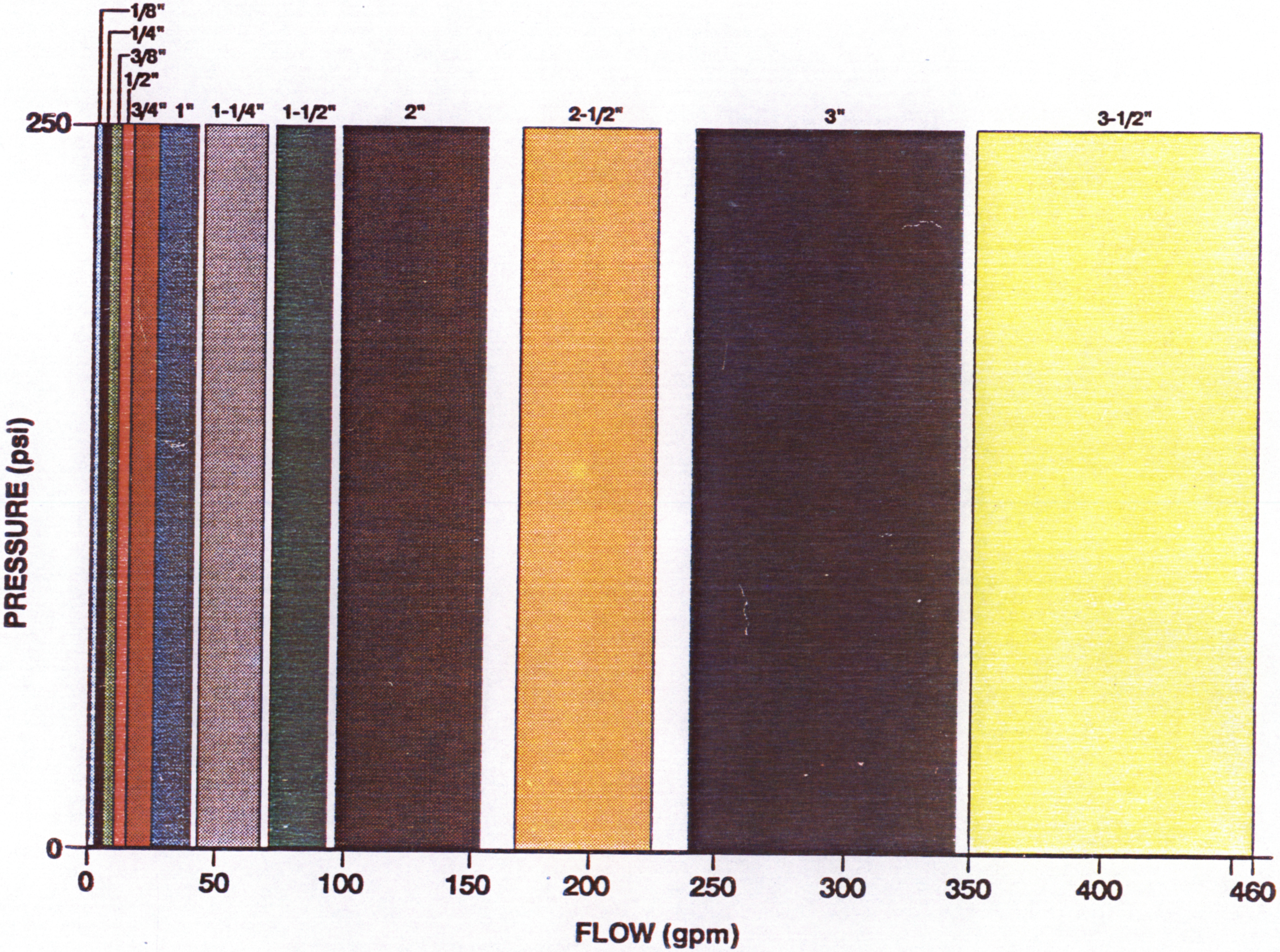
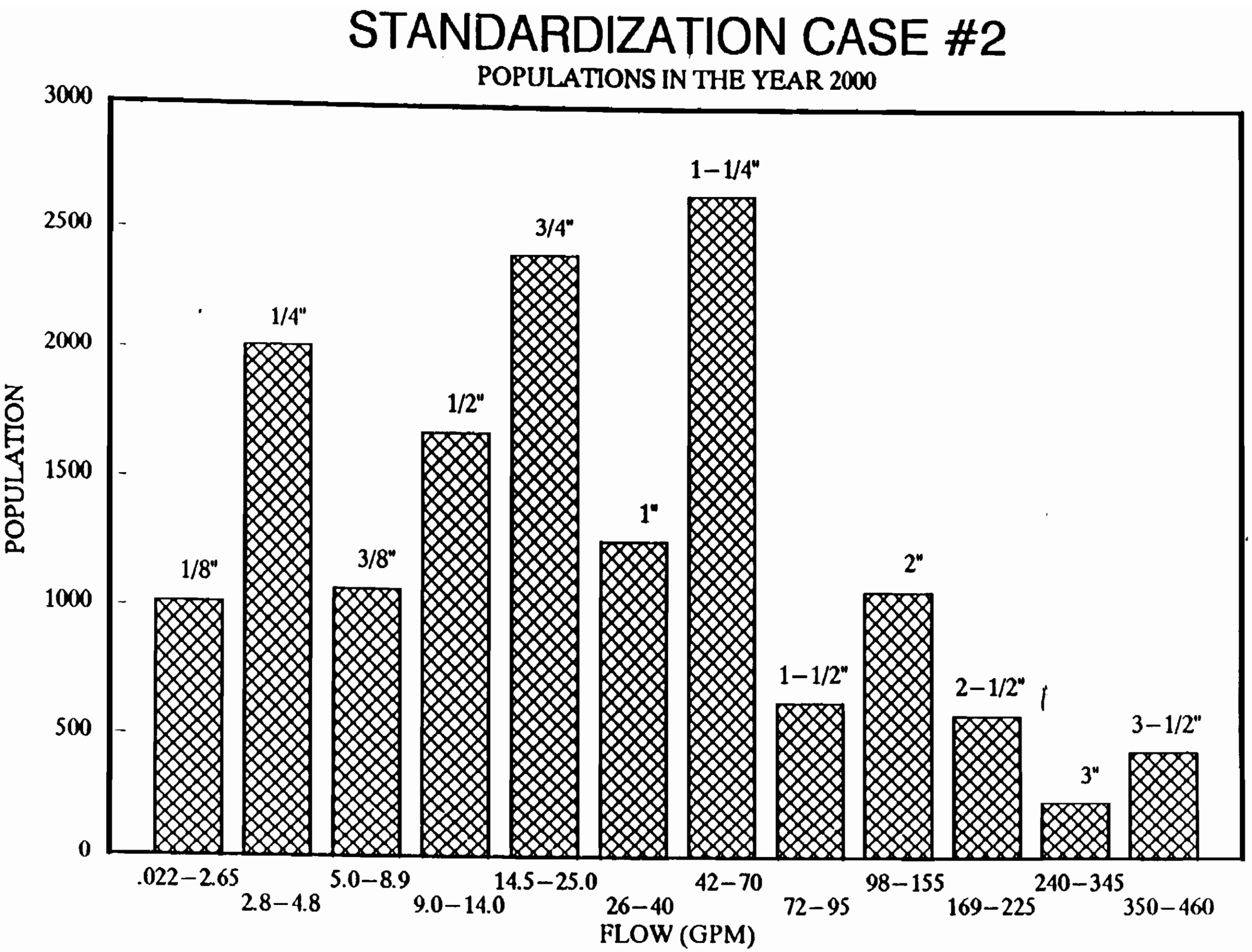


FIGURE 8, PROPOSED FLOW RANGES


STANDARDIZATION CASE #2

POPULATIONS IN THE YEAR 2000

FIGURE 9, PROJECTED POPULATION

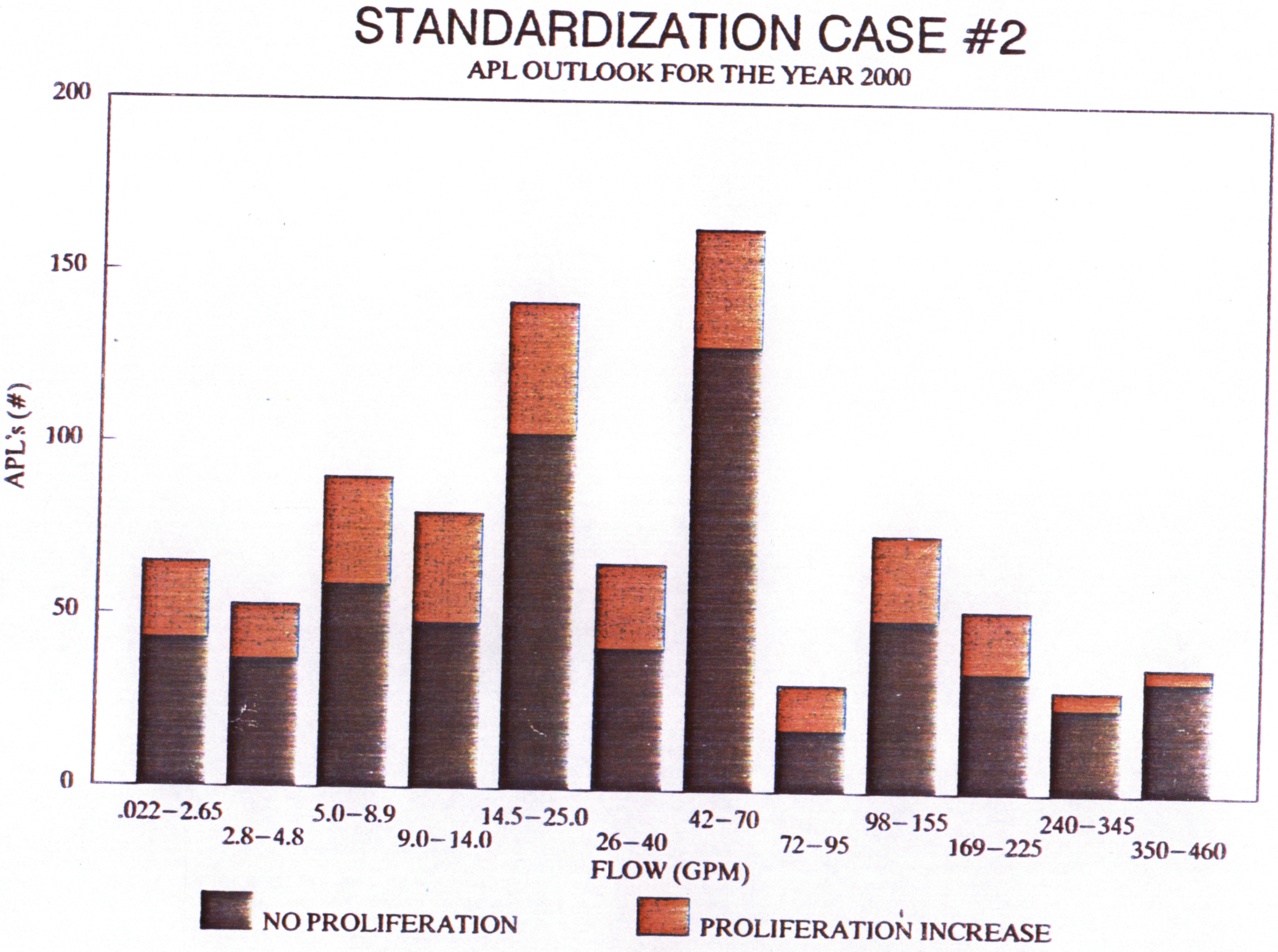


FIGURE 10, PROJECTED PROLIFERATION

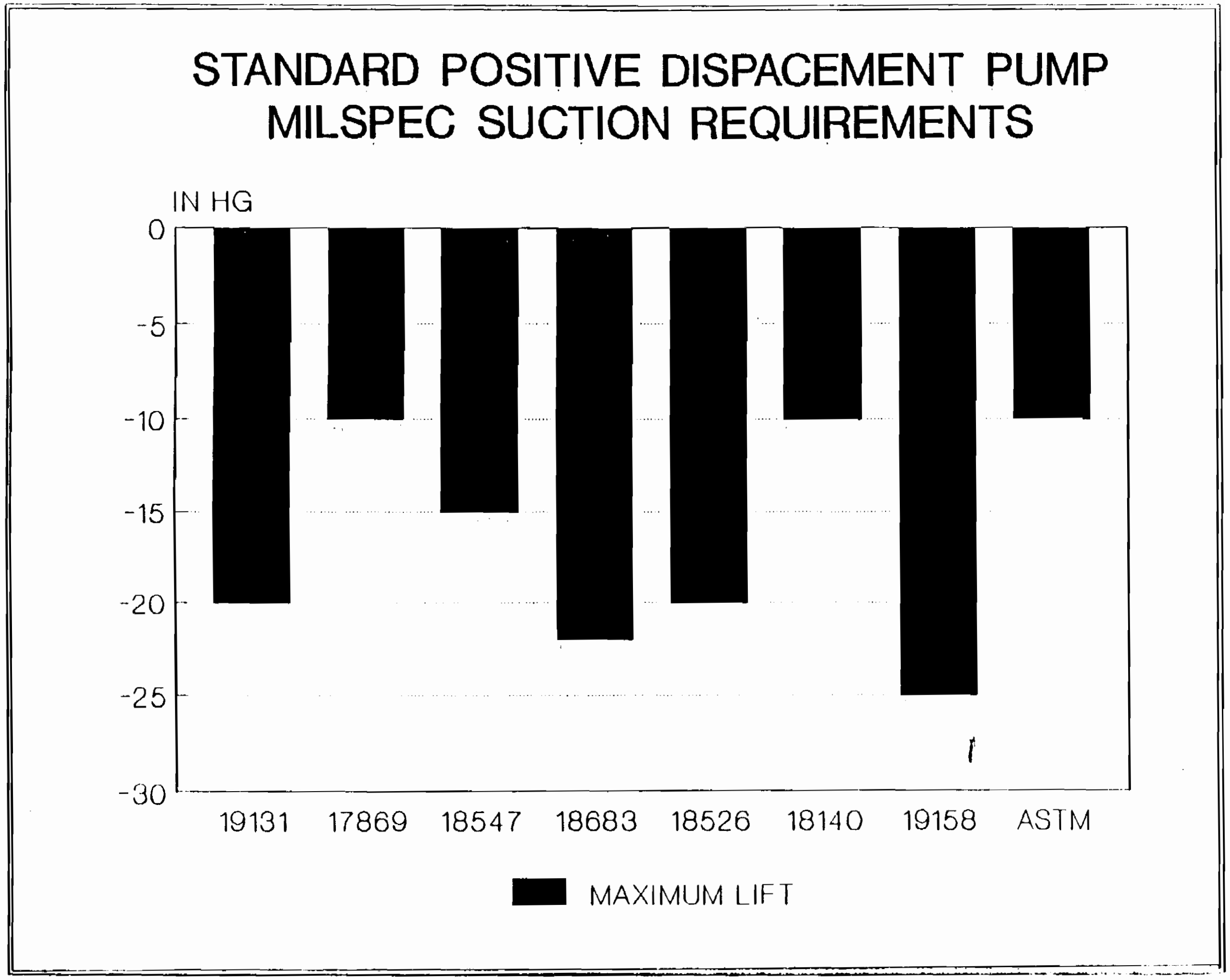


FIGURE 11, MIL-SPEC SUCTION REQUIREMENTS

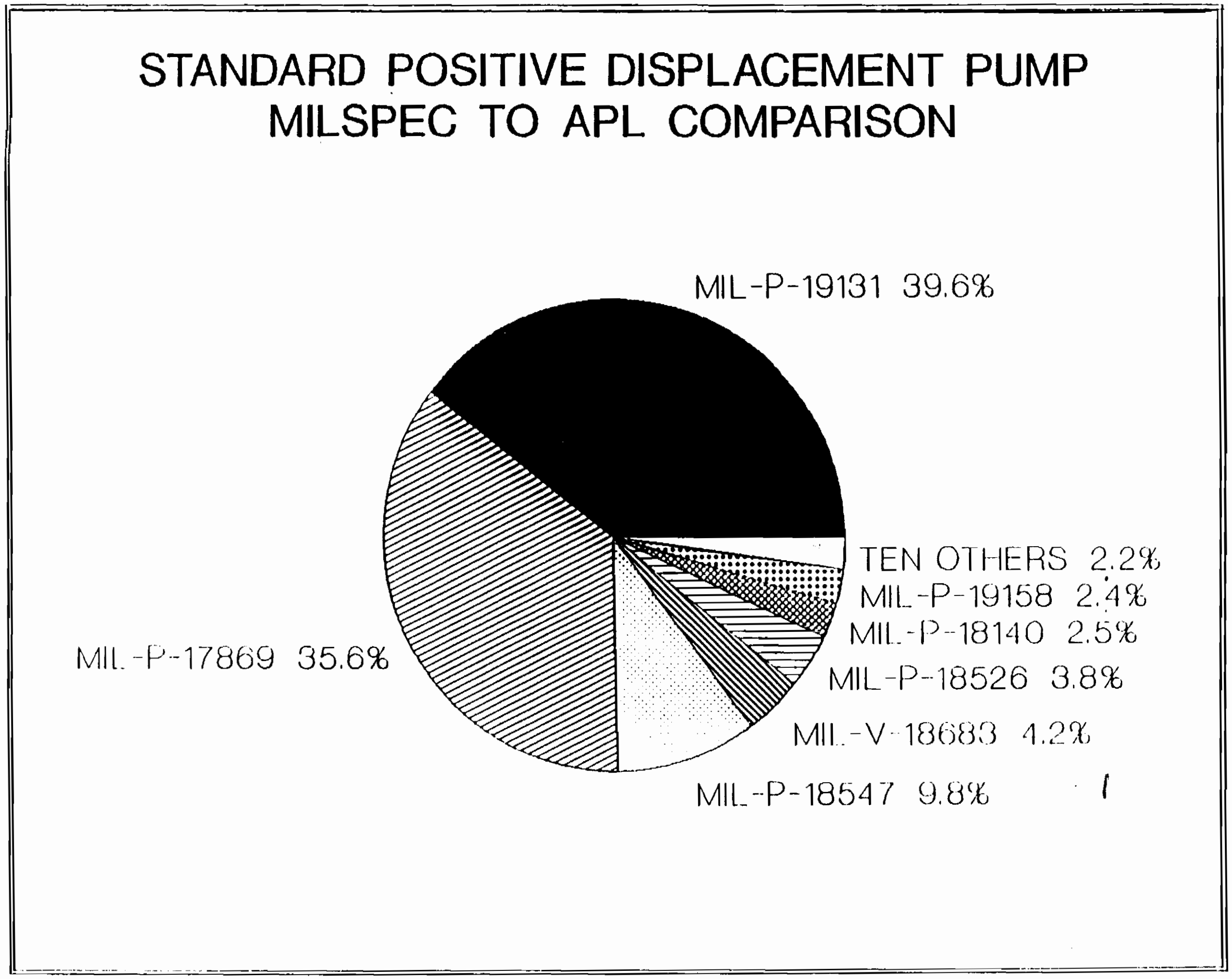


FIGURE 12, BREAKDOWN BY MIL-SPEC

C. FY92 PROGRAM RESULTS

From the Standardization Selection Criteria Costs Benefits Study for a Case II defined as: If all pumps were to be standardized in a region bounded by yellow shown in Figure 7 then: (1) Total cost savings less maintenance charges total 84.1M for a 20-year time frame as shown in Figure 13; (2) Figure 14 indicates overall data populations by type are: 22% gear, 25.5% Vane and 14.4 % screw; (3) Figures 14 indicates that for below 250 psi and 400 gpm; 43% are vane, 21% screw and 24% piston; (4) Half of the 64% bounded by yellow in Figure 7 are fuel pumps; (5) Over all savings indicates that for Case II, 47% result from acquisition, 29% are APL reductions, 17.8% are "ILS" costs savings and 31.9% repair parts costs savings; however, specific savings by flow ranges as shown in Figure 15 indicates that the 200 gpm range has the highest cost savings.[7] (6) When the overall elements of cost savings are applied in finer detail to each flow range, Figure 16 results with the best 2-candidates based on PAS alone in the 50 and 200 gpm ranges.

These findings provide two best possible cases for an economic evaluation. Design "A" is a 50 gpm pump where

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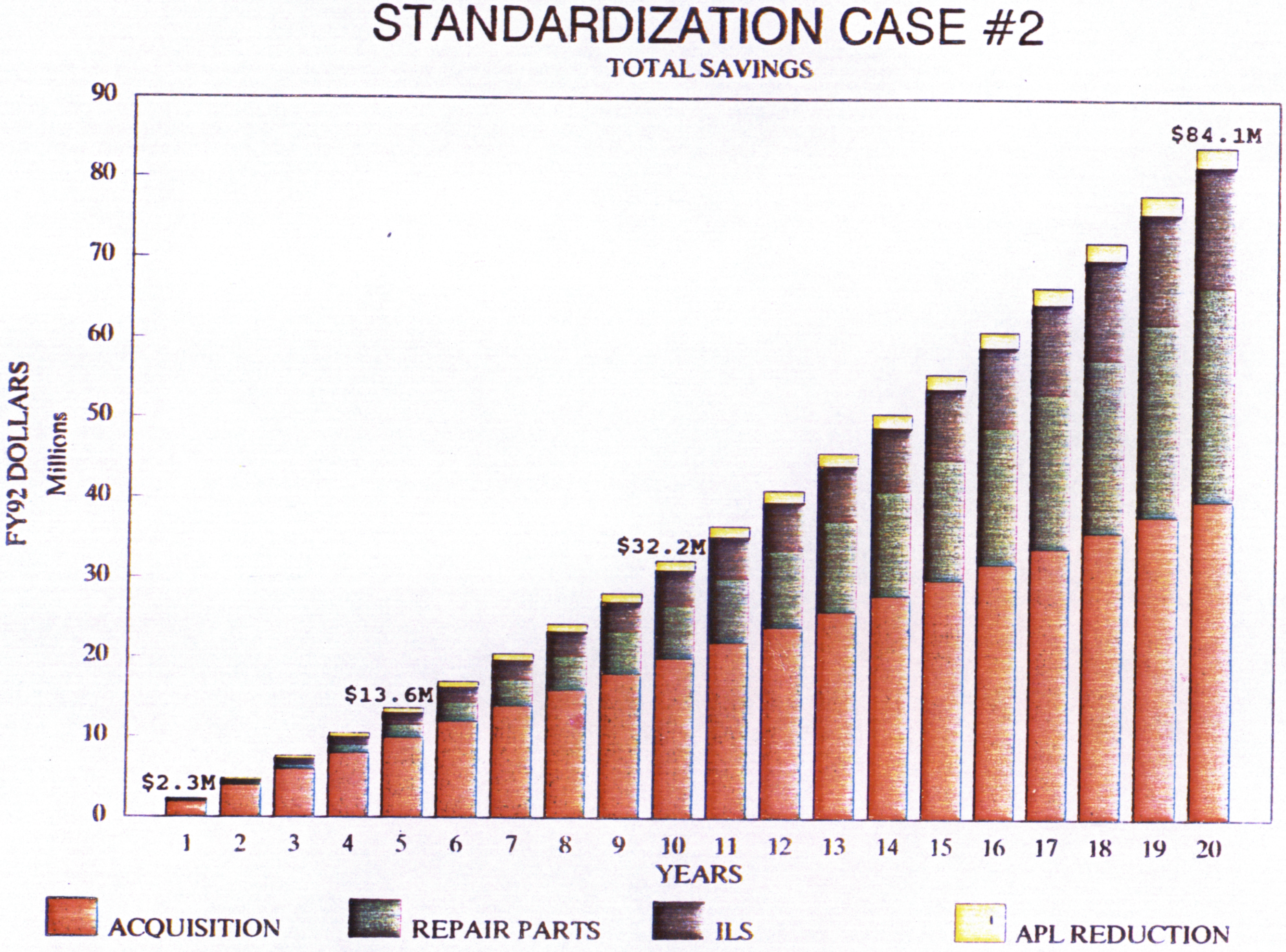
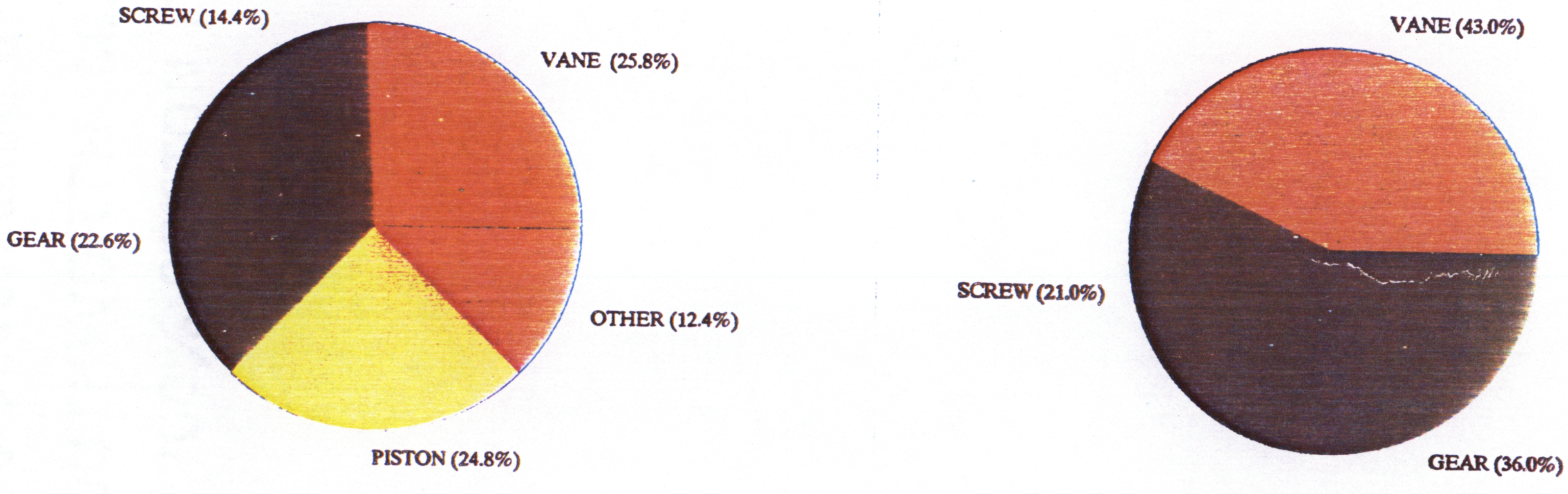
[7] "Results of FY92 Standardization Study", Doyne and Hibbard.

there is a demonstrated high Navy need in the areas of quantity and reduction of proliferation. Design "B" is a 200 gpm pump having highest potential savings based on acquisition costs. By modeling these two candidates as potential standardized designs in an economic evaluation against status quo, a selection for an optimum can be made based on shortest payback period. Other features such as the scale of cost will be determined. Although it is apparent that both designs are candidates for standardization and are in fact different, it is the objective of this study to select a single best case for a new design effort involving standardization.



Source: NAVSEALOGCEN
SCSC Analysis

FIGURE 13, ESTIMATED TOTAL SAVINGS



APL BREAKDOWN BY PUMP TYPE

BREAKDOWN BY PUMP TYPE
(<250 psi and <460 gpm)

FIGURE 14, BREAKDOWN BY PUMP TYPE

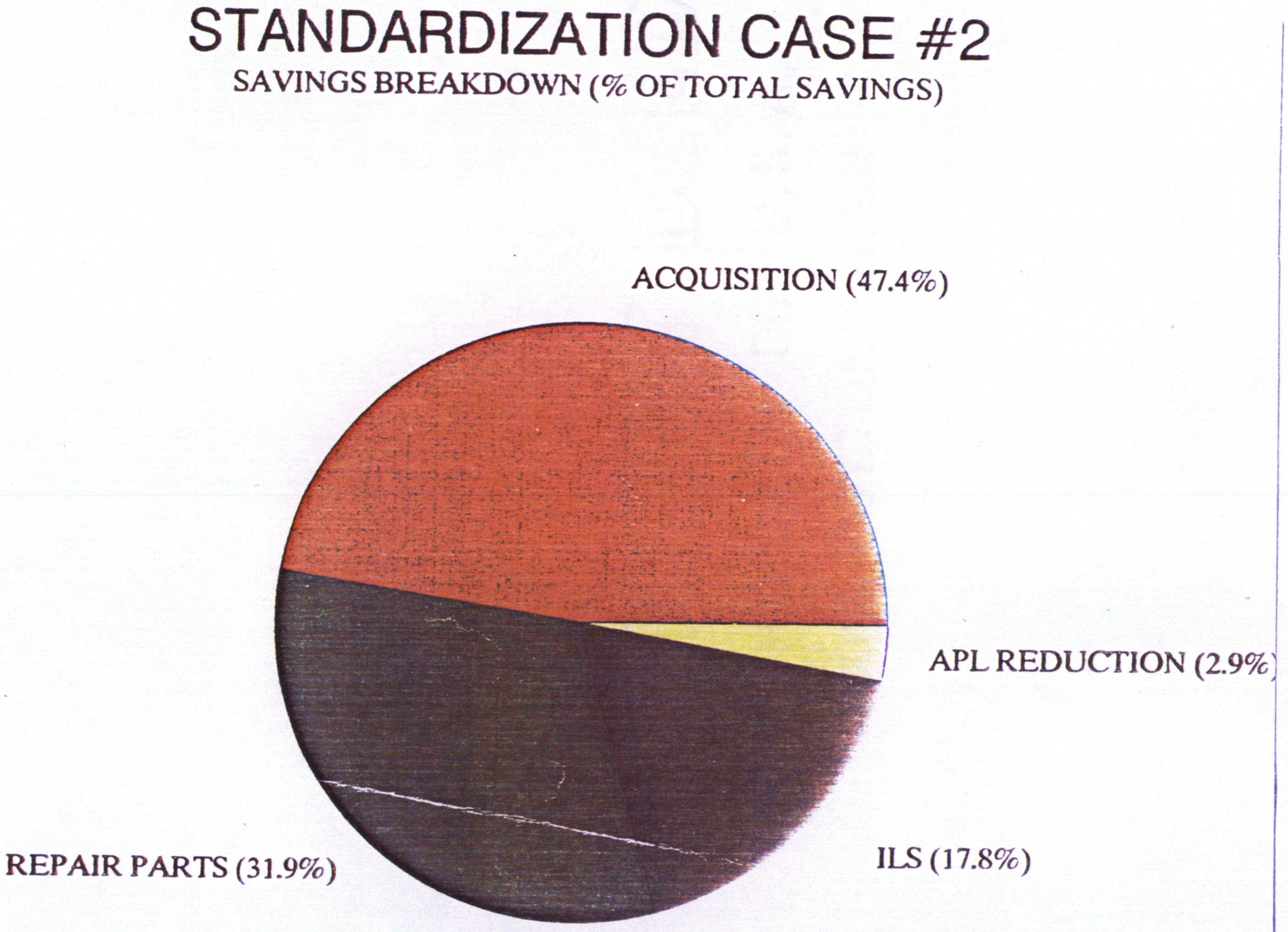


FIGURE 15, SAVINGS BY PERCENT

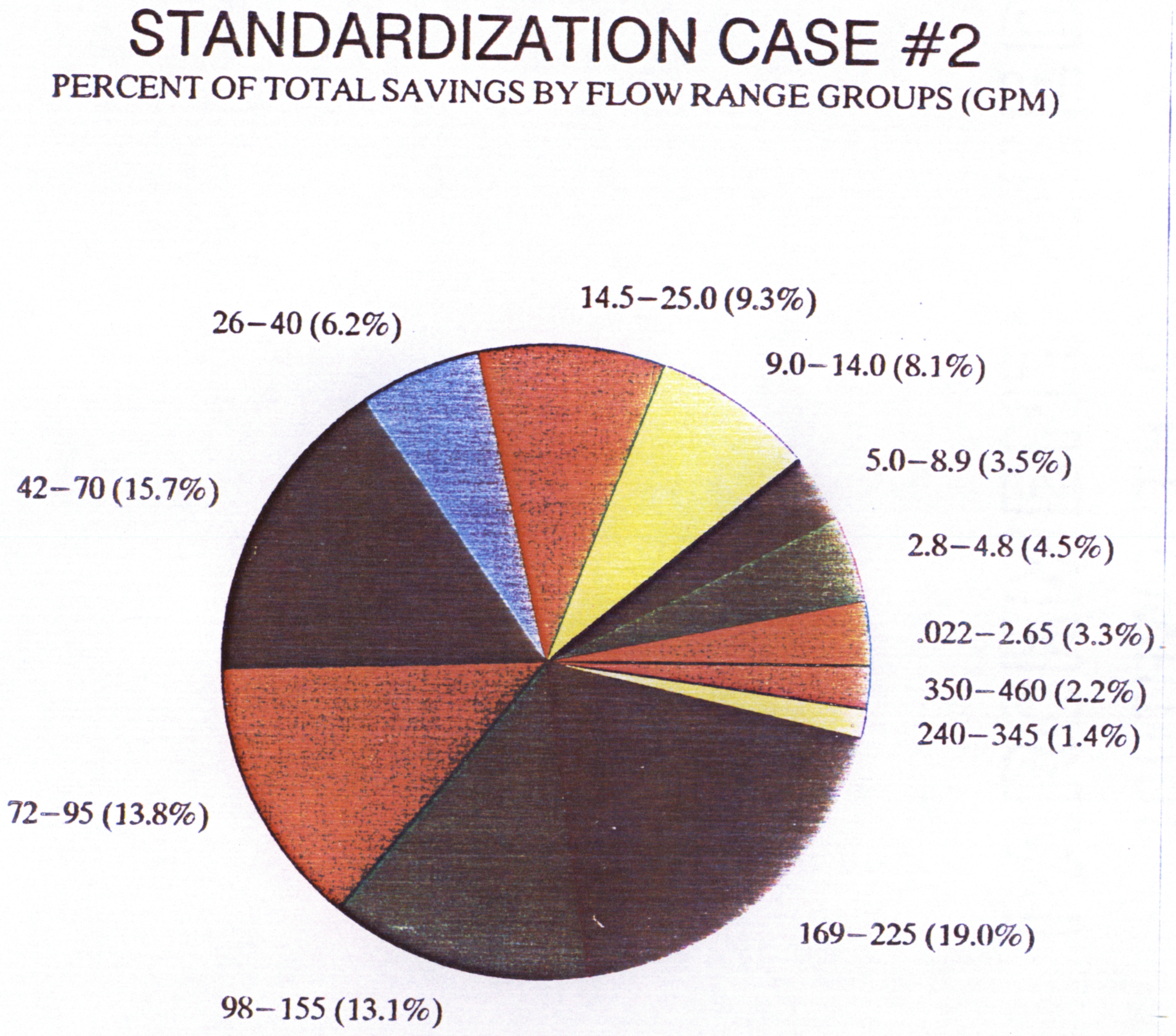


FIGURE 16, SAVINGS BY FLOW RANGE

D. RELIABILITY AND MAINTENANCE ESTIMATES

Data from the reliability and maintainability estimate forms the estimate used in the Logistics and Maintenance portions of the economic evaluation. Results are graphed in Figure 17 normalized to population for a 5-year historical period. Data is believed to be incomplete since all maintenance actions may not be put through the Navy's 3M system. Using the data requires judgement resulting in an assumed factor of 2 multiplier used in calculations tabulated in Appendix C. Most conclusive results prior to using any correction factor indicate:

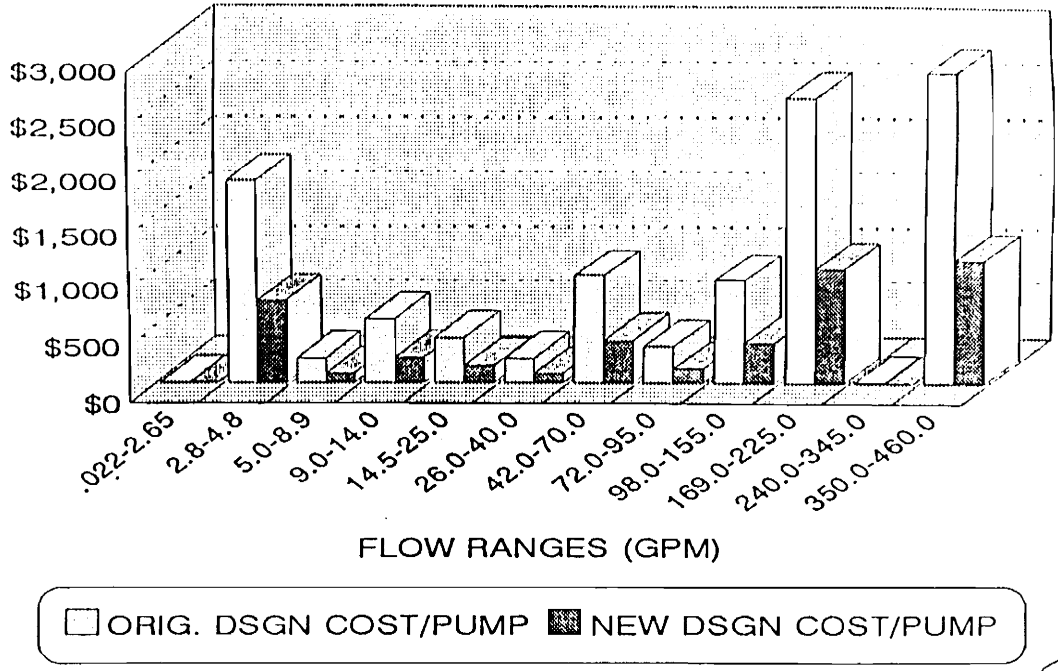
(1) A 40% improvement criteria,. Total maintenance cost savings are realized due to proposed design improvements.

(2) Improvements in the 50 gpm range provide a factor of 2.0 increase in savings.

(3) Improvements in the 200 gpm range provide a factor of 2.5 increase in savings.

Since cost savings are estimated as proportional to MTBF and the method for calculating MTBF = 1/(reliability), estimated cost savings = 1/.40 = 2.5. Differences in factors arise from the non-linearity of MMHR costs vs PC and values used in the tabulation are estimated by scale from Figure 17 as provided.

Cost Information by Flow Range
1/1/88 - 12/31/91



NSWC CARDEROCK DIVISION

Equipment Assessment
& Alterations Department
Naval Ship Systems Engineering Station
TCK 11/16/92

FIGURE 17, RELIABILITY AND MAINTENANCE COSTS

STANDARD POSITIVE DISPLACEMENT PUMP CONCEPT

1. Description: Concept hardware is comprised of a corrosion and contaminant tolerant pump making use of the type of technology proposed by Navy patent pending case number 75373 (Cohen) and possibly Patent #5,025,849 in a format capable of meeting the stated technical performance measures. Use of standard flange interfaces and embedded sensors interfacing with a standard data bus and a monitoring system are employed. Although six pump sizes are available corresponding to standard piping interface requirements coupled with 250 psi maximum pressure envelope requirements, only two of the highest payoff pump designs are chosen for this study. Selection for candidate design flow ranges are Design "A" a 50 gpm pump, and Design "B" 200 gpm pumps in accordance with Detail Functional Specifications, and they pump Class "A" and "B" fluids. Design philosophies provide trade-offs; and although there are high initial costs due to design developments, hard corrosion resistant materials, and machining costs, there are low logistics costs. The mission includes pumping fluids in all categories and meets all profile requirements for all hours over a life-cycle.

Monitoring subsystems are employed within the new design to lower the maintenance and logistics costs.

Monitoring systems are identical from one pump size to another Over the life-cycle, cost savings are achieved using machinery monitoring to solve present deficiencies in tracing pump statistics and as application for a preventive maintenance tool. On-line diagnostics describe systems health (what is actually going on at the present moment) and has an ability to flag the user (customer) about problems resulting from operator error or for maintenance. Long term trending analysis provides life-cycle managers (customer) with statistical data necessary for life-cycle costing and for scheduling maintenance.

Systems health monitoring includes acoustic, pressure, flow, thermal, and logic performance measures. Technical Performance measures include: (1) Acoustic sensors allowing noise measurements and comparisons with acceptable levels for habitability (human factors), ship's signature and, the diagnostic parameter describing pump component vibration. Excessive acoustic pressure emissions and their form indicate a pump maintenance action and the potential cause; (2) Pressure (and derived flow) sensors providing pump discharge, suction and the resulting differential pressure allow comparison with specification requirements indicating worn or damaged pump components, ship systems operating error indicating closed valves, dry suctions, and clogged filter; (3) Flow sensors indicate dry running situations; (4) Monitoring thermal sensors in pump and motor bearing cap provides a key to pump health in determining pump diagnostics; (5) Firmware imbedded in a diagnostic computer allows preprogrammed logic and data acquisition that provides possible causes and solutions for troubleshooting problems. Linked computers provide part numbers (NSNs and APLs) with availability of affected components.

2. Concept Technical Performance Measures

Physical and performance requirements are as follows:

Pressure: 250 psi

Flow: 50 & 200 GPM

Accuracy: Percent inclusive of flow range

Shaft speed: 1200 rpm

Fluid Media: Category "A" and Category "B"

Dimensions (LxWxH, inches):

	50 GPM	200 GPM
Overall:	40x18x18	80x30x36
Pump:	17x17x17	27x30x25
Motor:	27x17x17	30x30x20
Coupling:	4x15x15	8x20x20
Monitoring Module:	.5x1	.5x1

Weight (pounds):

Overall	296	550
Pump	45	100
Motor	75	250
Foundation	175	200
Monitoring Module	1	1

Monitoring module electronic and acoustic:

Sensitivity	500mV/g
Frequency Response	0-10KHz

Mounted resonance	35 kHz
Bonding and Shielding for	EMI, RFI, and EMP
Data interface	NEMA 0183 Data bus/LAN
Electric motor material and design guidance:	60 Hz, 240V, 3PH, (MIL-M-17060E, 1981 Motors, Alternating current, integral-horsepower, shipboard use.)
Pump design, material and guidance:	(MIL-P-19131, 1956, or-Commercial equivalent, Pumps, Power Driven, Miscellaneous.)
Piping design and guidance:	Corrosion resistant piping. (MIL-P-777, Piping), ANSI B16.5 (1988), Pipe Flanges and Fittings.
Environmental:	
Location	Shipboard, Machinery spaces
Thermal	0-180 °F
Humidity	0-100%
Foundation and Structure:	MIL-STD-740B, Shipboard Noise requirements.

Shock and vibration (Noise):	1000g, MIL-STD-167, Shipboard Vibration and shock requirements.
Human factors:	
Noise	OSHA Air-borne requirements for shipboard machinery spaces.
Pressure envelope	ASME Pressure vessel and piping code with a 4:1 safety factor.
Operational Life-cycle:	
Complete system	30 years
Utilization:	
Worst case cycle	24 hrs/day, 365 day/yr
Operational Deployment and Distribution:	
Complete Systems Quantity	4 SPDPS/ship
Monitoring subsystems	4 /SPDPS
Deployment	Navy wide surface combatant
Alternative uses:	U.S. Coast Guard Ships Army water craft NOAA Ships NATO ships Dual use such MARAD ships and land based facilities

On-site transportation and support	Ships supply
support	Maintenance/support ship
Base Support	Land site (Navy Base, Shipyard)
Personnel:	
On-Site	4
Support Ship	10
Base Support	25
Operational date:	May, 200X

F. ECONOMIC EVALUATION

The economic evaluation makes uses a life-cycle cost estimate comprised of costs associated with tasks identified at the concept level associated with Table 9, Systems Engineering Acquisition Management Plan. Cost breakdown descriptions are defined in Table 10 and resulting tabulated data is presented in Table 17, Appendix C. Life-cycle cost comparisons result in Figures, 18 through 22.

Most relevant findings indicate:

(1) Yearly costs for status quo are an additive progression due to proliferation effects as depicted in Figures 18 and 19 based on present year dollars.

(2) Figure 20, Cost comparisons based on present year dollars indicates a very large spike for new proposed standard designs in year-6 for the competitive bulk purchase. Other years costs are very low.

(3) Figure 21, Integration of baseline Yearly Costs provides the occurrence of a payback. Payback is realized in years 12 and 16 for standard Design "A" and "B" respectively. This translates to 12 - 5 = 7 years operational time and 16 - 5 = 11 years operational time, respectively, from program inception.

(4) Figure 22 presents 5% discounted cost comparisons by year and indicates a slightly longer payback time and much lower scale of cost. Payback time is increased from early in year-12 to late in year-12 for Design "A", and from year-16 to year-18 for Design "B".

(5) Design "A" has a lower scale of cost or a life-cycle cost savings ratio:
{(Status quo "A")/(Design "A")}/{(Status quo "A")/(Design "A")} = 2.9/1. Savings is realized in terms of scale of cost, or the amount of funds required to achieve the savings. Based on cost alone Standard Design "A" has the best overall potential for

standardization over Standard Design "B" despite an higher indicated PESS for Design "B".

(6) Table 14, Cost break down structure results indicate that for Design "A", there is an investment cost of: 3.1 + 3.4 + 2.8 = 9.3 % excluding hardware. Similarly, Design "B" has an investment cost of 1.2 + 1.4 + 2.7 = 5.3%. This up front investment cost yields low logistics and maintenance cost of 8.7% and 4.7% of the total costs for Design "A" and "B" respectively. The majority of cost for new standard Designs is in the product measured at 82.6% and 90.2%. Largest costs for status quo "A" results from logistics, with status quo "B" costs being nearly split between and logistics and maintenance and production and procurement. In summary, it is shown that potential costs savings come from competitive bulk procurement and lowered logistics costs realized from a long term investment cost.

TABLE 14, COST BREAKDOWN STRUCTURE RESULTS

PRESENT YEAR COST ESTIMATES ITEM DESCRIPTION	% OF TOTAL
RESEARCH AND DEVELOPMENT:	
DESIGN "A"	3.1
DESIGN "B"	1.2
STATUS-QUO "A"	0.0
STATUS-QUO "B"	0.0
DESIGN COSTS	
DESIGN "A"	3.4
DESIGN "B"	1.4
STATUS-QUO "A"	0.0
STATUS-QUO "B"	0.0
TEST AND EVALUATION	
DESIGN "A"	2.8
DESIGN "B"	2.7
STATUS-QUO "A"	0.0
STATUS-QUO "B"	0.0
PRODUCTION AND PROCUREMENT	
DESIGN "A"	82.6
DESIGN "B"	90.2
STATUS-QUO "A"	18.9
STATUS-QUO "B"	51.8
LOGISTICS AND MAINTENANCE	
DESIGN "A"	8.7
DESIGN "B"	4.7
STATUS-QUO "A"	81.1
STATUS-QUO "B"	48.2
BASELINE CURRENT YEAR CUMULATIVE SUM	
DESIGN "A"	100.0
DESIGN "B"	100.0
STATUS-QUO "A"	100.0
STATUS-QUO "B"	100.0

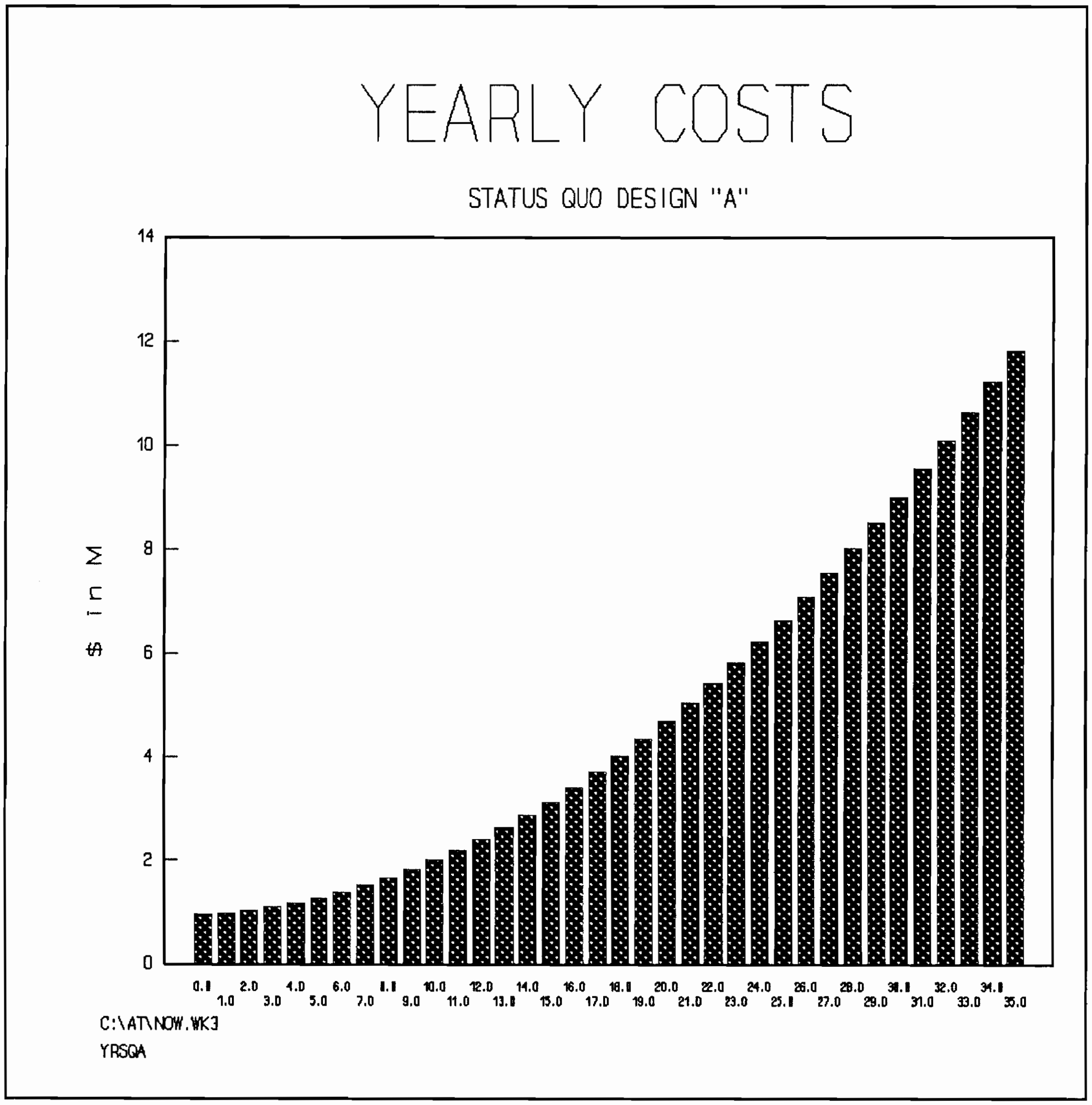


FIGURE 18, YEARLY COSTS STATUS QUO DESIGN "A"

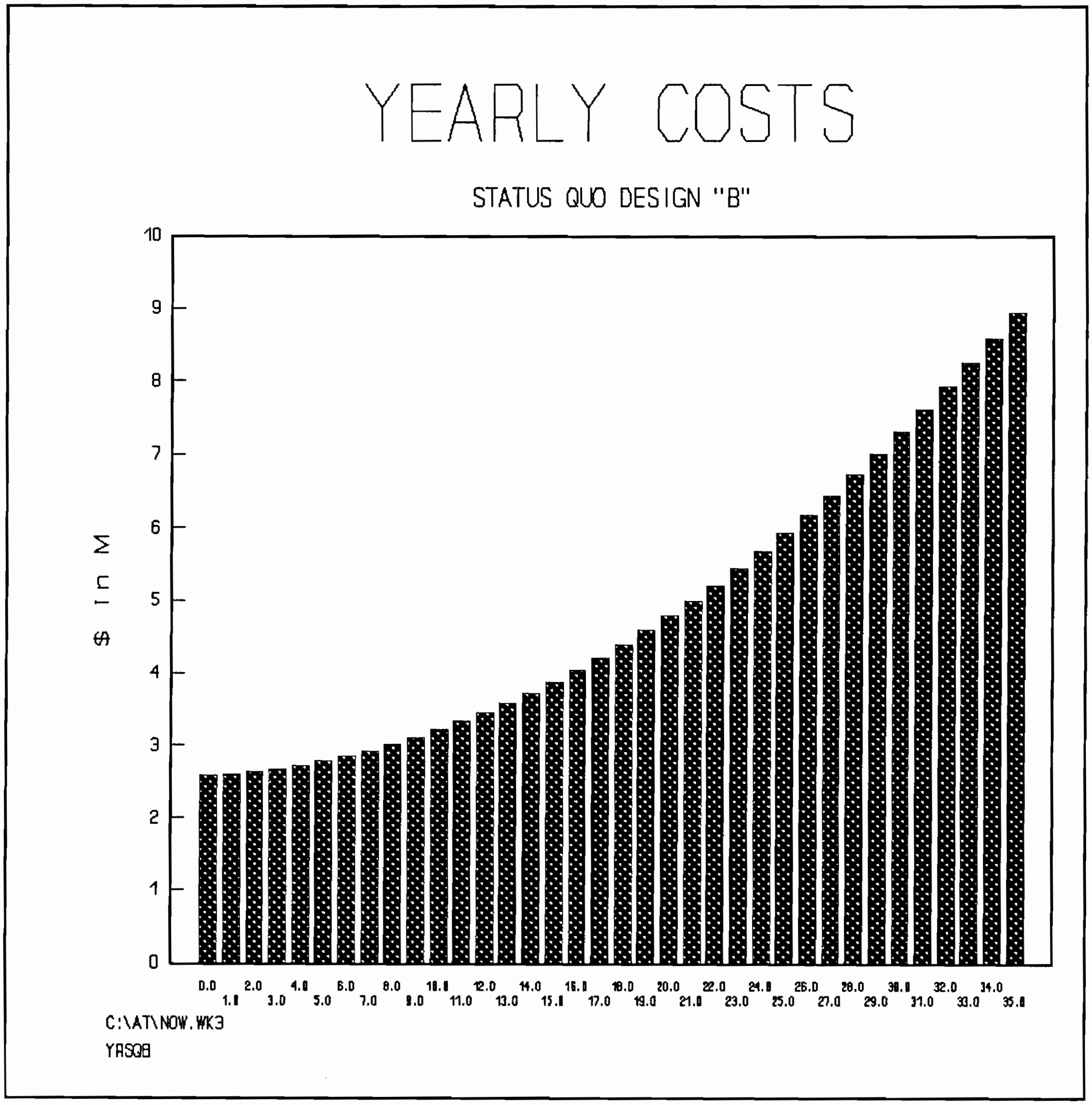


FIGURE 19, YEARLY COSTS STATUS QUO DESIGN "B"

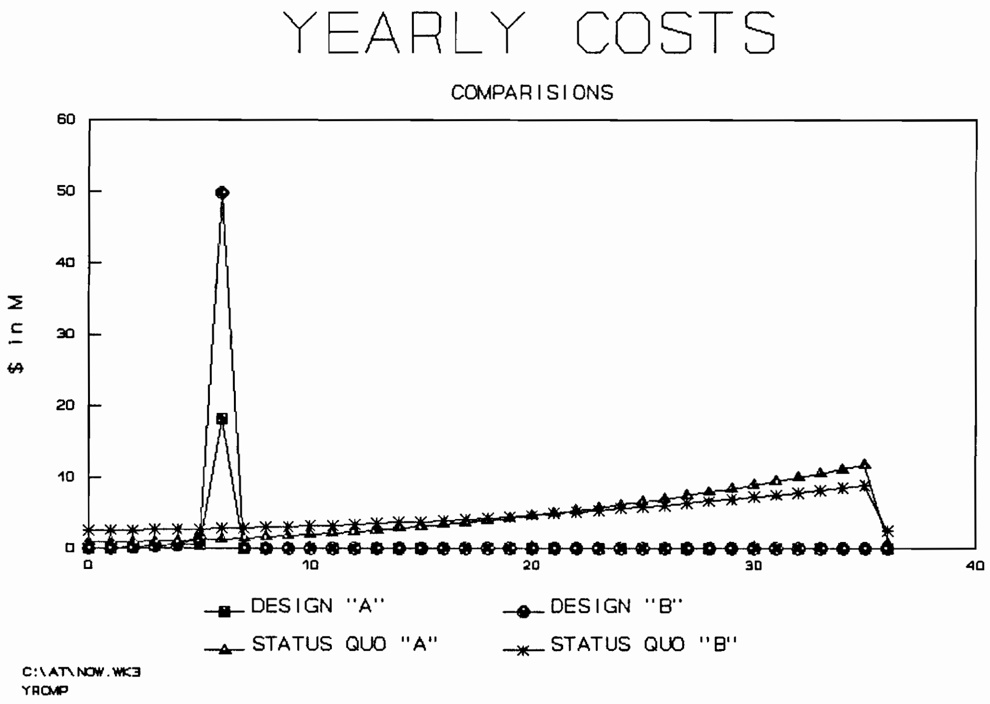


FIGURE 20, COST COMPARISONS BY YEAR

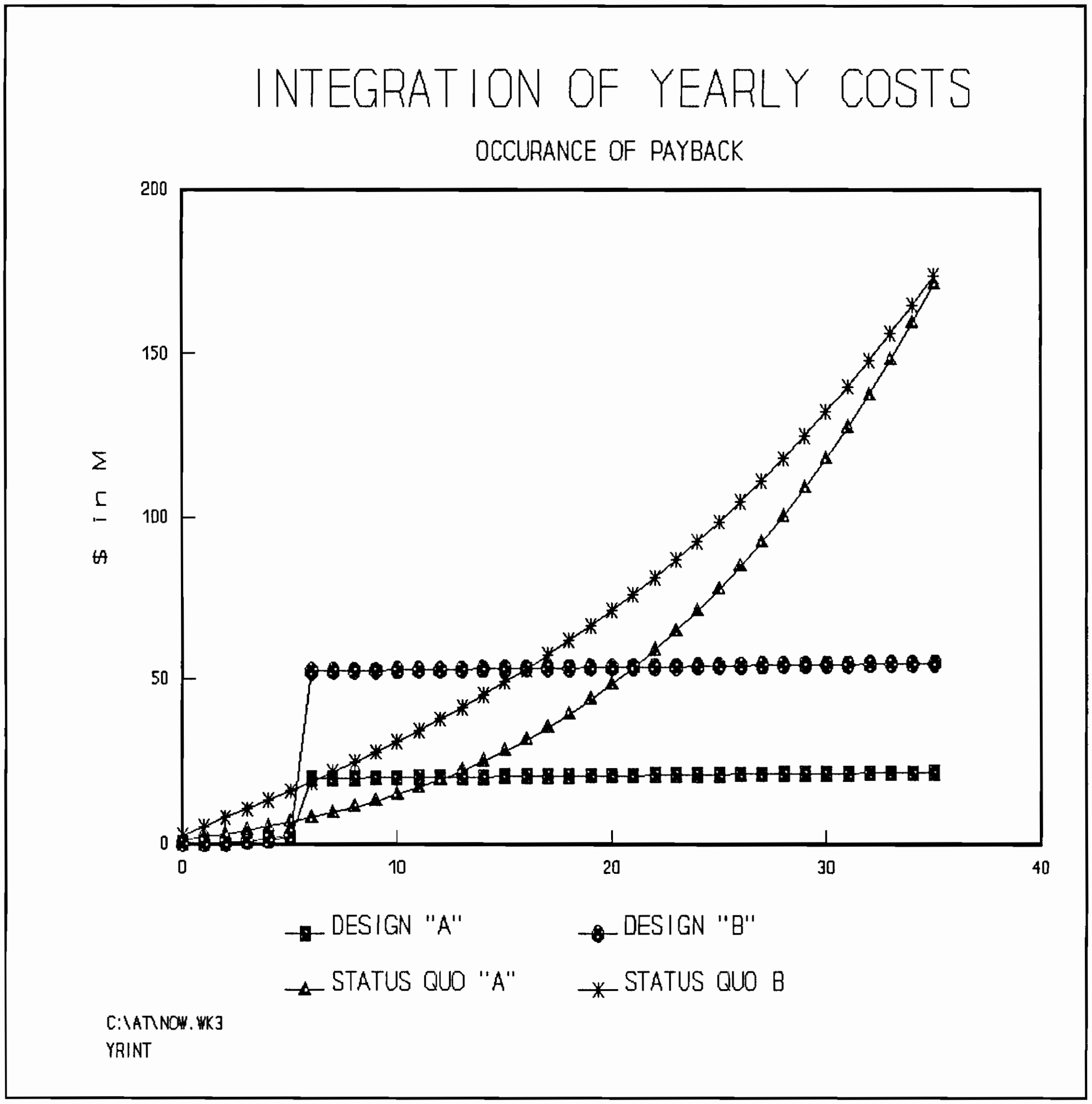


FIGURE 21, INTEGRATION OF YEARLY COST, OCCURRENCE OF PAYBACK

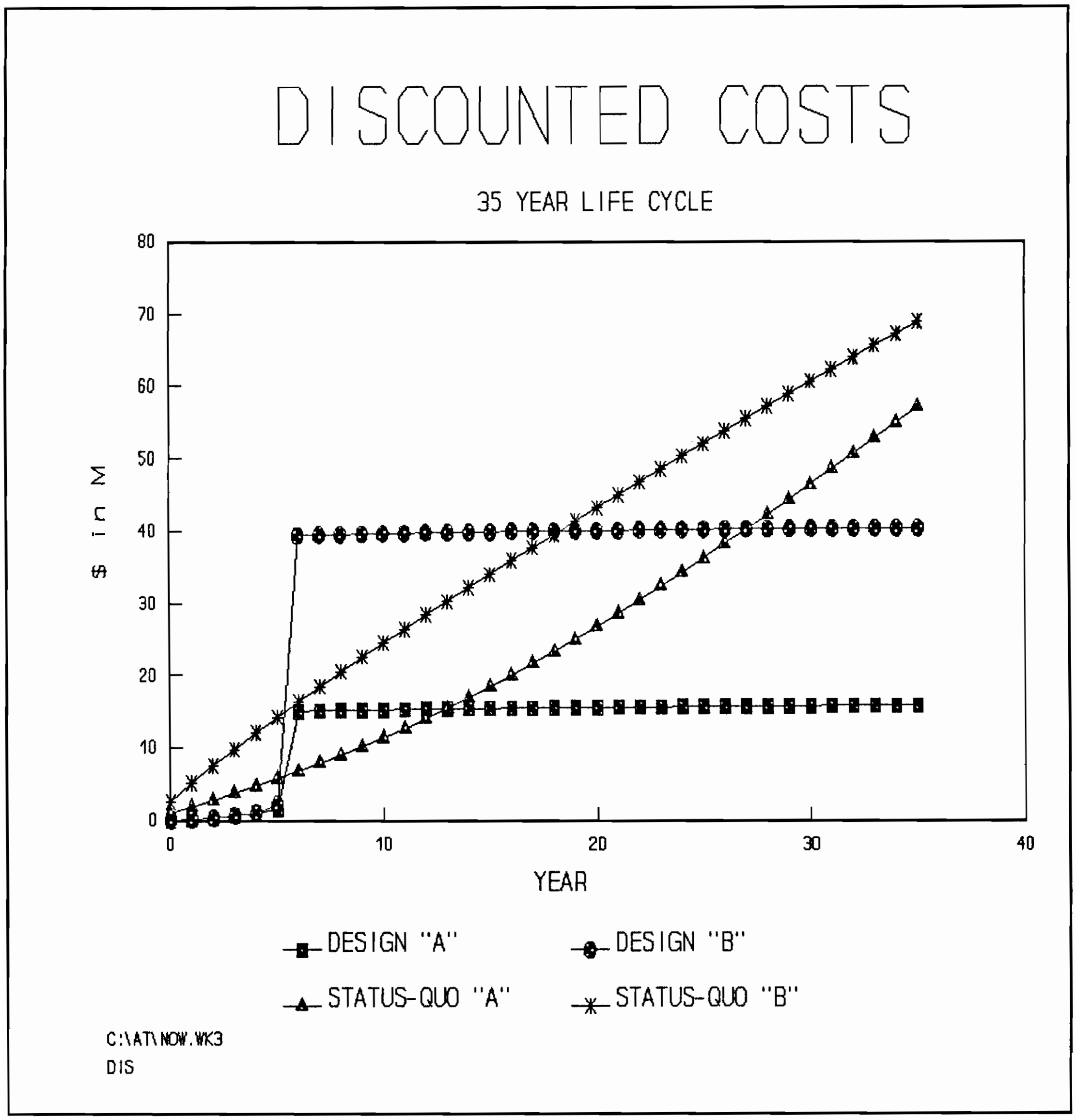


FIGURE 22, DISCOUNTED COSTS

G. EVALUATION SUMMARY

Results from the Evaluation Summary, Table 15, indicate that based on Naval Ships Systems criteria, standard pump Design "A" has a 22% margin of selection over standard Design "B". Factors affecting this selection have been selected subjectively with the assumption that these may be built into a new Design. All scores are nearly the same; however, the small quantities requirements and high cost by piece results relative scores.

TABLE 15, EVALUATION SUMMARY

		STANDARD DESIGN			SCORE	
ITEM		"A"	B"	FACTOR	"A"	B"
1	COMBAT CAPABILITY	10	10	10	100	100
2	ACQUISITION COST	10	1	10	100	10
3	SHIP DISPLACEMENT	10	10	5	50	50
4	ENERGY CONSERVATION	10	10	5	50	50
5	MANNING REDUCTION	10	10	5	50	50
6	OPERABILITY	10	10	5	50	50
7	PASSIVE SURVIVABILITY	10	10	5	50	50
8	BLOCK UPGRADE/FUTURE GROWTH	10	5	5	50	25
9	HABITABILITY	10	10	2.5	25	25
10	APPEARANCE	10	10	2.5	25	25
11	MINIMUM RISK	7	1	2.5	15	2.5
12	STANDARDIZATION	10	8	2.5	25	20
TOTAL SCORE					590	457.5

V. DISCUSSION

A. DATA BASE AND PROPER NOMENCLATURE USAGE

As of 1992, the positive displacement pump base as supplied has data fields missing information with percentages shown in Figure 23, Data Availability. Descriptions are somewhat inconsistent with industry practice and military specifications making data description recognition questionable. It is noted that this is being corrected with time, but is cost driven. Recommendations herein identify standard proper nomenclature usage listed in Table 16, Appendix "A". These descriptions are recommended for developing standard designs, data entry, maintenance, supply, procurement and design specifications.

Expanding currently supported data item descriptions found in the Lead Allowance parts Lists or Commodity Codes to accept better definition could add clarity and additional technical detail that may promote optimum utilization such as dual use. Although additional data and technical correctness in data entries will cost more money, payoffs are realized in fleet usage and possible dual usage through commercialization of military designs.

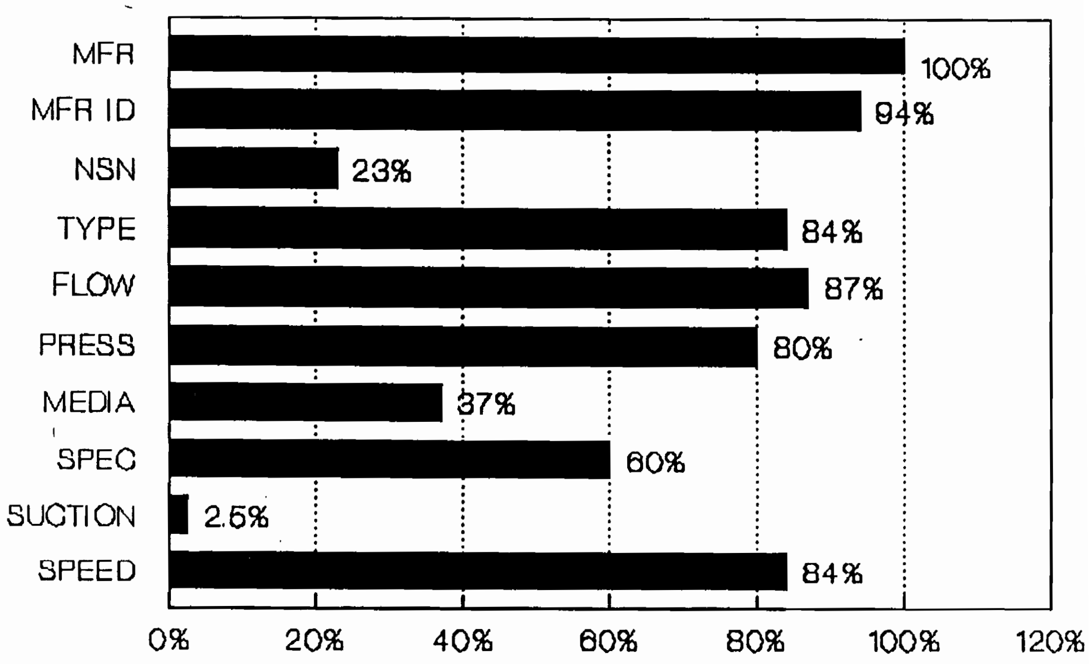


FIGURE 23, DATA AVAILABILITY

B. ALGORITHM AND ESTIMATING CONSIDERATIONS

Standardization Candidate Selection Criteria Phase I equipment nominations omits time factors and is based on present ship configurations by assuming that all standardized components are off-the-shelf (present dollars). Estimating when new standardized component introductions are realized better defines mission need but does not necessarily coincide with standardization potentials that are based on current quantities. The rule-book described herein provides time preprocessor philosophy that considers ship status thus allowing for ship births, deaths and suspended states. Time preprocessing considerations are necessary where investing in new technology provides developments over time that can be shown. Present worth analysis applied to candidate design estimates presented herein evaluates proposed paths on an equivalent basis. The realization that technology, global climate, economic factors are variable and will change, cannot directly be accounted for in a cost benefit analysis indicating its weakness (i.e the future cannot be predicted but we can model some possibilities). Standardization Candidate Selection Criteria does provide a conservative analysis based on historical trends with present year dollars as a baseline cost savings for implementing standardized equipments now.

Logistics cost data with maintenance man-hours cost and subjective ranking factors such as ship impact due to availability as presented better define the scenario. These improvements could provide more accuracy based on labor cost and a good indication of possible improvements in standardized products. Logistics data utilization throughout the entire life-cycle is important in standardized design implementation as evidenced in reference 5 and should be emphasized to include maintenance man-hours costs.

C. RESULTS OF DATA

Data bases as presented are valuable standardization tools well worth investing in since they provide ships, design offices, life-cycle managers, engineers and logisticians Navy owned cataloged information. Automating data entry and validation could flag errors (similar to Navy repair actions data entry into the 3M system) where data entry into fields is validated on-line against known terminology and parameters. Long term HEDRS improvements are viewed as a valuable asset that might one day include even more detailed information such as graphs, costs, detail design data and maintenance indicators (similar to supportability indicators) when the data format and media allows for this. Integrating some portions of procurement, maintenance, supply and design databases could promote utilization of standard nomenclature descriptions and computer code format that could provide additional cost savings, streamline operations, and reduce data entry errors.

Results from the data indicate six standard pump families are possible. Two candidates for the estimating portion of this study are: 50 gpm range and 200 gpm range. Differences in these two ranges are variations in projected future demand and acquisition cost. The 50 gpm range has a high Navy need or demand whereby such large quantities and designs variations should result with a high payback due to a 25% acquisition savings achieved during bulk competitive procurement. Alternatively, the 200 gpm range has a high initial procurement cost, even though there are low quantities. Results from the life-cycle cost estimate indicate that life-cycle cost savings is different than PAS as defined. A comparative estimate may potentially have a better definition when applied to life-cycle costs.

Weighing factors found in Table 12 modify cost values making this an excellent example of how a low acquisition cost of non-standard designs, standardization and practical application relate. Weighing factors most prevalent are:

(1) Standardization very low 2.5 out of 10, (2) Acquisition cost very high at 10 out of 10.

Practical reasons for not selecting pumps in low flow regimes (below 25 gpm) deal primarily with application. Lower flow range pumps have wider varying application and are more varied by type than middle flow range pumps. Some form of standardization is proposed as a candidate for further study. As evidenced by the scatter plot, the data indicates higher flow range pumps (beyond 450 gpm) falling into Class "B" fluids category and do not present an R & D design challenge. Methods for standardizing in this range have been proposed by vendors. Trends in data indicate reductions in mid-range pressures due to elimination of boiler fired ships. Pumps in high pressure ranges tend to be commercially available hydraulic units that may be standardized as portions of already skid mounted machinery such as standard UNREP and steering gear systems.

Results from the reliability and maintenance analysis indicate that using a 40% improvement criteria, total maintenance cost savings are realized by a factor of 2.0 for 50 gpm flow range and 2.5 for 200 gpm flow range.

D. ECONOMIC EVALUATION

Since the yearly costs for status quo are an additive progression due to proliferation effects as depicted in Figures 18 and 19, costs for supporting such infrastructure becomes the unacceptable burden as modeled. Cost comparison indicate a very large spike for new proposed standard designs in year-6 for a competitive bulk purchase with other years costs being relatively steady. A large funding amount is required in year-6 for a competitive purchase and becomes an issue beyond this report.

Integration of baseline yearly costs on present year dollars provides a payback occurrence realized in year-12 and 16 for standard Designs "A" and "B", respectively. This translates to lower than expected 7 and 11 years operational time. Since the goal was originally 5 years, the decision to proceed at a 7-year payback must be evaluated by those who establish and/or use a 5-year criteria. Modifying cost factors are discounting, inflation, deflation, productivity, and depreciation. Discounting, deflation, technological improvements and productivity will degrade the benefits of standardization whereas inflation, depreciation and long life-cycles improve standardization benefits.

The integration of discounted yearly costs as presented in Figure 21 indicates an occurrence of payback realized in year-12 and 18 for standard Designs "A" and "B" respectively. Based on reference 27, inflation and depreciation will increase the quality of savings and the payback period. Productivity and deflation will decrease the payback period.

Since standard Design "A" has a lower scale of cost ratio of 2.9 over standard Design "B" based on present year dollars or baseline dollars. This infers that a smaller investment is required to achieve a greater payback. As modeled, standard Design "A" has a best overall potential for selection over standard Design "B". Observations from the results indicate that mission need or, in this case usage rates of 100 vs 69 and a larger number of reduced APLs for Design "A" are major contributors to the results. By modifying mission need to create a large demand, there could potentially be even lower acquisition and support costs. This might be realized through the commercialization of Navy designs in a dual-use effort.

E. EVALUATION SUMMARY

Factors for ranking Design "A" vs "B" scores in the selection of an optimum are subjective and relative. With only two possibilities the variation in ranking is amplified. Although both designs are candidates for a new design effort involving standardization, Design "A" is an overall better choice when considering cost, implementation, quantity and scale of size.

VI. CONCLUSIONS

The case for standardizing positive displacement pumps is non-trivial due to: the present infrastructure; many design variations; selection; implementation; procurement; global climate; market demand; logistics support, and so on. Other complications include: (1) There is a current rapid rate of downsizing, beyond predicted, where actual applied parts lists and usage rates are being reduced far faster than the implementation of a standardized pump; (2) Although PESS are stated, there are no real comparative actual costs for near term workable standard designs, only estimates; and, (3) Companies that have supplied pumps over many years have captured a market with low acquisition costs and strong advocation, so that any real standardization effort would consider dual-use application.

For the purposes of this academic study only, and for those assumptions made, the 1992 data and projections provides an indication that there appears to be a good market for a standard pump design. This market is driven by historic trends where proliferation of design variations have lead to the numbers of presently supported designs over time. Potential cost savings appear to exist for a standardized, pragmatic, and cost-worthy design having a reasonable economic payback over the life-cycle based on a new standardized concept design that might possibly replace and out-perform the numbers of supported designs. Optimum candidate(s) for an ideal standard pump design modeling effort are best aimed at future quantity mission needs. Qualitative conclusions from this study's modeling estimates indicate that Design "A" is the best candidate for standardization based on shortest payback time and logistics based ranking factors. Additionally, Design "A" has a lower scale of cost by a ratio of 2.9 as compared to Design "B". Payback time for Design "A" is approximately 7 years based on baseline present year dollars and is slightly longer than a 5-year goal. Discounting lengthens the payback time for a new standardization effort as compared to status quo, whereas inflation, depreciation and long life-cycles may enhance the payback period. Lower acquisition and support costs might be realized through a dual-use effort whereby Navy owned designs are commercialized. Realizing a payback from standardized pumps as modeled requires long term funding commitments for hardware that meets or exceeds system life-cycle requirements.

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VIII. APPENDIX

APPENDIX A, PUMPS

Navy fluid services utilize "Kinetic" or "Displacement" type pumps. "Kinetic" pumps are termed centrifugal and special effect types whereas reciprocating and rotary types comprise "Displacement" pumps (Positive Displacement Pump or PDP). Within "Kinetic" and "Displacement" categories there are far too numerous forms and terminologies and to describe these goes beyond this paper's scope. However, more common types are described herein providing an example of an existing dilemma: Many Types.

"Kinetic Pumps": For comparison, single stage centrifugal pump operation consists of fluid motion resulting from kinetic energy developed via centrifugal force. A rotating impeller spinning within a casing accelerates the fluid, then the high velocity fluid is diffused to a higher pressure at a lower velocity. Typically, centrifugal pumps have lower volumetric efficiencies compared to positive displacement pumps, produce higher flows, lower pressures per physical dimensions, and have non-contacting surfaces (see Table 16) excluding shaft seals and bearings. Centrifugal pumps are ideally suited to circulating (peripheral) and propulsion services (axial flow).

Other pump forms that are not "displacement" are termed "Jet" pumps operating from derived pressure. These special effects pumps are typical to educator services operating from an auxiliary source energized by centrifugal pumps.

"Displacement": Or positive displacement pumps operate through moving finite fluid volumes in pressure sealed envelopes within a pump housing. Unlike centrifugal pumps, most positive displacement pumps have close tolerances or contact regions promoting dynamic fluid sealing that potentially causes interfacial wear. Suction and discharge performance are fluid sealing quality indicators. There are many pump types, each having geometric pressure sealing envelope variations. Multiple rotor design variations include rotors having internal and external timing gears with benefits being that no contact occurs between gear timed rotor surfaces. Commonly used generic pump varieties shown in Table 16 reveal design variations making for many pump types having specific and overlapping applications. In addition to many types, there are slight design variations within each type.

Identifying a particular positive displacement pump for an application is non-trivial. References 7 through 13 describe pumps through nomenclature descriptive of design, casing, service, performance and form. There are many possibilities for selection and even many variations in descriptive titles per pump. Using standard nomenclature (or similar) as proposed herein simplifies pump classification beyond present, but a do-all positive displacement pump design may be neither practical or possible, as evidenced by evolution of many designs.

Positive displacement pump designs are ideal for applications requiring design predictability independent of variable system parameters such as metering and filtering. Other positive displacement pump characteristics include high volumetric efficiencies, high pressure, and good suction capabilities. Table 16 comparisons indicate, positive displacement pumps produce flow directly proportional to rotational speed with pressure capabilities relating to envelope design, internal stresses, input torque and system demand. In general, positive displacement pumps are self priming, have higher volumetric efficiencies, wider envelope of operating speed ranges, have flow nearly directly proportional to speed, and provide higher pressures whereas centrifugal designs produce much higher flows at lower pressures.

Generic comparisons indicate that reciprocating positive displacement pumps produce highest pressures followed by multi-staged centrifugal and rotary designs. Rotary designs tend to produce higher pressures as compared to single staged centrifugal designs. Centrifugal pumps compared to displacement type pumps have simpler operation and fewer moving parts. Typical Naval positive displacement pump applications include fuel, lube, seawater, hydraulic and bilge water services.

TABLE 16 (continued), GENERIC PUMP COMPARISONS

TYPE (1)	DRY SUCTION (2) CAPABILITIES	CHARACTERISTICS
Single Rotor, Vane Pump (4)	Good	Good for producing low to medium pressures. Corrosion and contaminant resistant are possible; i.e. Hydraulic services are constructed of iron or steel with bilge and fuel services using stellite, bronze, stainless and plastics.
Single Rotor, Flexible Member Pump (4)	Good	Good for producing low pressures and low flows. Contaminant and corrosion resistant are common; i.e. flexible impeller types used for cooling water. Constructed from bronze and rubber.
Multirotor, Gear Pump (4,5)	Fair	Good for producing low pressure and low flows. Corrosion resistant but not contaminant resistant designs exist; i.e. attached lube oil pumps. Constructed of steel, iron and bronze.
Multirotor, Screw Pump (4,5)	Fair	Good for producing low to high pressures and flows. Corrosion resistant but not contaminant (severe services) resistant designs exist; i.e. lube oil pumps. Constructed of steel, iron and bronze.
Multirotor, Lobe Pump (4,5)	Fair	Good for producing low to medium pressures. Corrosion resistant designs exist but not contaminant resistant (severe services); i.e attached oil pumps with timing gears.

NOTE (5): External, internal and no timing gear designs exist. Services where contamination exists requires timing gears external to the pumped media.

TABLE 16, GENERIC PUMP COMPARISONS

STANDARD NOMENCLATURE (1)	DRY SUCTION	TYPICAL CHARACTERISTICS
Single Stage Centrifugal Pump (3)	Poor. Requires priming unless immersed in media.	Good for circulating flow. Does not produce high volumetric efficiencies at low flows (i.e. 70% below 100 GPM). Typical low pressure (below) operation with higher pressures attained through staging. Contaminant and corrosion resistant designs exist; i.e. Navy standard designs constructed of composite materials.
Reciprocating Piston Pump (4)	Excellent	Good for producing high to very high pressures. Generally over 90% volumetric efficiencies. Corrosion resistant designs exist but not good for contamination. i.e. Hydraulic services constructed generally of iron or steel.
Single Rotor, Screw Pump (4)	Excellent	Good for producing low pressures. Contaminant and corrosion resistant exists; i.e. Bilge and sludge applications constructed of a metallic screw turning within a elastomeric housing.

NOTE (1): Generic pressure comparisons: Low Pressure 0-1000 psi, Medium pressure 1000-2500, High pressure 2500-5000 psi, and very high pressure above 5000 psi.

NOTE (2): Dry suction infers no liquid in the pumping chamber; i.e. priming applications during startup. Ratings are subjective with wear considerations.

NOTE (3): Flow is not directly related to speed. Pressure is related to, speed and diameter.

NOTE (4): PDP, where flow is directly related to displaced volume and speed.

APPENDIX "B"

SAMPLE ANNOTATED COST ESTIMATE CALCULATION

Cost estimates are derived from: (1) Data and formula as provided in the cost benefits portion of the Standardization Candidate Selection Criteria; (2) Reliability and maintenance estimates, and (3) considerations paid to reference 1, Appendix C where no other information was available. A LOTUS 1-2-3 spreadsheet is used to tabulate life-cycle cost estimates on a yearly basis to year-35.

Method used for achieving the estimate in Table 17:

(1) Number of years, as shown in the first row.

(2) Projected proliferation rate, as shown for all four. Status quo usage rates are on a yearly basis as provided by the data whereas the standardized rates reflect the procurement method over the life cycle. It is assumed that there are two standard APLs for each Design "A" and "B" required in year-6.

(3) Status quo usage rates are on a yearly basis as provided by the data, whereas new standardized designs are modeled as a large quantity in year-6 reflecting a cumulative purchase.

(4) Average pump costs for status quo are provided from the data whereas standard designs are estimated slightly lower.

(5) PAS is calculated for the implemention of standard Designs "A" and "B" using the formulas presented in the main text.

(6) In a similar fashion, the ILS savings is calculated for standard Design "A" and "B".

(7) In a similar fashion, APL reduction rate savings is calculated for standard Design "A" and "B".

(8) In a similar fashion, Maintenance savings (MS) is calculated for standard Design "A" and "B".

(9) Present year dollar cost savings due to standardization is the summation of PAS +ILS +APL +MS.

(10) Estimate of actual costs in performing those tasks on

in the Research and Development stages is performed on a yearly basis.

(11) Estimate of actual costs in performing those tasks in the design stages is performed on a yearly basis.

(12) Estimate of actual costs in performing those tasks in the Test and Evaluation stages is performed on a yearly basis.

(13) Estimate of actual costs in performing those tasks in the Production and Construction stages is performed on a yearly basis.

(14) Estimate of actual costs in performing those tasks in the Logistics and Maintenance stages is performed on a yearly basis.

(15) Summation of baseline costs on a yearly basis.

(16) Cumulative sum.

(17) Discounting factors by each year are tabulated from reference 1

(18) Yearly costs multiplied by the discounting factors.

(19) Discounting factors multiplied by the baseline cumulative sum costs that provide the final discounted cost

SAMPLE CALCULATION WITH DETAIL ANNOTATION:

Since the payback period occurs in year-7 for Design "A" after operation, a sample calculation is performed as an example to show the flow of information.

(1) Number of years = 5 + 7 = 12 = (from year 0)

(2) Projected proliferation rate:

Proliferation Rate= 4.3 (Provided by the SCSC)
Number of new standard APLS = 2 (Assumed)

(3) Status quo usage rates = 100

(4) Average pump costs for status quo = 9k (From Data)
New average pumps cost for standardization = 8k (estimated)

NOTE: Cost savings are determined to estimate life-cycle costs under the assumption that if the amount of savings can be determined, then the elements of the life cycle costs can be estimated.

(5) PAS = PBV*ASF*N = 0, (Note: No procurement in year-12, all procurement is in year-6)
PAS (year-6) = 8K * .25 * 30 * 100 = 6000k

Where CP = [450 + (131.25 * P)] * L, (The number of parts, P = 17 from the data, and L is the year), then
CP = [450 + (131.25 * 17)] * 7/1000 = 18.7K
CM = [448 * (P * (APR) * .25)]*[.5 * L *(L + 1)], the term [.5*L(L+1)] is an assumed arithmetic progression factor for NSN increases.
CM = [448 * (17 * 4.3 *.25)]*[.5 * 7 *(7 + 1)/1000
CM = 229k
ILS = 229 + 18.6 = 248k

(7) APL = (L/(30)*[448*P*.25*(# apls)]*.5*L/1000
Where (# apls) are those reduced
= (# apls) = 30 yr * 4.3 apls/yr = 129
APL = (7/30)*[448*17*.25*(129)*.5*7/1000
APL = 200.5k

(8) MS = Correction*(cost/years)*(% improvement)*(AUR)
Where the percent improvement is shown in Figure 17
MS = 2*(1000/5)*.5*(100)/1000
MS = 20k

(9) Total = PAS +ILS +APL +MS
= 0 + 248 + 200 +20
= 468k

(10) C_R = 0 For Design "A" in year-12
= 0 For status quo in any year
(11) C_{DB} = 0 For Design "A" in year-12
= 0 For status quo in any year
(12) C_{TE} = 0 For Design "A" in year-12
= 0 For status quo in any year
(13) C_{PP} = 0 For Design "A" in year-12 since all procurement is in year-6 where C_{PP} in year-6 is:
PBV*(1-ASF)*N = 8K*100*30*.75 =18,000k
PBV*N = 9k*100 = 900k for status quo in every year
(14) C_O = %X*(C_O-Status quo) for Design "A", where %X is a function of the number of supported Designs and improvements due to reliability increases.
%x = ILS * (1 new design)/(129 old designs) +.5 (MS) =

C_O = ILS/129 + MS/2 = 20k +30k (For Design "A" and evaluated in year-35)

C_O = ILS + APL + MS (for status quo)
= 780k + 691k + 40k = 1,511k

(15) $C = C_R + C_{DE} + C_{TE} + C_{PP} + C_O$ (Baseline Dollars, Design "A")

C = 0 + 0 + 0 + 0 + 63k = 63k (for Design "A")

= 0 + 0 + 0 + 900k+ 1,511k = 2,411k (Status quo)

(16) Cumulative sum = 21,341k (Baseline Dollars, Design-"A")
Cumulative sum = 19,541k (Baseline Dollars, Status quo)

(17) Discounting factors @ 5% = .5568

(18) .5568*63k = 35k (Discounted Dollars, Design- "A")
.5568*2,411k = 1,342k (Discounted Dollars, Status Quo)

(19) .5568*20,341k = 15,298k (Discounted Dollars, Design-"A")
.5568*19,541k = 14,028k (Discounted Dollars, Status Quo)

APPENDIX C

TABLE 17, TABULAR COST ESTIMATE CALCULATIONS

TABLE 17 (CONTINUED)

STATUS-QUO "A"	55	86	134	198	279	375	489
STATUS-QUO "B"	96	115	144	183	231	288	355
BASELINE CURRENT YEAR DOLLARS SUMMATION BY YEAR							
DESIGN "A"	50	100	150	425	500	525	18163
DESIGN "B"	50	100	150	425	500	1425	49867
STATUS-QUO "A"	955	986	1034	1098	1179	1275	1389
STATUS-QUO "B"	2596	2615	2644	2683	2731	2788	2855
BASELINE CURRENT YEAR CUMULATIVE SUM	0	1	2	3	4	5	6
DESIGN "A"	50	150	300	725	1225	1750	19913
DESIGN "B"	50	150	300	725	1225	2650	52517
STATUS-QUO "A"	955	1941	2975	4073	5252	6527	7916
STATUS-QUO "B"	2596	5211	7856	*****	13269	16057	18912
NET PRESENT WORTH (5%FACTOR)	1	.952	.907	..863	..822	.783	.746
DOLLARS SUMMATION BY YEAR							
DESIGN "A"	50	95	136	367	411	411	13553
DESIGN "B"	50	95	136	367	411	1116	37211
STATUS-QUO "A"	955	939	938	949	970	999	1036
STATUS-QUO "B"	2596	2491	2398	2317	2246	2184	2130
NET PRESENT WORTH CUMULATIVE SUM	0	1	2	3	4	5	6
DESIGN "A"	50	145	281	648	1060	1471	15024
DESIGN "B"	50	145	281	648	1060	2176	39387
STATUS-QUO "A"	955	1894	2832	3781	4750	5750	6786
STATUS-QUO "B"	2596	5087	7485	9803	12049	14233	16364

TABLE 17 (CONTINUED)

SUMMATION BY YEAR							
DESIGN "A"	0	0	0	0	0	0	6055
DESIGN "B"	0	0	0	0	0	0	4236
BASELINE COST ESTIMATES	0	1	2	3	4	5	6
RESEARCH AND DEVELOPMENT:							
DESIGN "A"	50	100	150	200	100	75	0
DESIGN "B"	50	100	150	200	100	75	0
STATUS-QUO "A"	0	0	0	0	0	0	0
STATUS-QUO "B"	0	0	0	0	0	0	0
DESIGN COSTS							
DESIGN "A"	0	0	0	350	250	150	0
DESIGN "B"	0	0	0	350	250	150	0
STATUS-QUO "A"	0	0	0	0	0	0	0
STATUS-QUO "B"	0	0	0	0	0	0	0
TEST AND EVALUATION							
DESIGN "A"	0	0	0	0	150	300	100
DESIGN "B"	0	0	0	0	150	1200	100
STATUS-QUO "A"	0	0	0	0	0	0	0
STATUS-QUO "B"	0	0	0	0	0	0	0
PRODUCTION AND PROCUREMENT							
DESIGN "A"	0	0	0	0	0	0	18000
DESIGN "B"	0	0	0	0	0	0	49680
STATUS-QUO "A"	900	900	900	900	900	900	900
STATUS-QUO "B"	2500	2500	2500	2500	2500	2500	2500
LOGISTICS AND MAINTENANCE							
DESIGN "A"							63
DESIGN "B"							87

TABLE 17 (CONTINUED)

7	8	9	10	11	12	13	14	15	16	17	18
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
4	4	4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3	3	3
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100	100	100
69	69	69	69	69	69	69	69	69	69	69	69
"B" =32K (Estimate); STATUS-QUO "=9K (From data); STATUS-QUO "											
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
30	57	93	136	188	248	316	393	477	570	671	780
20	37	58	85	116	152	193	238	289	344	403	468
16	37	65	102	147	201	262	332	409	495	589	692
10	21	38	60	86	117	152	193	238	288	343	402
40	40	40	40	40	40	40	40	40	40	40	40
86	86	86	86	86	86	86	86	86	86	86	86

TABLE 17 (CONTINUED)

86	134	198	279	375	489	618	764	926	1105	1300	1512
115	144	183	231	288	355	431	517	613	718	832	956
7	8	9	10	11	12	13	14	15	16	17	18
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
900	900	900	900	900	900	900	900	900	900	900	900
2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
63	63	63	63	63	63	63	63	63	63	63	63
87	87	87	87	87	87	87	87	87	87	87	87

TABLE 17 (CONTINUED)

618	764	926	1105	1300	1512	1740	1984	2244	2521	2815	3124
431	517	613	718	832	956	1090	1233	1386	1548	1720	1901
113	63	63	63	63	63	63	63	63	63	63	63
137	87	87	87	87	87	87	87	87	87	87	87
1518	1664	1826	2005	2200	2412	2640	2884	3144	3421	3715	4024
2931	3017	3113	3218	3332	3456	3590	3733	3886	4048	4220	4401
7	8	9	10	11	12	13	14	15	16	17	18
20026	20089	20152	20215	20278	20341	20404	20467	20530	20593	20656	20719
52653	52740	52827	52913	53000	53087	53173	53260	53347	53433	53520	53607
9434	11098	12925	14930	17130	19542	22181	25065	28209	31631	35345	39370
21843	24861	27973	31191	34524	37980	41570	45304	49189	53237	57457	61858
.710	.677	.644	.613	.584	.556	.530	.505	.481	.458	.436	.415
80	43	41	39	37	35	33	32	30	29	27	26
97	59	56	53	51	48	46	44	42	40	38	36
1079	1126	1177	1231	1286	1343	1400	1457	1512	1567	1621	1672
2083	2042	2007	1975	1948	1925	1904	1886	1869	1854	1841	1829
7	8	9	10	11	12	13	14	15	16	17	18
15105	15147	15188	15227	15263	15298	15332	15364	15394	15423	15450	15477
39484	39543	39598	39652	39702	39751	39797	39840	39882	39922	39960	39996
7865	8991	10168	11399	12686	14029	15428	16885	18397	19965	21585	23257
18447	20489	22496	24471	26420	28344	30248	32134	34003	35857	37698	39527

TABLE 17 (CONTINUED)

19	20	21	22	23	24	25	26	27	28
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
4	4	4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3	3	3
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100	100
69	69	69	69	69	69	69	69	69	69
36 From Data									
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
897	1023	1156	1298	1448	1607	1773	1948	2130	2321
537	611	690	774	862	955	1053	1156	1263	1375
802	921	1048	1183	1326	1478	1637	1805	1981	2166
466	536	609	688	771	859	952	1050	1152	1259
40	40	40	40	40	40	40	40	40	40
86	86	86	86	86	86	86	86	86	86

TABLE 17 (CONTINUED)

1740 1090	1984 1233	2244 1386	2521 1548	2815 1720	3124 1901	3450 2091	3793 2292	4152 2501	4527 2721
19	20	21	22	23	24	25	26	27	28
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
900	900	900	900	900	900	900	900	900	900
2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
63	63	63	63	63	63	63	63	63	63

TABLE 17 (CONTINUED)

87	87	87	87	87	87	87	87	87	87
3450	3793	4152	4527	4918	5326	5751	6191	6648	7122
2091	2292	2501	2721	2949	3188	3436	3693	3960	4236
63	63	63	63	63	63	63	63	63	63
87	87	87	87	87	87	87	87	87	87
4350	4693	5052	5427	5818	6226	6651	7091	7548	8022
4591	4792	5001	5221	5449	5688	5936	6193	6460	6736
19	20	21	22	23	24	25	26	27	28
20782	20845	20908	20971	21034	21097	21160	21223	21286	21349
53694	53780	53867	53954	54040	54127	54214	54300	54387	54474
43720	48413	53464	58891	64710	70936	77587	84678	92227	100249
66449	71241	76242	81463	86912	92600	98536	104729	111189	117925
.395	.377	.359	.341	.325	.310	.295	.281	.268	.255
25	24	23	22	21	20	19	18	17	16
34	33	31	30	28	27	26	24	23	22
1721	1769	1814	1855	1894	1931	1964	1995	2022	2046
1817	1806	1796	1785	1774	1764	1753	1742	1731	1718
19	20	21	22	23	24	25	26	27	28
15501	15525	15548	15569	15590	15609	15628	15646	15663	15679
40030	40063	40094	40123	40152	40178	40204	40228	40252	40274
24979	26748	28561	30417	32311	34242	36206	38201	40223	42269
41344	43150	44945	46730	48504	50268	52021	53763	55494	57212

TABLE 17 (CONTINUED)

29	30	31	32	33	34	35
0	0	0	0	0	0	0
0	0	0	0	0	0	0
4	4	4	4	4	4	4
3	3	3	3	3	3	3
0	0	0	0	0	0	0
0	0	0	0	0	0	0
100	100	100	100	100	100	100
69	69	69	69	69	69	69
0	0	0	0	0	0	0
0	0	0	0	0	0	0
2521	2728	2943	3167	3399	3639	3887
1492	1614	1740	1872	2008	2148	2294
2358	2559	2767	2984	3209	3443	3684
1371	1488	1609	1735	1866	2002	2142
40	40	40	40	40	40	40
86	86	86	86	86	86	86

TABLE 17 (CONTINUED)

4918	5326	5751	6191	6648	7122	7612
2949	3188	3436	3693	3960	4236	4522
29	30	31	32	33	34	35
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
900	900	900	900	900	900	900
2500	2500	2500	2500	2500	2500	2500

TABLE 17 (CONTINUED)

63	63	63	63	63	63	63
87	87	87	87	87	87	87
7612	8118	8640	9179	9735	10306	10895
4522	4818	5122	5437	5761	6094	6437
63	63	63	63	63	63	63
87	87	87	87	87	87	87
8512	9018	9540	10079	10635	11206	11795
7022	7318	7622	7937	8261	8594	8937
29	30	31	32	33	34	35
21412	21475	21538	21601	21664	21727	21790
54560	54647	54734	54820	54907	54994	55080
108760	117778	127319	137398	148033	159239	171034
124947	132264	139887	147824	156085	164679	173616
0.2430	0.2314	0.2204	0.2099	0.1999	0.1904	0.1813
15	15	14	13	13	12	11
21	20	19	18	17	17	16
2068	2087	2103	2116	2126	2134	2138
1706	1693	1680	1666	1651	1636	1620
29	30	31	32	33	34	35
15694	15709	15722	15736	15748	15760	15772
40295	40315	40334	40352	40369	40386	40402
44338	46424	48527	50643	52769	54902	57041
58918	60612	62292	63958	65609	67245	68866

TABLE 17 (CONTINUED)

4918	5326	5751	6191	6648	7122	7612
2949	3188	3436	3693	3960	4236	4522
29	30	31	32	33	34	35
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
900	900	900	900	900	900	900
2500	2500	2500	2500	2500	2500	2500

APPENDIX "D"

DISCUSSION OF STANDARD PUMPING SYSTEMS RECOMMENDATIONS, CONSIDERATIONS AND APPLICATION

1. Implementation: Life-cycle cost savings will only be realized through implementation. Optimizing standardization usage requires clear implementation directives from the top down. A current catalog of available pump types and standardized components is now available on HEDRS. Utilization of HEDRS CD ROMs promotes standardization utilization infrastructure via optical disk catalog and personal computer. HEDRS eventually provides a vehicle for standardization pump selection via a standardized components list. Optimum standard positive displacement pump utilization will only come about with top level management mandates in the form of directives, tight ship building procurement and overhaul specifications mandating hull, mechanical and electrical end users to utilize standardized pumps (i.e specified applied parts lists maintained as part of a competitive bulk procurement) as government furnished equipment or direct purchase.

Overshadowing any directive is the present standard positive displacement pump implementation scenario dilemma: Navy owned standard positive displacement hardware does not presently exist and may not, possibly for many years to come or at all. Since standard positive displacement pumps are not near term, they cannot be specified.

2. Suction and Systems: Life-cycle cost savings are realized through the implementation of a standard positive displacement pump that meets the pumping system requirements. Recognizing limitations in pump suction capabilities, (particularly with wear and/or varying viscosity) requires locating pumps within realistic distances from tank levels and not necessarily near convenient manifolds. Long suction legs having bolted connections and/or seals potentially allows air entrainment even if line hydrostatic pressure tests indicates integrity. Air entrainment degrades pump performance by limiting suction capabilities and increasing noise generation. Noise and suction are both specification performance measures. Alleviating long suction runs having air entrainment possibilities can be achieved using distributed pumping architectures whereby more and smaller pumps are located near or in the tank. Standard positive displacement pumps would most likely see an operational range between 5-15" Hg.

3. Alternative Lube Oil Architectures: Life-cycle cost savings may be realized through architectural changes where savings result from impacting other systems. Most lube oil

pumps servicing machinery tend to be fixed displacement pumps; however, oil has varying viscosity with temperature and pressure. Current architectures for normal operations requires throttling across unloader or relief valves where energy is lost and designs are not optimum. The combined effect of machinery operations and media characteristics promotes variable conditions where cold oil becomes hot allowing supply pressures to drop to near design values plus a margin; but excessive drops due to wear usually requires maintenance in time. Reference 24 indicates forty percent margins are typical values for sizing fixed displacement lube oil pumps, however using variable volume lubricating oil positive displacement pumps provides constant pressure at required demand variable flow without throttling. This translates to an energy savings. Alternative architectures utilizing variable volume lube oil systems may possibly simplify systems operation, save energy and extend equipment operational range especially when combined with pre-lube operations. Practically applying this alternative architectures requires equivalent reliability.

4. Design Formats: Although this report explores life-cycle cost savings by implementing proposed standard positive displacement pumps, there are infinite variations for achieving this goal. The method chosen assumes fluid

category "A" and "B" combined; however, different results may be realized for separate pumps per fluid. Materials utilized in services requiring corrosion and contamination resistance or Class A fluids would benefit from hardened materials such as ceramic. Benefits are seen in logistic and supply costs savings with added ship capabilities. Utilizing corrosion and contaminant tolerant pumps in applications not requiring this feature may benefit where standard Navy designs may cost less than alternative lower quality pumps (i.e keeping applied parts lists to a minimum). Cost savings projected herein are based on broad generalizations lacking necessary design detail that renders hardware; however, future iterations in the design spiral should look at better-segregated, hardware-oriented data. This might lead to pumps directed towards either of two fluid classifications presented herein.

5. Operation: During the life-cycle it is important to logistically measure pump performance. Although actual pump operation is not known, it is speculated that dry running conditions and incorrect valve positions are both potential operator errors that may be avoided with the simplest detection schemes that could enhance ship operation and avoiding pump failures. These include using a single differential pressure alarm to more advanced accelerometers

as modeled in "Standard Positive Displacement Pumping System" report for ENGR 5004 and presented herein. Life-cycle cost saving could therefore result from the infusion of imbedded sensors technology.

6. Interface: Since life-cycle cost savings results through the reduction of supported parts standardizing on systems interfaces may further enhance savings. Selecting standard pump design requirements requires a standard interface form. Currently, there are many piping interfaces describing flanges to include, Navy, ANSI, SAE, and DIN standards. Choices in tube and pipe diameters exist as well. Advantages for using commercial standards are cost driven, but limitations in physical size, military effectiveness and coverage make commercial standards less desirable as compared to Navy flanges. Integrating flange specifications so that only one specification exists could lower acquisition and support costs through commercializing some of the aspects found in Navy flanges (i.e dual use advantages).

The initial effort taken herein defines pump families based on standard schedule 40, steel pipe sizes and commercially available American National Standards flange sizes.

VITA

The author is a 34-year old Mechanical Engineer at the Naval Surface Warfare Center Carderock Division, Annapolis Detachment, (CDNSWC). Working in the areas of Marine Machinery since 1983 and more recently positive displacement pumps from 1990 to 1993, the author has applied those skills gained while taking courses in Virginia Tech's Systems Engineering program towards areas of expertise.

During the Standard Positive Displacement Pump Program effort the author has documented trends within this project and report. Additionally, a patent has been applied for in the area of structural ceramics technology directed towards Navy standard pump utilization addressing producability, contamination, corrosion and wear.

Other employment includes several years of shipyard experience for the United States Coast Guard and as a U.S. Army government contractor specializing in army water craft development and modification. The author's career began as a professor's assistant at the University of Maryland.

Edward I. Cohen