SL101-AA-GYD-010

REVISION 5

NAVSEA TECHNICAL PUBLICATION

SHIPBOARD ENERGY CONSERVATION GUIDE

CAUTION: WHILE DIRECTIVE IN NATURE, NOTHING IN THIS GUIDE SHALL OVERRIDE OR SUPPLEMENT THE TECHNICAL, CONFIGURATION, AND OPERATIONAL COMPLIANCE REQUIREMENTS OF ENGINEERING OPERATIONAL SEQUENCING SYSTEM (EOSS), ENGINEERING OPERATIONAL PROCEDURES (EOP), TYCOM INSTRUCTIONS, OR OTHER REQUIREMENT DOCUMENTS. THE ENERGY EFFICIENT PRACTICES PROVIDED IN THIS GUIDE SHALL BE USED WHENEVER OPERATIONAL COMMITMENTS AND ENVIRONMENTAL CONDITIONS PERMIT, AND SOLELY AT THE DISCRETION OF THE COMMANDING OFFICER.

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FOREWORD

This shipboard ENergy CONservation (ENCON) Guide and the Energy Survey Checklist for Improved Fuel Economy (Appendix A) provide procedural and operational initiatives that ship operators can use to improve ships' operational readiness, save fuel, and lower equipment repair and maintenance costs. Reduction of fuel consumption per steaming hour can be accomplished if ships and their associated engineering plants are operated with a better understanding and awareness of the factors affecting ship handling, plant efficiency, and fuel consumption. This document is intended for all hands and is a "must read" document, as it is sure to chart an efficient course to successful energy conservation measures aboard ships. Although the program was developed for the Navy, the principles and techniques used can be applied to commercial shipping and shore activities, as well as military ships.

CAUTION

While directive in nature, nothing in this Guide shall override or supplement the technical, configuration, and operational compliance requirements of Engineering Operational Sequencing System (EOSS), Engineering Operational Procedures (EOP), Type Commander (TYCOM) instructions, or other requirement documents. The energy efficient practices provided in this Guide shall be used whenever operational commitments and environmental conditions permit, and solely at the discretion of the Commanding Officer (CO).

This Guide was originally developed to supplement the NAVSEA incentivized Energy Conservation (iENCON) Program. The iENCON Program was established by NAVSEA in 1993 and has evolved over the years. Most recently, the program helped support the Maritime Working Group of Task Force Energy (TFE), headed by OPNAV N45, to help meet the Secretary of the Navy (SECNAV) and Chief of Naval Operations (CNO) energy conservation goals. In October of 2014, the iENCON Program officially began its transition to becoming a Fleet-run program, with NAVSEA playing a supportive role to Commander Naval Surface Force Atlantic (CNSL) and Commander Naval Surface Force Pacific (CNSP). For the most recent updates on the progress of this transition, please contact CNSL N43 or CNSP N43.

The Fleet (CNSL/CNSP) and individual ships use this document to obtain NAVSEA approved engineering and operating techniques that will save fuel and energy while underway and in-port. As of the publication of SL101-AA-GYD-010, Revision 5, Fleet Energy Managers (FEMs) are in place with the iENCON Program transition to directly train ships with energy saving techniques. Revision 5 updates this document with the latest NAVSEA approved energy saving techniques and operating philosophies from which CNSL/CNSP and the FEMs can develop their local training materials and methodology. Such updated ENCON information is vital to the Fleet and ships in order to continue the improved fuel consumption trends that are leading towards meeting the SECNAV/CNO fuel consumption goals for 2020.

Energy conservation provides operational benefits to all ships. Additionally, individual ships may be recognized with awards when outstanding energy conservation is achieved. These awards and benefits include (see details in Chapter 1):

a. SECNAV Energy Awards (annual)
b. Environmental Protection and Energy Conservation (EPEC) Awards (annual)
c. Federal Energy and Water Management Awards (annual)
d. Top five ships pictured on iENCON website (www.i-encon.com) (quarterly)
e. Top 25 ships listed on iENCON website (quarterly)
f. FITREP (Fitness Report)
g. Extended periods between replenishments (Range-Distance-Time)
h. Good stewardship (for energy conservation)
i. Increased fuel for training
j. Reduced machinery repair and maintenance costs

NAVSEA's establishment of the iENCON Program has led to the development of a multitude of tools so that all personnel in the Navy can become knowledgeable on the benefits of energy conservation. These tools include:

- The iENCON website (www.i-encon.com), which hosts all legacy iENCON information inclusive of the energy checklist, ENCON Guide, training videos and PowerPoint briefings, current and past iENCON and SECNAV award winners, past "Top Five iENCON Performers" with ship pictures and a "Top 25" list, and the latest ENCON news.

- The Ship Energy Conservation Assist Training (SECAT) Tool, which facilitates ships' development of fuel consumption curves, determining optimum transit speeds for various plant alignments, and replenishment requirements.

- The Battlegroup Optimum Transit Speed Calculator (BOSC) Tool, which aids in determining the optimum transit speed of multi-ship Fleet operations in order to achieve fuel savings.

Task Force Energy (TFE) was established by the CNO in 2008 to meet the Energy Security Challenges, which can be identified by the following elements of today's energy environment:

- High dependency on petroleum.
- Volatile and rapidly fluctuating energy costs.
- Strategic implications of oil reserves and transport.
- Tactical vulnerabilities during fueling operations.
- Availability of foreign oil in times of crisis.
- Desire for reduced carbon footprint.

The objectives of TFE are to:

- Raise visibility and awareness of energy as a strategic resource.
- Optimize energy considerations in budgeting and acquisition.
- Recommend Navy-wide energy conservation and alternative energy strategies.
- Meet SECNAV energy goals for FY 2012, FY 2016, and FY 2020.

TFE is headed by the Task Force Energy Executive Steering Committee and the Navy Energy Coordination Office (OPNAV N45). It includes working groups for Maritime, Aviation, Expeditionary, Shore, Fuels, Science & Technology, and Research & Development (R&D).

The Maritime Working Group (NAVSEA 05T) focuses on ships and is following a Maritime Energy Road Map which includes Strategic Planning, Technology, and Operations. The two primary initiatives of the Maritime Working Group are:

- Energy efficiency improvements via R&D and equipment/system modifications, which support the Strategic Planning and Technology initiatives.
- Operational initiatives for the reduction of fuel consumption via procedural and operational modifications (i.e., culture change).

In 2009, the SECNAV set forth five energy goals that provide energy reduction and alternate energy objectives for both shore-based infrastructure and ships (http://greenfleet.dodlive.mil/energy). The energy goals that pertain to ships are:

- FY 2012: Sail the Great Green Fleet (GGF) during the Rim of the Pacific (RIMPAC) exercise using alternative fuels. The Navy demonstrated alternative fuel blends on all ships and aircraft that participated in the 2012 RIMPAC exercise. Ship and air systems operating with alternative fuel blends performed at full capability during the exercise.
- FY 2016: Deploy the GGF. The GGF is a year-long, Department of the Navy initiative that demonstrates the sea service's efforts to transform its energy use. The centerpiece of the GGF is a Carrier Strike Group (CSG) that deploys on alternative fuels, including nuclear power for the carrier and a blend of advanced biofuel made from beef fat and traditional petroleum for its escort ships. The CSG also uses energy efficient technologies and operating procedures referred to as Energy Conservation Measures (ECMs) during the course of its normal operations (http://greenfleet.dodlive.mil/energy/great-green-fleet/).
- FY 2020: 50 percent of the total Department of Navy energy consumption will come from alternative sources.

In 2010, the CNO set forth three energy goals that provide energy reduction and resiliency goals for both shore-based infrastructure and ships. These goals were published in October 2010 by ADM Roughead in "Navy Energy Vision for the 21st Century." The energy goal that pertains to ships is:

- FY 2020: Increase efficiency and reduce fuel consumption afloat by 15 percent compared to the average of FY 2009, 2008, and 2007.

Ships performing energy conservation functions, strategies, and techniques, such as those outlined in this Guide, will be instrumental in achieving the SECNAV energy goals.

This document is organized as follows:

Chapter 1, Introduction

Chapter 2, Energy Efficient Ship Operations

Chapter 3, Energy Efficient Propulsion Plant Operations

Appendix A, Energy Survey Checklist for Improved Fuel Economy

Appendix B, SECAT Tool

Appendix C, Plant Alignment Status Boards and Nomograms

Appendix D, BOSC Tool

Appendix E, List of Acronyms

NAVY DISTANCE SUPPORT (DS) CUSTOMER ASSISTANCE CONTACT INFORMATION

Fleet users of this technical manual may request NAVY 311 assistance. NAVY 311 is the Fleet's single point of entry for technical and logistics support whenever routine sources of support are unavailable or are not readily identifiable. NAVY 311 is operated via the Global Distance Support Community (GDSC) of geographically dispersed, centrally coordinated, Tier 1/2 call centers that function on a 24/7 basis. Point of entry options:

Phone: 1-855-NAVY311 (1-855-628-9311)/DSN 510-NAVY311 (510-628-9311)

Navy Distance Support/Navy 311 Web: http://www.navy311.navy.mil/ (unclassified) or https://www.navy311.navy.smil.mil/ (classified). (Provides program information and links to an online Support Request Form and Support Request Status, Live CHAT with a Call Center Rep, Knowledge Base Searching, etc.)

Email: Navy311@navy.mil or Navy311@navy.smil.mil

TMDER INSTRUCTIONS

Ships, training activities, supply points, depots, Naval Shipyards and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals (TMs). All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA TMs shall be submitted as a Technical Manual Deficiency/Evaluation Report (TMDER). All feedback comments shall be thoroughly investigated and originators will be advised of action resulting there from.

The NAVSEA/SPAWAR Technical Manual Deficiency/Evaluation Report form, NAVSEA 4160/1, is included at the back of the TM.

The following methods are available for generation and submission of TMDERs against unclassified TMs:

For those with a Technical Data Management Information System (TDMIS) account, the most expedient and preferred method of TMDER generation and submission is via the TDMIS website at: https://mercury.tdmis.navy.mil.

For those without a TDMIS account, generate and submit TMDER via the Naval Systems Data Support Activity (NSDSA) website at: https://mercury.tdmis.navy.mil/def_external/pubsearch.cfm. (TDMIS accounts may be requested at https://nsdsa.nmci.navy.mil.)

When internet access is not available, submit TMDER via hardcopy to:

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COMMANDER
CODE 310 TMDERs
NAVSURFWARCENDIV NSDSA
4363 MISSILE WAY, BLDG 1389
PORT HUENEME, CA  93043-4307
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Additional copies of the TMDER form may also be downloaded from the Naval Systems Data Support Activity (NSDSA) website at: https://nsdsa.nmci.navy.mil/, by clicking on the blue tab labeled “Reference Docs/Forms”.

TMDERs against classified/restricted (includes all NOFORN) TMs must be submitted using the hardcopy method cited above.

Urgent priority TM deficiencies shall be reported by Naval message with transmission to Port Hueneme Division, Naval Surface Warfare Center (Code 310), Port Hueneme, CA. Local message handling procedures shall be used. The message shall identify each TM deficiency by TM identification number and title. This method shall be used in those instances where a TM deficiency constitutes an urgent problem, (i.e., involves a condition, which if not corrected, could result in injury to personnel, damage to the equipment or, jeopardy to the safety or success of the mission).

Complete instructions for TMDER generation and submission are detailed on the NSDSA website at: https://nsdsa.nmci.navy.mil/, by clicking on the blue tab labeled “TMDER/ACN” and then clicking on the gray button labeled “TMDERs”.

CHAPTER 1
INTRODUCTION

CAUTION

While directive in nature, nothing in this Guide shall override or supplement the technical, configuration, and operational compliance requirements of EOSS, EOP, TYCOM instructions, or other requirement documents. The energy efficient practices provided in this Guide shall be used whenever operational commitments and environmental conditions permit, and is solely at the discretion of the CO.

1.1 SHIPBOARD ENERGY CONSERVATION GUIDE STRUCTURE.

The Shipboard Energy Conservation Guide is applicable to all fossil-fueled ships, and is structured as follows:

a. Chapter 1 outlines topics not directly related to ship operational strategies, including a history of the legacy NAVSEA iENCON Program, details of the transition to a Fleet-managed (CNSL/CNSP) ENCON Program, as well as additional discussions on the importance of energy conservation and methods to achieve it.

b. Chapter 2 explains energy efficient ship operational strategies applicable to all aspects of ship operations, regardless of propulsion system.

c. Chapter 3 provides energy efficient propulsion plant operational strategies applicable to specific propulsion systems including gas turbine, diesel engine, and steam turbine propulsion.

d. Appendix A provides an ENCON checklist that ships can use to perform a self-analysis of their current energy usage, and to highlight actions that the ship could take to further reduce their fuel consumption.

e. Appendix B provides instructions for using the NAVSEA Ship Energy Conservation Assist Training (SECAT) Tool for developing fuel consumption curves and planning transits.

f. Appendix C provides useful charts and tables for specific ship classes which supplement the SECAT Tool in determining the most efficient plant line-ups for reducing fuel consumption.

g. Appendix D provides instructions for using the NAVSEA Battlegroup Optimum Transit Speed Calculator (BOSC) Tool for determining optimum group transit speeds and fuel savings for planned transits.

h. Appendix E provides a list of acronyms.

1.2 NAVSEA LEGACY iENCON PROGRAM.

The iENCON Program was established by NAVSEA in 1993 to assist the U.S. Navy in saving fuel by providing incentives to the Fleet for operating their ships efficiently. In October of 2014, the iENCON Program began a transition to a Fleet-run program, with CNSL sponsoring the Atlantic Fleet ENCON Program, and CNSP sponsoring the Pacific Fleet ENCON Program.

During this transition, some of the incentives of the legacy NAVSEA iENCON Program were not carried over. These incentives include the Fleet TYCOM's Augmented OPTAR Cash Awards (annual). An individual ship that underburned its respective Underway (UW) and/or Not-Underway (NUW) baseline rate in a quarter was eligible for a cash award (typically $1,000-$50,000) in the form of augmented OPTAR funding, if funding was available during the fourth quarter. Each fiscal year, about 90 percent of ships received cash awards. The Fleet TYCOM's Augmented OPTAR Cash Awards were characterized by the following:

a. A ship was not penalized for overburning their class baseline during a quarter.

b. Baselines for new ship classes were developed after a ship was in service and had submitted a minimum of six quarters of Navy Energy Usage Reporting System (NEURS) data.

c. The award period covered Q4 of the previous fiscal year and Q1 through Q3 of the current fiscal year. For example, during Q4 of FY 2014, ships received awards based on their performance during Q4 of FY 2013 and Q1 through Q3 of FY 2014.

d. The CNO monitored individual ships and Fleet underway and not-underway fuel rates utilizing OPNAVINST 4100.11, the NEURS, as part of their overall evaluation of Navy fuel consumption and conservation within the Fleets. From this data, iENCON produced quarterly and annual reports for all active fossil-fueled surface ships to determine the recommended OPTAR cash award value for each ship. This process incurred no additional reporting burden on any individual ship. As long as a ship submitted NEURS reports, it was eligible for cash incentive awards.

The NAVSEA iENCON Program currently provides support to the Fleet-managed (CNSL/CNSP) ENCON Program, including:

1.2.1 Energy Savings Techniques. Providing (via this manual) safe and effective, NAVSEA approved, energy saving techniques that the Fleet can train and implement as appropriate.

1.2.2 Technical Warrant Authority. Technical warrant authority for energy equipment and tools developed or updated.

1.2.3 Analyses. Special studies, analyses, and trend reports as required by OPNAV, OSD, etc.

1.2.4 Quarterly Reports. Quarterly reports are generated by iENCON to present ship-by-ship comparisons of quarterly actual fuel consumption rates versus class average baseline rates to identify fuel savings, which were used to provide recommended incentive awards during the fourth quarter.

1.2.5 Top Five Ships. The top five ships are pictured on the iENCON website (www.i-encon.com) (quarterly). The top five ships that underburn their respective baseline rate based on their iENCON score have their pictures displayed on the iENCON website for the quarter following this achievement. An archive is available to check the past top five performing ships for each quarter.

1.2.6 Top 25 Ships. The top 25 ships are listed on the iENCON website (quarterly). Ships that perform in the top 25 in terms of underburning their baseline rates have their names posted on the iENCON website for the quarter following this achievement. An archive is available to check the past top 25 performing ships for each quarter.

1.3 FLEET-MANAGED (CNSL/CNSP) ENCON PROGRAM.

For the remainder of this document, "ENCON Program" refers to the new Fleet-run Energy Conservation Program currently under transition/development. "iENCON" refers to the legacy NAVSEA-run incentivized Energy Conservation Program no longer in existence.

1.4 AWARDS AVAILABLE TO SHIPS.

Available awards vary from year-to-year and are dependent on sponsoring organization resources and policies. Such awards include, but are not limited to:

1.4.1 SECNAV Energy Awards (Annual). The Secretary of the Navy presents annual awards for energy conservation to ships in three categories: Large Hull (crew size >400), Medium Hull (crew size 250-400), and Small Hull (crew size <250). Awards are presented to ships with command-level involvement in comprehensive energy conservation programs that have well-staffed and trained energy teams, aggressive energy awareness campaigns, crew training, innovative energy conservation measures, and consistent reduction in energy consumption. Each category has four levels of awards. They are:

a. SECNAV Award (Highest Level): Award winners are authorized to fly the SECNAV energy flag for a period of 1 year. Additionally, they receive a monetary award ($30,000-large ship category, $25,000-medium ship category, and $20,000-small ship category), and are recognized at a prestigious award ceremony with a plaque and a certificate of achievement. Travel expenses to ceremony are reimbursed.

b. Platinum Level Award: Winners at this level receive a monetary award ($5,000-large ship category, $5,000-medium ship category, and $5,000-small ship category), a plaque, a certificate of achievement, and are invited to the awards ceremony. Travel expenses to ceremony are reimbursed.

c. Gold Level Award: Winners at this level are listed in the awards ceremony program and are invited to the awards ceremony. They receive a plaque and certificate of achievement in the mail.

d. Blue Level Award: Winners at this level are listed in the awards ceremony program and receive a plaque and certificate of achievement in the mail.

1.4.1.1 SECNAV Award Criteria. SECNAV Award criteria are sent out in a message every year and include the following four categories:

a. Total Energy Saved (45 points): Total energy saved in the previous fiscal year as calculated in barrels, compared to prior year iENCON baselines for underway, not-underway, and gains/losses by inventory.

b. Cold Iron Energy Saved (10 points): Dockside shore power energy savings achieved by reducing hotel load demands while optimizing cold-iron support. Ships must provide a detailed description of actions taken to achieve the savings identified.

c. Awareness and Training (20 points): Ships may earn the 20 points through a combination of:

(1) Documented use of ENCON strategies and program materials such as this Guide and the SECAT Tool, and

(2) Attendance of ENCON training sessions.

d. Innovation (25 points): Any documented new ideas and innovative features that make the approach to energy conservation unique and/or achieve technical or economic benefits, other than those already listed in this Guide or the Checklist (Appendix A).

1.4.2 Environmental Protection and Energy Conservation (EPEC) Awards (Annual). The EPEC Award is a newly developed award by Fleet Forces Command (USFF MSG 090900Z FEB 12) which will advance Navy Energy Conservation and Environmental Protection objectives by recognizing those ships that consistently meet established goals for reducing fuel consumption and protecting the maritime environment. The EPEC Award, first included in the calendar year 2012 competitive award cycle, will be used as a factor in determining the winners of battle efficiency competitions. One of the major criteria for the EPEC Award is for the CO to attend ENCON training once a year. The EPEC Award will be used as a factor in determining the winners of their respective battle efficiency competitions.

1.4.3 Federal Energy and Water Management Awards (Annual). The Federal Energy and Water Management Awards recognize individuals, groups, and agencies for their outstanding contributions in the areas of energy efficiency and water conservation. These awards are not provided solely to U.S. Navy ships; rather, they are much broader and open to all Federal agencies and organizations. Individual U.S. Navy ships are, however, eligible to receive this award. Due to the limited number of nominations each agency can submit, any nominations should be coordinated with the Navy Agency Coordinator in advance.

1.4.4 Top Five Ships Pictured on iENCON Website (www.i-encon.com) (Quarterly). The top five ships that underburn their respective baseline rate based on their iENCON score had their pictures displayed on the iENCON website for the quarter following this achievement. An archive is still available to check past Top five performing ships each quarter.

1.4.5 Top 25 Ships Listed on iENCON Website (Quarterly). Ships that perform in the top 25 in terms of underburning their baseline rates had their names posted on the iENCON website for the quarter following this achievement. An archive is still available to check past Top 25 performing ships each quarter.

1.4.6 FITREP (Fitness Report). Fuel conservation efforts are a major contribution to meeting the Energy Security Challenge and augmenting a ship's readiness to perform its mission. Therefore, officers and crew members who desire good fitness reports and evaluations for promotions can document their energy conservation efforts in their FITREP.

1.4.7 Extended Periods Between Replenishments (Range-Distance-Time). Tactical vulnerabilities during fueling operations are one of the major elements of the Energy Security Challenge in today's energy environment. Thus, there is an incentive to extend the period between replenishments to reduce the number required and the associated vulnerability.

1.4.8 Good Stewardship (for Energy Conservation). Some individuals want to do all that they can to preserve the environment, save the world's resources, and reduce our dependence on foreign oil. This can provide a powerful incentive to conserve shipboard energy and save fuel.

1.5 SHORE-BASED REQUIREMENTS FOR EFFECTIVE ENCON PROGRAM.

While the legacy iENCON Program primarily focused on energy savings underway, ships also play an important role in energy conservation while in-port. Major U.S. naval bases have already begun installing shore power meters at piers and berths to document and evaluate ship's shore power usage. Additionally, shore-based commanders play an important role when assigning ships speed of advance, deployment and training schedules, and other underway tasking. In order to have an effective all-around energy conservation program, these shore-based commanders also need to be aware that their decisions can greatly impact the overall Navy's goal of energy conservation.

1.5.1 Shore-Side Energy Advisors. Major U.S. naval bases have begun implementing Shore-Side Energy Advisors who work closely with Ship's Force while in-port. The Energy Advisors are responsible for educating and training the Fleet on conservation initiatives, equipment, procedures, and methods that will aid in at-sea and shore-side energy saving efforts. As shore power meters become available at major bases, the Energy Advisors will be responsible for analyzing and evaluating ship energy consumption while connected to shore power. Contact CNSL N43 or CNSP N43 for further information regarding Energy Advisors.

1.5.2 Shore Power Usage. While attached to shore power, COs will make energy related all-hands announcements while using water and electricity in port, as the ship's energy usage will be monitored and evaluated. Notes in the Plan of the Day (POD), Standing Orders, and other methods are acceptable. The shore power performance of each ship is used in the annual SECNAV Energy Award evaluations. Ships are expected to detail their in-port best practices in their annual SECNAV award submittals, as well as their annual EPEC award submittal per the latest Fleet messages. These Fleet messages detail specific ship actions for consideration of the annual EPEC award to advance Navy energy conservation and environmental protection objectives by recognizing those ships that consistently meet established goals for reducing fuel consumption and protecting the maritime environment.

1.5.3 Base/Operational Commanders Action. The Base/Operational Commanders need to cooperate with ship operators to enhance the effectiveness of shipboard energy conservation initiatives. The following examples illustrate how actions by Operational Commanders, Base Commanders, Schedulers, and associated shore-side personnel are necessary for supporting shipboard energy conservation:

a. Speed of Advance (SOA): Operators and Schedulers need to be energy conscious when tasking a ship to transit to a specific destination. If possible, allow the ship to use an optimum transit speed and plant alignment. The BOSC Tool, outlined in Appendix D, can assist with determining an optimum speed for groups of ships traveling together.

b. Restricted Maneuvering Doctrine (RMD): At the discretion of the CO, it is recommended that ships secure from RMD as soon as feasible. However, this may be dependent on wind conditions, availability of tugs, and other factors.

   (1) Typical practice is to remain at full power until doubled up and the brow is over, which usually takes at least an hour. This procedure burns a significant amount of fuel when up to seven engines are operating [based on four Main Propulsion and three Ship Service Generators (SSGs)].

   (2) When safely moored, the ship can reduce the propulsion plant down to the minimum number of engines and/or generators needed based on the ship's configuration.

   (3) In addition, the number of SSGs can be reduced to two instead of three, and if the electric load allows, one generator can be used.

c. Operational/Base Commanders Coordination: A team effort must exist between operations and shore commands to prevent excessive idle time at sea while waiting to enter port. In one example of team effort, a DDG was allowed to enter port on a Friday night by the base command vice remaining at-sea to wait for refueling on Monday. In this example, the shore command paid $5K overtime to save taxpayers the approximate $255K it would have cost to keep the DDG at-sea over the weekend.

d. Replenishment at Sea (RAS): During RAS operations, ships are accustomed to getting on station ahead of time so they are ready to "go alongside" at the scheduled RAS. This practice requires as many as seven engines on-line (four main and three SSGs), which consumes an excessive amount of fuel. For example, 30 minutes to 1 hour operating seven engines may consume 5,000 to 6,000 gallons of fuel. Therefore, the ship being replenished should be cognizant of the additional equipment on-line and should not go to full power more than 15-30 minutes ahead of alongside time.

e. Hull/Propeller Cleaning: Fouled hulls and propellers can lead to an increase in fuel consumption by as much as 18 percent. In some instances, ships have lost up to 2 knots due to underwater hull growth, or require additional power (and, therefore, fuel) to maintain speed. TYCOMs and Squadron Commanders in charge of scheduling hull cleanings should make every effort possible to ensure that all ships are able to receive their regular hull and propeller cleaning.

1.6 REQUIREMENTS FOR AN EFFECTIVE SHIP ENCON PROGRAM.

A strong command commitment is necessary for a ship to have a successful energy conservation program. The CO needs to promote shipboard energy conservation awareness and management. An energy conservation management plan shall be developed, including the creation of an Energy Conservation Board (ECB) led by the Shipboard Energy Manager. To be effective, the management plan must involve the entire crew. Steaming at-sea or working in-port, each member of the crew should understand his or her role in the Navy-wide effort to conserve energy and receive positive reinforcement. An Energy Survey Checklist for Improved Fuel Economy is provided in Appendix A to identify initiatives that can be taken to support effective energy conservation management and awareness. The CO and Executive Officer must be committed to expanding this awareness.

1.7 BENEFITS OF ENCON.

The ENCON Program brings numerous benefits to the Fleet (in addition to cost savings and individual ship awards) by following the procedures and techniques provided in table 1-1 below and described in Chapter 2 and Chapter 3 of this Guide. The estimated savings in gallons per hour (GPH) for each of the procedures and techniques identified in table 1-1 is also provided. A majority of the techniques can be put in place immediately, as all they require are operational discipline and a commitment to reducing fuel consumption. The benefits include, but are not limited to:

a. Increased mission performance
b. Increased combat capability
c. Increased ship endurance range
d. Increased readiness (more fuel for training)
e. Increased energy security
f. Decreased fuel replenishment frequency
g. Decreased machinery maintenance
h. Decreased machinery wear and tear
i. Decreased electric and water consumption
j. Decreased heat stress
k. Reduced air pollution

Table 1-1. Potential Fuel Savings for Various Operational Techniques.

Class	Operational Technique (efficient operation listed first)	Savings GPH *(estimated)*	Savings	Section Hyperlink
All classes	100kW electrical load reduction	8		2.2.12
Gas Turbine Ships	Two SSDGs at 75% load in ring bus configuration vice four SSDGs at 37% load in split plant configuration (FFG 7 Class)	120		3.2.6
Gas Turbine Ships	Operation of one Ship Service Gas Turbine Generator (SSGTG) at 90% load vice two paralleled units at 45% load	150	35% in SSGTG rate; 10% in overall plant rate at 15 knots	3.2.6
Gas Turbine Ships	Securing bleed air from one SSGTG	25	16.5%	3.3.7
Steam Ships	Economical in-port “steaming auxiliaries” vice “steaming modified main”	50-150		3.5.3
Steam Ships	Securing main circulating pump at 8 knots vice typical policy of 12 knots	30-95		3.5.21
Steam Ships	Average savings for trimming boiler excess air at speeds of 8-16 knots	40-63	4-7%	3.5.14
Steam Ships	Economical single boiler cross-connected operation vice typical two boiler split plant operation at 12 knots	80-440		3.5.8
Steam Ships	One Boiler Economical Alignment (1260 GPH) at 12 knots vice Two Boiler Typical Alignment (1735 GPH)	475	27%	3.5.8
Steam Ships	Elimination of simultaneous making-up and dumping of auxiliary exhaust	50-100		3.5.23
Steam Ships	Elimination of 100 GPH steam and water leaks	2.5-3.75		3.5.20
Steam Ships	Elimination of practice of idling a main feed pump in standby mode	40		3.5.25
Steam Ships	Operation of two distilling units on auxiliary exhaust vice live steam	52		3.5.20.5
Steam Ships	Maintaining position at night during independent exercises by anchoring vice steaming at 10 knots	165	30%	2.2.5
Steam Ships	Operation of one electric motor-driven fire pump vice two turbine-driven fire pumps at 8 knots	62		3.5.18

CHAPTER 2
ENERGY EFFICIENT SHIP OPERATIONS

2.1 INTRODUCTION.

Energy conservation is an all-hands effort that requires diligent consideration when planning ship movements, conducting Fleet exercises, and standing watches. Support for energy conservation is necessary from all hands, from the most senior officers to junior enlisted personnel. ENCON shall be utilized whenever situations and opportunities permit. All actions provided in Chapter 2 and Chapter 3 of this Guide are provided as recommendations for reducing energy consumption. These techniques shall only be acted on when mission and the environment allow it, and at the direction of senior officers, so as to not increase risk or reduce the capability to perform the mission. COs should encourage and support engineering to utilize economical propulsion plant alignments, and ensure that optimum propulsion plant performance is maintained. Chief Engineers should ensure that watch standers are trained and that equipment is properly operated and maintained for maximum efficiency. Chief Engineers should also implement standing orders covering execution of energy conservation measures consistent with CO standing orders to facilitate execution of the provisions of this Guide.

2.2 STRATEGIES FOR ALL SHIPS.

This chapter covers energy conservation strategies that are applicable to the operation of all fossil-fueled ships. These strategies shall always be taken into account when planning ship movements, as well as during actual underway operation. Many of these strategies are based on realistic and logical applications. Improved awareness and continuous practice of these strategies will maximize fuel savings.

2.2.1 Energy Conservation Awareness, Management Planning, and Training. To be successful, energy conservation efforts must involve the entire crew. Whether steaming at-sea or working in-port, each member should understand his or her role in the Navy-wide effort to conserve energy.

2.2.1.1 CO's Role in Energy Conservation. One positive way for the CO to promote shipboard energy conservation is to make all hands aware of its importance via announcements of fuel and water usage. Daily fuel and water usage should also be documented for trend analysis or published in the POD to encourage ship personnel to actively conserve fuel and water. The CO and Executive Officer should be committed to expanding energy conservation awareness not only to their own crew, but also by sharing valuable lessons learned with the entire battlegroup.

2.2.1.2 Energy Conservation Board (ECB). An ECB, which is comprised of the Executive Officer, Department Heads, and the Main Propulsion Assistant, and headed by a designated Shipboard Energy Manager, is recommended. The ECB would be responsible for day-to-day energy conservation related operations, which consist of identifying a number of areas that the ship could decrease energy consumption yet still maintain operational proficiency. Suggested focus areas include: operational planning, internal plant efficiency, and crew awareness and compliance. In addition to in-house items, the ship's ECB should schedule periodic outside maintenance, such as hull cleaning to reduce drag, HVAC and chill water system grooming, and Gas Turbine Main (GTM)/Ship Service Gas Turbine Generator grooming during pre-deployment and post-deployment periods to make the propulsion plant more energy efficient.

2.2.1.3 Interdepartmental Zone Inspections. In conjunction with Interdepartmental Zone Inspections, energy wasting deficiencies such as water or steam leaks, missing insulation or lagging, broken hinges on Air Condition (A/C) boundary doors, improperly set and maintained A/C boundaries (topside and internal accesses), etc., should be noted for prompt remediation. Interdepartmental Zone Inspections allow personnel not exposed to a department on a daily basis to notice items that might be missed by personnel who normally maintain the space. A checklist is provided in Appendix A to support this recommendation.

2.2.1.4 Fuel Consumption Curves, Optimum Transit Speed Curves, and Plant Alignment Status Boards. Fuel consumption curves, optimum transit speed curves, and plant alignment status boards should be posted on the bridge as well as in the machinery spaces so that personnel can become familiar with their use. These curves should also be taken into consideration when planning ship operations. Operating at or near the most economical speed as frequently as possible during transits will save significant amounts of fuel. If the Engineering Officer of the Watch (EOOW) knows in advance what to expect regarding the demands on the propulsion plant, the plant can be aligned in the most economical configuration for continuous operation versus having to be instantly ready for extreme fluctuations in demand at all times. It should also be noted that securing redundant idling equipment does not necessarily increase the risk of a casualty due to speed changes.

2.2.2 Economical Plant Alignment. Operating with the most economical machinery alignment often involves the acceptance of some degree of reduced plant redundancy, since it requires securing non-essential components. In general, the minimum machinery alignment represents the very best fuel consumption rate a ship can achieve. NAVSEA SECAT Team experience during past ship surveys has demonstrated a greater than 20 percent fuel savings in underway steaming and 50 percent fuel savings in not-underway steaming using economical machinery alignments by minimizing operating redundant equipment (on-line or idling) when operational and environmental conditions permit. While the fuel saved by securing some individual pieces of equipment might seem small, it is additive and becomes significant on multi-plant ships, especially over extended periods of time. For steady-state peacetime independent steaming in uncongested waters, economical plant alignment shall be utilized as a continuous mode of operation, so long as mission readiness and safety of ship can be maintained. Appendix C of this Guide contains documented plant alignments which save fuel and require only operator training, confidence in operators' abilities, and diligent monitoring to obtain all of the benefits that result from operations using economical plant alignments. Thus, commands can effectively implement the fuel conservation practices presented in this Guide without degrading the ship's peacetime or wartime mission capabilities.

2.2.3 Optimum Transit Speed and Alignment. The most economical speed is the steady-state speed at which a ship burns the least amount of fuel to travel between two locations for a given mission or transit. Figure 2-1 provides an example of optimum transit speed curves for trail shaft, split plant, and full power alignments that were developed for a typical gas turbine powered DDG using the NAVSEA SECAT Tool outlined in Appendix B. This example shows that 14-16 knots is the most economical speed range for this particular ship (trail shaft), and, at full power, the most economical speed range is between 16-18 knots. In order to achieve maximum energy conservation results, it is recommended that ships develop their own customized fuel curves using the NAVSEA SECAT Tool.

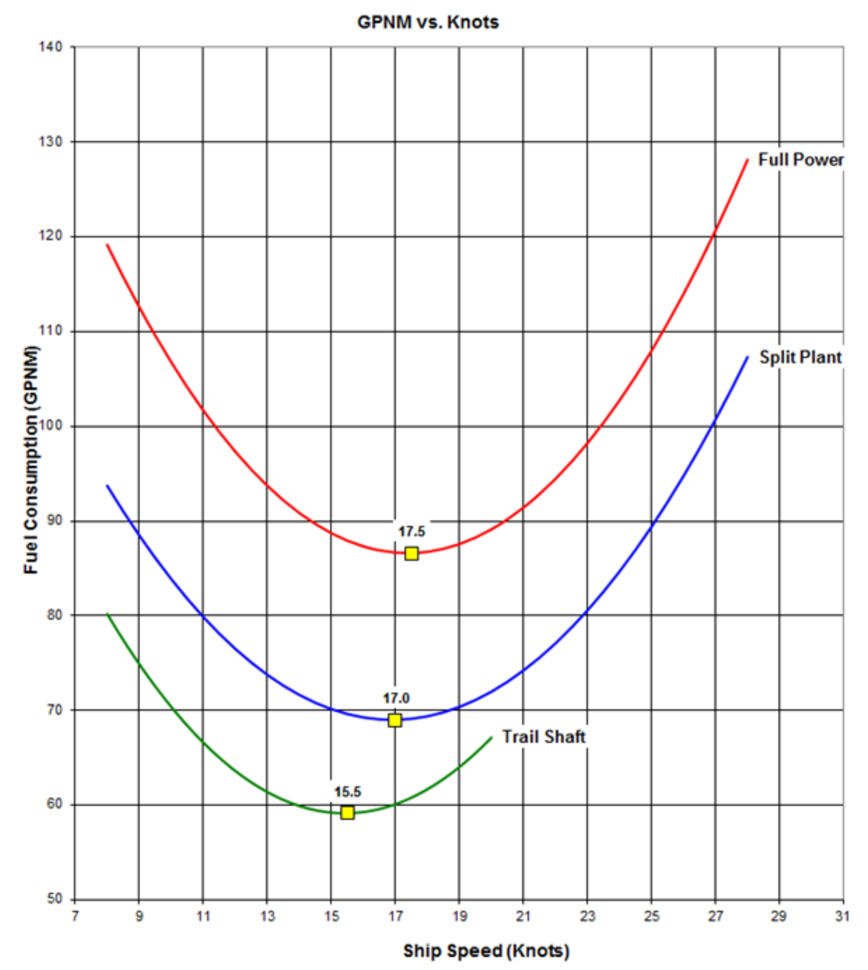


Figure 2-1. Typical Optimum Transit Speed Curves (Based on a DDG 51 Class Ship).

2.2.3.1 Optimum Transit Speed and Alignment Example Calculation. As an example of the fuel savings potential that can be achieved from operating with trail shaft versus split plant alignment, the total transit time required and fuel burned for 12 knots, 15 knots, and 18 knots are shown in table 2-1 for a DDG 51 Class ship with an assumed transit of 1,000 nautical miles.

Table 2-1. Representative DDG 51 Class Ship Fuel Requirements for 1,000 NM Transit.

(1)	Speed	12 Knots	15 Knots	18 Knots
(2)	Distance, NM	1,000	1,000	1,000
(3)	Fuel Rates (from figure 2-1, GPNM) [1/]			
	Trail Shaft	64	59	62
	Split Plant	77	70	69
(4)	Time Required, Days	3.5	2.8	2.3
(5)	Total Fuel Burned, GAL			
	Trail Shaft	64,000	59,000	62,000
	Split Plant	77,000	70,000	69,000

NOTE:
[1/] GPNM: gallons per nautical mile

2.2.3.2 Fuel Savings as a Result of Optimum Transit Speed and Alignment. The data in table 2-1 indicates that operating in an economical alignment (e.g., trail shaft) at or near the most economical speed (15.5 knots) can save anywhere from 3,000 – 5,000 gallons of fuel for a 1,000-mile transit, compared to transiting at 12 or 18 knots. However, the split plant data presented for this scenario shows that, when operating near the most economical speed (17 knots), the ship can save anywhere from 1,000 – 8,000 gallons of fuel when compared to transiting at 12 or 15 knots.

2.2.3.3 Fuel Savings as a Result of Operating at a Steady-State Speed. It should also be recognized that transits at average ship speed and steady-state ship speed will not necessarily yield the same fuel consumption. To illustrate this, assume that a 1,200-mile transit must be made within a 100-hour transit time. If the ship elects to proceed at 16 knots for the first 50 hours (800 nautical miles), and 8 knots for the second 50 hours (400 nautical miles), its total fuel consumption for the transit will be higher than for a steady-state transit at 12 knots over the same total distance. Using the trail shaft fuel consumption rates from figure 2-1 and table 2-1, the resulting fuel savings from transiting at a steady-state speed of 12 knots would be (80 GPNM x 800 miles + 69 GPNM x 400 miles) – (64 x 1,200 miles) = 14,800 gallons.

2.2.3.4 Minimizing Speed Changes. Economical transits are best achieved by minimizing speed (throttle) changes made during a transit. The scenario of “hurry up and wait” should be avoided. Ships have been observed to “start the clock” on a Planned Intended Movement (PIM) 3 to 4 hours before actually getting underway. This process necessitates higher than normal speeds to get back on schedule and is not advised when actual operational time constraints are minimal. Therefore, operating at or near the ship’s optimum transit speed for the majority of a transit will save significant amounts of fuel compared to the “hurry up and wait” method.

2.2.4 Track Selection. In selecting a track for a longer transit, a great circle route provides the shortest distance from point to point; however, factors such as weather and currents must also be taken into consideration. Use of Optimum Track Ship Routing (OTSR) for Navy ships is also recommended, when operating circumstances permit. Also, use of ship routing weather forecasting by Tactical Environmental Support System (TESS) will assist in fuel saving. As one of their many energy savings initiatives, TFE is currently developing and testing the Smart Voyage Planning Decision Aid (SVPDA), a computer tool which will utilize ship performance characteristics and real time environmental data in order to optimize ship route selection. Trip planning shall consider alternate routes and optimum transit speeds as part of the planning process.

2.2.5 Anchoring at Night. Ships operating during periods of independent exercises will at times have no commitments scheduled from late afternoon until the next morning. With suitable anchorages, the CO may have the option of anchoring for the night or at least operating at minimum speeds to just maintain headway. Anchoring, drifting, or slow steaming during this period can result in significant fuel savings. These savings can be further increased depending on what is secured for the period. For example, based on SECAT fuel measurements aboard a typical steam powered Amphibious Transport Dock class ship, about 30 percent less fuel per hour is consumed at anchor than steaming at 10 knots (i.e., for modified main at anchor, 370 GPH is consumed, but while steaming at 10 knots, 535 GPH is consumed). Steaming auxiliaries versus modified main in steam turbine powered ships can be employed to achieve further savings if at a safe anchorage and weather and sea state permit, and if no need to get underway rapidly exists. Gas turbine and diesel engine powered ships routinely secure their main engines during these periods to obtain additional savings, since they may be started and operational on short notice.

2.2.6 Drift Operations. Drift operations involve a ship shutting down their main engines and drifting with the wind/current. Ships that are powered by diesel engine or gas turbine propulsion plants can practice drift operations to save fuel, as their main engines can be placed on-line in a relatively short period of time when needed. This saves the ship from having to keep its engines at idle to allow for maneuvering at slow speeds, resulting in fuel savings, as an LM 2500 gas turbine can consume around 280 GPH while idling.

For example, a ship could drift across its Regional Patrol Sector (RPS) by positioning itself at the extreme upwind boundary of its assigned picket station. To maximize fuel conservation, it would shut down main engines, enabling the ship to drift downwind through the assigned patrol area. Depending on true wind and sea state, a drift operation transit through the assigned patrol area would actually continue for hours before it became necessary to start a single gas turbine engine to reposition the ship upwind and then repeat the drift operations. One such employment of drift operations saved a frigate in excess of 16,000 gallons each week by drifting across their RPS, leading to a total savings of 9,000 barrels during the entirety of the mission.

This energy saving strategy can be practiced at the CO's discretion when the ship is operating in non-hostile waters, the open ocean, and in favorable weather and sea conditions.

2.2.7 Course and Speed Changes. During transits, speed and course changes should be minimized. This practice will allow the plant to remain in a steady-state condition. Shaft RPM on multi-shaft ships should be balanced to prevent induced drag caused by the need for constant rudder angle to maintain a steady ship heading. Deviation from the base course can increase the total distance traveled during a transit. In addition, excessive rudder angle to maintain course and acceleration/deceleration should be avoided as this can also contribute greatly to increased fuel consumption. Referring to figure 2-2, excess fuel is consumed when the helmsman is ordered to constantly correct for minor deviations from designated course. Instead, the helmsman should be instructed to keep course within 2 to 3 degrees, preferably with minimal rudder action as detailed under the "Optimum" column on figure 2-2. Under extreme weather or current conditions, the use of the auto pilot system is recommended to attain this objective, as it has been shown that at a constant speed, fuel consumption increases linearly with the extra distance a ship travels due to excessive course/rudder changes. Further complicating the issue, fuel consumption increases exponentially with increases in vessel speed.

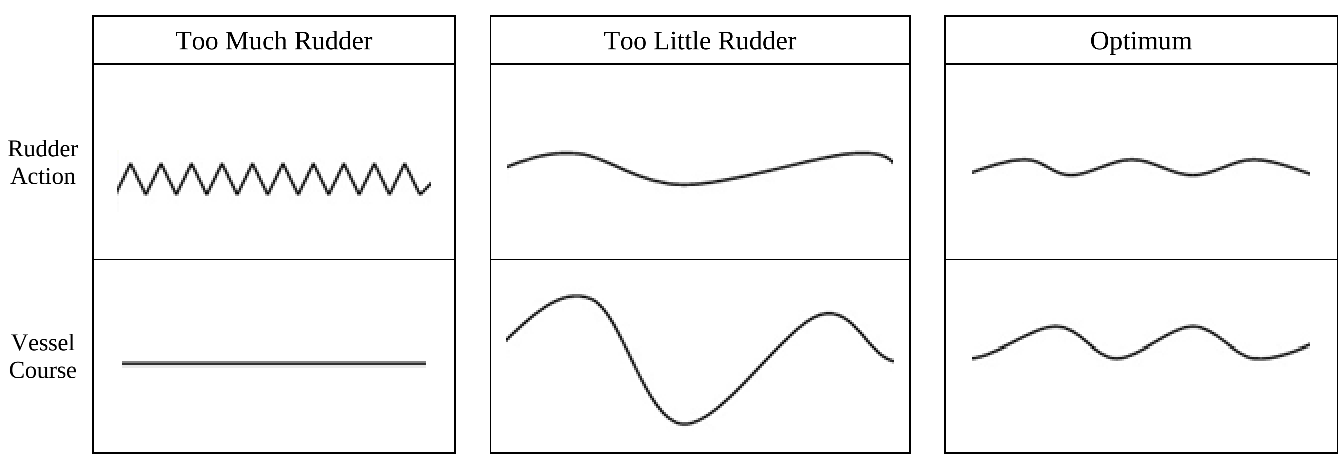


Figure 2-2. Proper Ship Handling.

2.2.8 Shallow Water Effect. When steaming in shallow water, the water passing below the ship is restricted between the ship's keel and the sea floor, causing the flow of water beneath the ship to accelerate, similar to flow through a nozzle. This increase in the flow of water will result in a decrease in the static pressure on the ship's hull (Bernoulli's Law) and cause the ship to "squat", or trim down by the stern. This squatting effect causes an increase in hull resistance, which in turn requires more power and fuel to drive the ship at intended course and speed. These effects can be further exaggerated if the ship is restricted laterally i.e., while entering or departing a shipping channel. As a rule of thumb, it is recommended that shallow water of a depth less than or equal to the length of the ship should be avoided when possible. When shallow water cannot be avoided and mission/safety allows, it is recommended to decrease ship speed to offset the increased fuel consumption caused by shallow water operations.

2.2.9 Trim Effect. A ship's powering requirements and fuel consumption are also influenced by trim. Improper trim conditions may result in reduced propulsion plant efficiency. Experiments conducted on typical twin screw combatant hulls at the Naval Surface Warfare Center Carderock Division indicated that, for combatants, the power required (i.e., fuel consumption) for a given speed increased up to 4 percent with a trim by the stern of only 0.22 degrees (form and separation resistance increase) and decreased slightly with trim by the bow. Additional design studies confirmed that fuel consumption on a typical LSD 41 Class will also be less with the bow down slightly. The effect of trim will vary with hull form and draft. The most economical trim condition is expected to be with the bow down slightly. From a fuel management consideration, ships without automatic seawater compensating fuel tanks should burn fuel from aft storage tanks first. Ships with automatic seawater compensating fuel systems should burn fuel from the forward storage tanks first, since the fuel burned in these tanks will be replaced with heavier seawater, causing a slight trim by bow. The ship's fuel loading plan shall always be followed to ensure stability and structural integrity.

2.2.10 Hull and Propeller Fouling. S9086-CQ-STM-010/081, Naval Ships' Technical Manual (NSTM) Chapter 081, Waterborne Underwater Hull Cleaning of Navy Ships, discusses the procedures and cleaning criteria required to maintain a vessel's optimum performance. Fuel consumption increases caused by hull and/or propeller fouling are often the largest single cause of excess fuel consumption. The buildup of marine growth on the hull may reduce fuel economy by up to 12 percent; similarly, propeller fouling may reduce fuel economy by up to 6 percent. Accumulated bio-fouling on ship hulls and appendages is a random condition occurring at different rates depending on geographic location, types of organisms, percent of time underway, and time since last cleaning.

2.2.11 Hull and Propeller Cleaning. Periodic hull and propeller cleanings may be required between dry dockings due to the degradation of anti-fouling paints and increased marine growth. Studies have shown that the fouling rate increases after each cleaning, dictating the need for periodic cleanings. Regularly scheduled hull and propeller inspections performed by divers can provide the necessary condition-based maintenance to determine periodicity for scheduling.

2.2.12 Electric Load Reduction and Power Generation. The ship's service generator electrical load directly influences fuel consumption. Depending on the generator type and configuration, a reduction of 100 kilowatts in electrical load can save approximately 8 GPH of fuel. Electrical load reduction is important when ships are on shore power, since a decrease in kilowatts will reduce the Navy's shore-side electrical requirements and costs.

Electrical load reduction can be accomplished by diligent effort from all hands. All unnecessary electrically driven machinery components, such as pumps, compressors, and fans, shall be secured. It is also necessary to reduce the hotel related electrical loads. This process includes actions such as:

a. Turning off lights in unmanned spaces
b. Maintaining clean light fixtures
c. Setting and maintaining A/C boundaries
d. Ensuring that all thermostats are properly set based on the season and space they serve
e. Turning up thermostats in unmanned spaces such as berthing
f. Testing and ensuring convection heaters are not on during summer cooling conditions to prevent heating and cooling spaces at the same time
g. Turning off electrical/electronic equipment if not required
h. Avoiding inadvertent or unnecessary running of galley ovens and ranges
i. Avoiding unnecessary running of laundry equipment – only run full loads
j. Keeping ventilation systems operating at peak efficiency by:
    (1) Cleaning duct work, filters, and coils

(2) Keeping diffusers in place for ventilation system balance

(3) Setting thermostats properly

(4) Keeping fan rooms clean

For a full list of recommended actions, see the checklist in Appendix A.

2.2.13 Shore Power/Services. Most major ports offer shore-based electrical power and other services when pier-side. When the length of in-port time is sufficient, shore power should be used and ship's service generators and major equipment should be secured. In most cases, shore power is more economical than ship's power. Some ports also offer such services as a pressurized fire main, steam, and compress air. Use of these pier-side services is normally more economical and allows for related equipment to be secured and maintenance to be performed. Also, machinery wear and tear and watch standing requirements are reduced.

2.2.13.1 Ship Nesting. When shore power and services are not available, ships nested together can share services, allowing some of the nested ships to secure their plants and auxiliaries for fuel savings, similar to when alongside a tender. Ships should be fully cognizant of the risks involved with this procedure in the event that the ship providing services to other ships loses power and/or services.

2.2.14 Freshwater Management. Reduction in potable water use is an all-hands evolution and requires constant vigilance. Consistent use of water conserving procedures and equipment will help improve fuel efficiency and operational readiness. Most ships are now equipped with low-flow showerheads, and some are fitted with metering or spring loaded faucets that reduce potable water consumption. Low-flow showerheads save a considerable amount of water and, ultimately, fuel. Other water conservation methods aboard large consumers such as aircraft carriers include examining laundry procedures, installing flow meters at key locations, and changing and improving galley equipment and/or operations. Routine announcements to remind the crew of the importance of water conservation and to request them to report any leaks found throughout the ship to the Engineering Department are a key part of a successful water management effort. While the ship is connected to a shore-based potable water system, water conservation measures should continue since significant use of water will increase the Navy's overall water bill. In some ports, the Navy is assessed penalties for excessive water use, especially where shore water shortages are critical.

2.3 MONITORING SHIP ENERGY CONSERVATION.

The following section contains suggestions to supplement data already gathered and reported. A ship can use these suggestions to provide more accurate determinations of fuel usage for self-evaluation and tracking of the effectiveness of energy conservation strategies and techniques.

2.3.1 Energy Survey Checklist for Improved Fuel Economy. The Energy Survey Checklist for Improved Fuel Economy in Appendix A is a useful tool for identifying areas where a ship may be able to improve energy conservation practices. Routine shipboard energy evaluation using this list, coupled with periodic monitoring of fuel consumption performance, will assist in maintaining an efficient engineering plant. All ship commands are encouraged to take advantage of the equipment, technical assistance, and incentive awards available, and to implement energy conservation strategies as frequently as possible.

2.3.2 Monitoring Not-Underway (NUW) Fuel Consumption. Generally, after light off, a steam ship has two possible states of not-underway engineering readiness. One is the "steaming auxiliaries" condition, in which the main condenser is not under vacuum; this condition will result in a lower fuel consumption rate. The other, "steaming modified main," occurs when the ship has the main condenser under vacuum.

2.3.2.1 NUW Plant Alignment (Steam Ships). The NEURS system only requires steam ships to report NUW steaming hours and NUW fuel consumed; it does not require steam ships to record their plant alignment. If this is the only information a steam ship has, it becomes difficult to determine when a ship's fuel consumption increases, and the cause of that increase. Is a gradual trend upward caused by a deteriorated material condition, or by an increase in time spent steaming modified main at anchor due to reduction in alongside berths or increased use of training anchorage? Without knowing the hours steaming NUW with steaming auxiliaries, and hours steaming NUW with modified main, the answer cannot be accurately determined. It is therefore recommended that NUW fuel consumption data for trend analysis contain the following additional information, which would have to be manually recorded as it is not captured in NEURS reports: (1) hours NUW steaming auxiliaries, and (2) hours NUW steaming modified main.

2.3.2.2 NUW Plant Alignment (Gas Turbine and Diesel Ships). While the above strategies apply to steam ships, both diesel and gas turbine powered ships can also implement not-underway energy conservation strategies by utilizing only the minimum number of ship's service generators necessary to provide electrical power when shore power is not available.

2.3.3 Monitoring and Utilizing Underway Fuel Consumption Rates with SECAT and Optimum Ship Transit Program (OSTP) Tool. Appendix B provides general guidelines for using the PC-based SECAT Tool to construct fuel curves comparing GPH vs. speed and GPNM vs. speed for economy and full power trials. The development of an accurate baseline fuel consumption curve is essential in order to evaluate future fuel consumption performance. It is a relatively simple process to construct the curves, once dedicated shaft time is obtained for this purpose and the crew is trained in maintaining proper plant alignments. In practice, the process can be done for one complete speed range in about 2 hours. Additionally, the SECAT Tool provides information for a ship to develop its own preliminary fuel savings estimates.

2.3.3.1 SECAT Generated Fuel Consumption Curves. Figure 2-3 and figure 2-4 were generated using SECAT Tool and fuel consumption data collected during past NAVSEA SECAT team visits. The SECAT Tool also provides agendas and data sheets to facilitate underway fuel consumption data collection and documentation to assist in interpreting results. Fuel consumption rates in figure 2-3 and figure 2-4 include SSGTG fuel consumption of 380 GPH for all alignments and at all speeds. OSTP enhances the capabilities of the tool by utilizing the fuel-efficient alignment data generated by the tool to determine the most economical plant alignment and speed for any given transit time and distance.

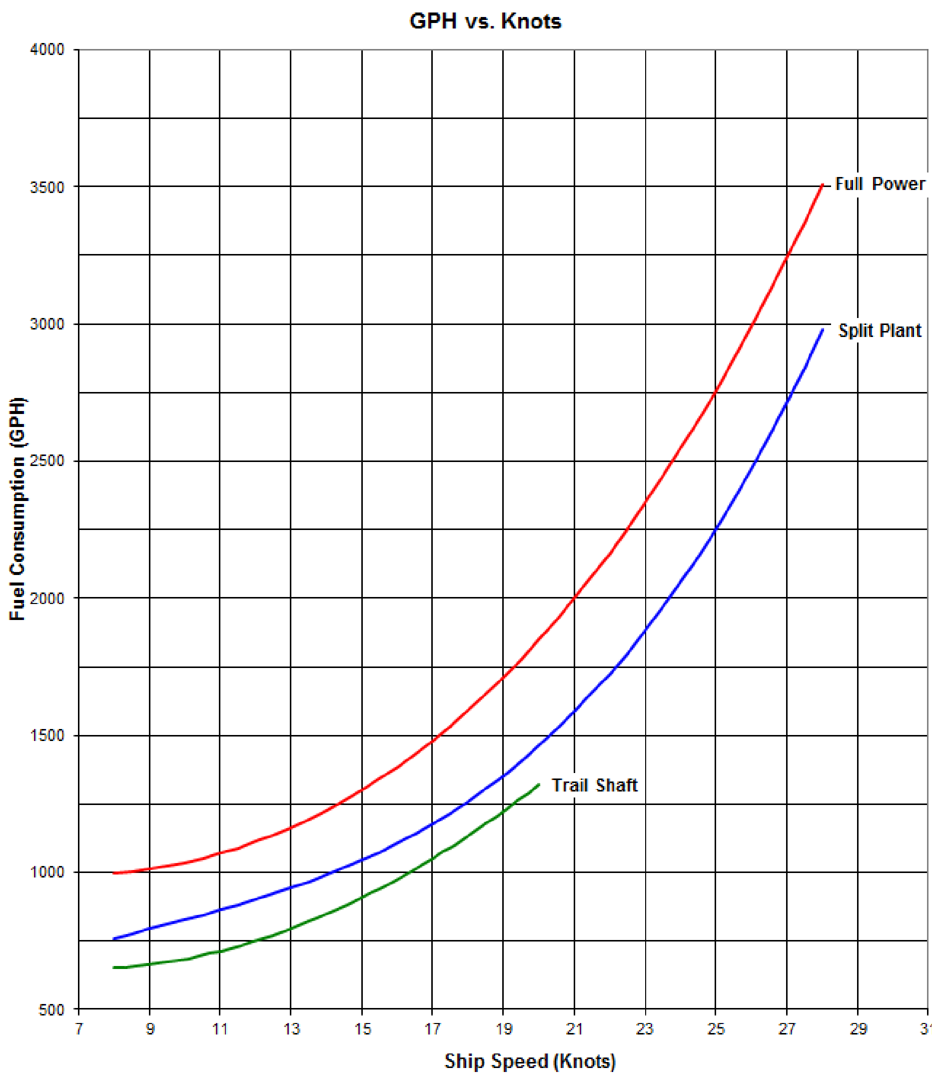


Figure 2-3. Typical Gas Turbine Ship GPH vs. Speed Curves.

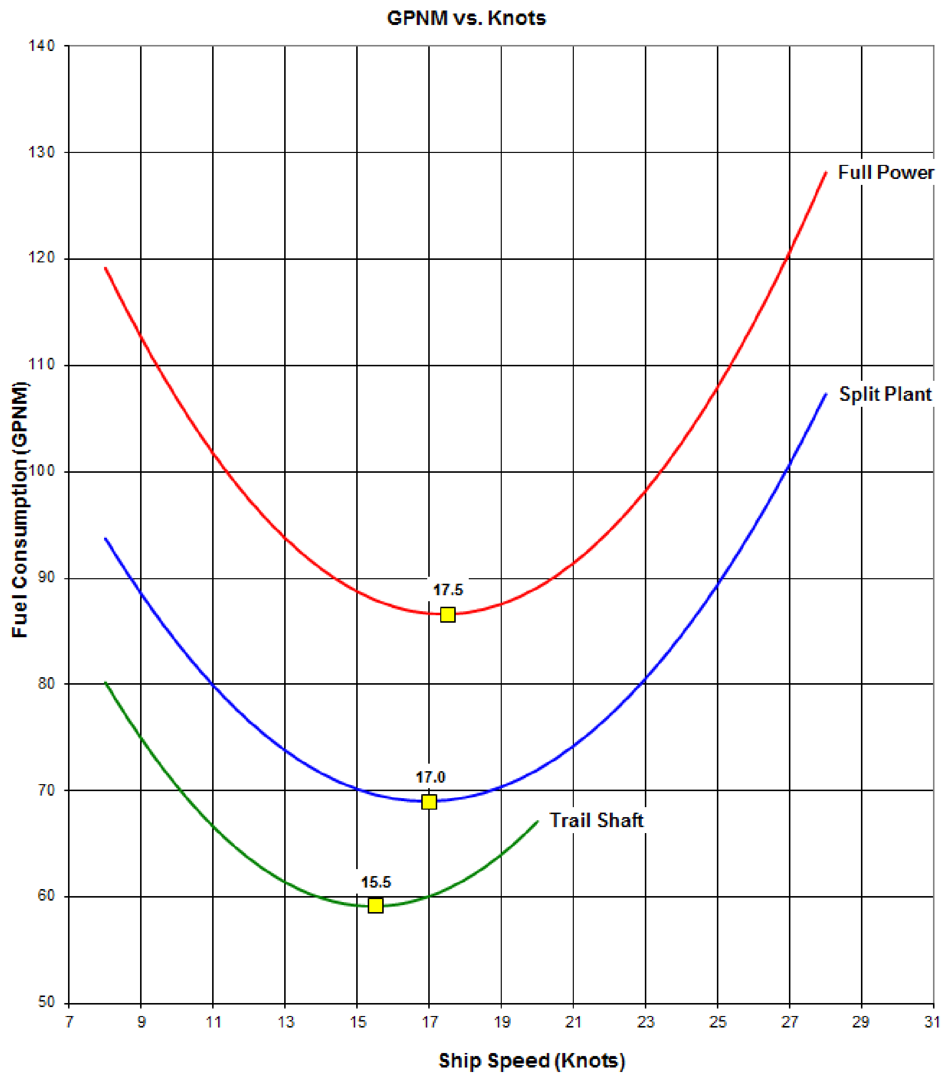


Figure 2-4. Typical Gas Turbine Ship Optimum Transit Speed Curves.

2.3.3.2 Annual Fuel Savings Calculation Example. Once the underway fuel rate data and a typical speed/time profile have been obtained, an annual fuel savings projection can be made. An example annual fuel savings projection summary table using the fuel rates in figure 2-3 and a typical speed/time profile is shown in table 2-2. The total annual fuel savings is calculated based on the assumption that the example ship operates at the most economical alignments (trail shaft versus twin screw, and twin screw versus full power) 50 percent of underway time. Therefore, half of the total fuel savings projection represents the annual fuel savings potential associated with routine operations in the most economical propulsion alignments.

Table 2-2. Annual Fuel Savings Projection from Operating in Economical Alignments.

SHIP SPEED, KNOTS [1/]	% OF TIME	ANNUAL OPERATING HOURS	FULL POWER, GPH	SPLIT PLANT, GPH	TRAIL SHAFT, GPH	ANNUAL SAVINGS, GAL/YR
0-8	4	1,144		760	650	125,840
8-12	17	442		900	750	66,300
12-16	19	494		1,100	980	59,280
16-20	17	442	1,850	1,460		172,380
20+ [1/]	3	78	2,170	1,720		35,100
TOTALS	100	2,600				458,900 GAL
ANNUAL FUEL SAVINGS AFTER ADJUSTMENT BASED ON ASSUMPTION THAT ECONOMICAL ALIGNMENT IS USED 50% OF TIME						229,450 GAL
EQUIVALENT FUEL SAVINGS DOLLAR VALUE [2/] 229,450 GAL x $2.97 PER GAL						$681,467

Notes:

[1/] Highest speed in range used for calculations. For 20+ knots, 22 knots was used.

[2/] DLA standard price effective 08 OCT 15.

2.3.4 Monitoring Plant Performance. Monitoring plant performance, regularly inspecting machinery conditions, and reviewing logs for trends all provide the operator with information needed to operate the propulsion plant efficiently or make necessary corrections. Constant monitoring will ensure optimum plant performance and fuel savings for all power settings/ship speeds and alignments.

For ships equipped with the Integrated Condition Assessment System (ICAS) energy dashboard, critical performance indicators are displayed at ICAS workstations for GTMs and Gas Turbine Generators (GTGs), including percent efficiency and fuel consumption. The ICAS dashboard also provides equipment configuration information and displays in a stop-light configuration when too many of certain equipment are on-line for the demand displayed, such as too many A/C plants on-line for the demand displayed or too many GTMs on-line for the speed displayed. (Mission requirements such as restricted maneuvering take precedent over energy dashboard recommendations.)

2.3.4.1 Machinery Operating Parameters. Machinery operating parameters are recorded regularly by watch personnel on log sheets or automatically by data logger systems. Watch standers shall be properly trained to correctly read instrumentation and record and interpret this data. A trend of degraded performance or readings outside normal values may be an indication of poor material condition, a need for maintenance, operator error, etc.

2.3.4.2 Propulsion System Historical Logs and Records. Steam turbine, gas turbine, and diesel engine propulsion system logs and records provide a comprehensive, chronological material history of the machinery's performance, maintenance, and repairs. If properly maintained, these logs and records can aid in troubleshooting problems and assist in monitoring trends, as well as providing necessary information for overhaul planning.

2.3.4.3 Daily Fuel Use Logs and Fuel and Water Reports. Daily Fuel Use Logs and Fuel and Water Reports also provide continuous means to monitor fuel and water consumption. These logs document fuel consumption and provide feedback data for supervisory personnel to use in evaluating overall plant performance.

From these logs and reports, fuel consumption for the previous day can be compared to class or ship-specific fuel curves in gallons per hour and gallons per nautical mile as well as class averages outlined in past iENCON quarterly reports (available at www.i-encon.com). Conducting these self-assessments can aid a ship's supervisory personnel in identifying opportunities to reduce fuel consumption while meeting mission needs.

2.3.4.4 Fuel Oil Meters and Stack Gas Analyzers. Fuel Oil Meters (FOMs) and Stack Gas Analyzers (SGAs) are performance-monitoring devices installed aboard many U.S. Navy ships. They have been in use for many years by utilities and commercial ships to help optimize plant performance. The FOMs provide operators with two critical pieces of information: fuel flow rate and total fuel consumption.

Many ships now have FOMs installed on main engines, boilers, and generators. The FOMs assist ships in accurately measuring fuel flow when conducting SECAT trails to validate and set ship-specific fuel consumption curves. The FOMs are also used by the ICAS energy dashboard to measure GTM and GTG performance for DDG 51 FLT IIA ships and other ship classes as part of a Fleet fuel monitoring strategy that provides feedback to ships in real time on fuel usage and configuration.

Information pertaining to FOM operation, installation, and maintenance is published in SN660-AT-MMA-010. For ships that do not have FOMs, contact the port engineer and have them installed in accordance with Machinery Alteration (MACHALT) 370 (steam ships) or MACHALT 370a (gas turbine and diesel ships).

2.3.4.5 Tank Soundings and Tank Level Indicators. Until recently, tank soundings or Tank Level Indicator (TLI) (and burner nomograms for steam ships) were the only means available to measure fuel consumption. Without an accurate, easy method to track consumption rates, it was difficult to measure fuel savings obtained through implementation of economic strategies and techniques. The FOM is an accurate device that an operator can utilize while tuning the propulsion plant. As more economic strategies are employed, the measured fuel rates should decline to a minimum value. This value becomes the target fuel rate to maintain in the future.

2.4 STRATEGIES FOR MULTI-SHIP OPERATIONS.

Included in this section are suggestions for achieving energy efficiency in multi-ship operations as well as a brief description of the NAVSEA-developed BOSC Tool (see Appendix D) which determines the optimum transit speed of a multi-ship steady state transit. Adoption of these suggestions and the BOSC Tool enables positive management and control of fuel usage and assets during multi-ship operations. See discussion of BOSC below.

2.4.1 Operational Scheduling/Planning. The high number of steaming hours and high-speed multi-ship operations consume a great deal of fuel. Task Group Commanders and schedulers should make every effort possible to have their ships complete all necessary mission and training assignments with fuel conservation in mind. Commanders can make an effort to extend the greatest possible management discretion to individual ship commands on how best to plan for and complete mission assignments, while at the same time practicing energy conservation. However, ship's commands should always make every effort to assist the Task Group Commander by completing required assignments within fuel allocations.

2.4.2 Additional Energy Conservation Actions for Task Groups. Task Group Commanders can further optimize energy conservation by considering the following actions when there is no negative effect on the mission.

NOTE

Optimizing the overall fuel consumption rate of a battlegroup underway, with individual ships given various mission assignments, is a complex effort and is beyond the scope of this document.

a. Allowing individual ships to operate in their most economical machinery alignments.

b. Minimizing maneuvers.

c. Maintaining a steady transit speed at or near the group optimum transit speed.

2.4.3 Accommodating for Steam Ship Plant Response Time. Economical machinery alignments in most steam turbine powered ships will require some additional response time if extreme speed changes are ordered. Group Commanders can work around this potential response delay by anticipating and ordering speed changes for steam ships well in advance of actual signal execution. These actions will allow individual ships to utilize the most economical alignments appropriate to the assigned tasks and thereby minimize fuel consumption.

2.4.4 Battlegroup Optimum Transit Speed Calculator (BOSC) Tool. NAVSEA developed the BOSC Tool to aid planning multi-ship transits. The BOSC Tool calculates the optimum transit speed for a user-selected group of ships. Using this data, the BOSC Tool also provides a comparative analysis of total fuel consumption for a planned multi-ship transit. For a full description of the BOSC Tool, see Appendix D.

CHAPTER 3
ENERGY EFFICIENT PROPULSION PLANT OPERATIONS

3.1 INTRODUCTION.

The overall plant efficiency and how it varies with load or ship's speed is the combined effect of all components in operation. As a general rule, machinery is most efficient when operating at or near the rated load. Figure 3-1 illustrates this graphically for alternative propulsion plants. Gas turbines show more dramatic improvements in efficiency from low to full power than steam plants. The steam plants shown tend to reach maximum efficiency between 30-80 percent of full power, because the overall propulsion system and major components were designed to be efficient at extended operations at partial power and ship speed.

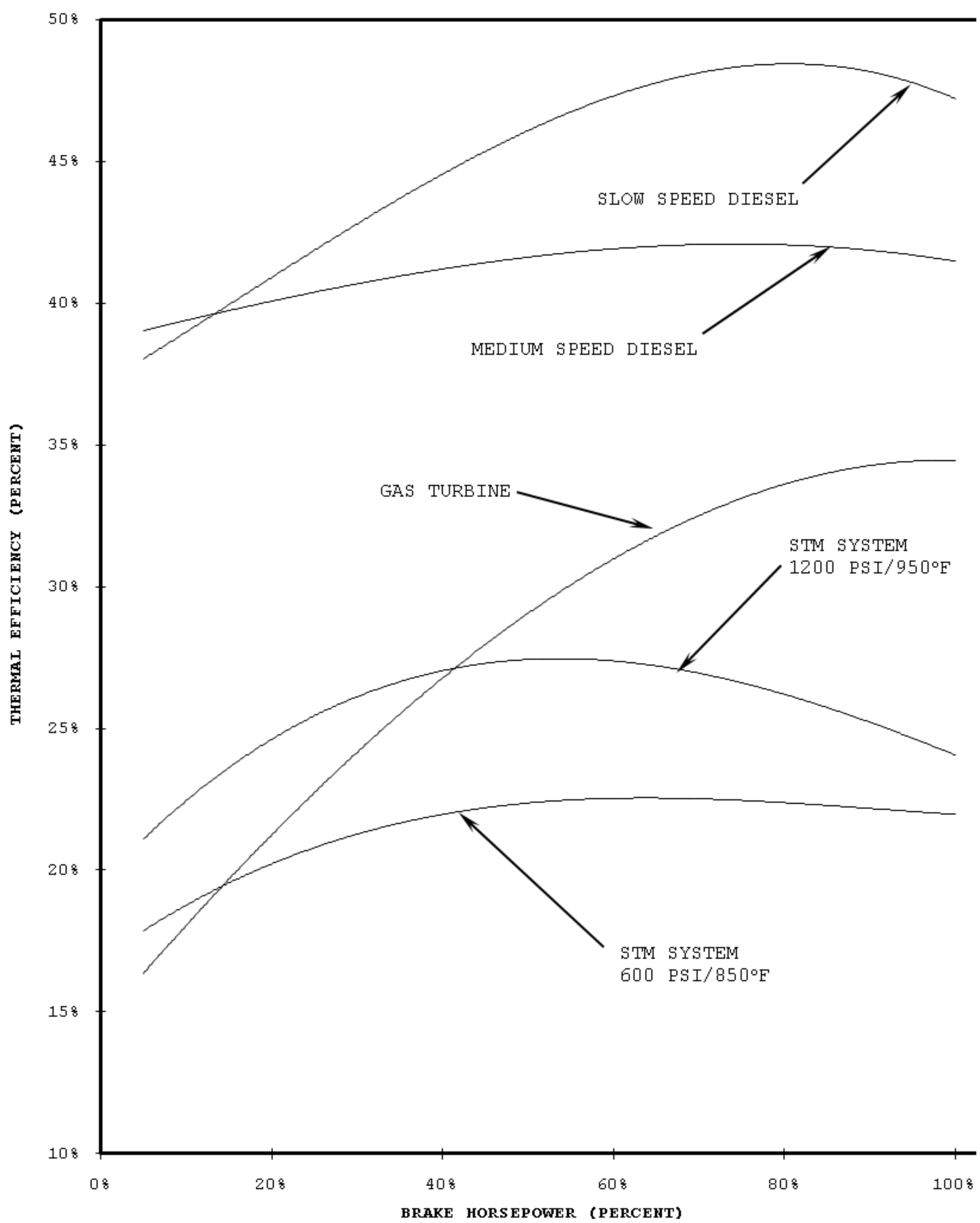


Figure 3-1. Propulsion Plant Thermal Efficiencies.

3.2 GENERAL OPERATIONAL STRATEGIES.

Gas turbine, diesel engine, and steam turbine powered Navy ships have many similarities, including multiple engines, multiple shafts, similar drive train components, and freshwater generators. Many plant auxiliaries (lube oil, fuel oil, cooling pumps, etc.) that support these engine types are self-regulating and are frequently attached to and directly driven by the engines. This section identifies efficient operational strategies that are applicable to all three of the aforementioned propulsion systems. Sections 3.3, 3.4, and 3.5 cover strategies specific to gas turbine, diesel engine, and steam turbine propulsion systems, respectively.

3.2.1 Selective Use of Engines. The fuel rates of companion engines fitted to the same shaft line should be compared at identical propeller RPM and pitch settings for a fixed period of time while each engine is operating separately. An energy conservation opportunity can exist when it is found that one engine has a lower fuel consumption rate than the other engine on the same shaft line. In some cases, this is an indication that the engine with the higher fuel consumption rate requires maintenance or repair. The engine with the lower fuel consumption rate should, therefore, be utilized more frequently until maintenance on the degraded engine can be performed (e.g., water washing a gas turbine, cleaning diesel engine fuel injectors, etc.). It is also possible that one engine may burn less fuel during low speed operations, while the other burns less fuel during higher speeds. Balancing operating hours by scheduling specific engines for operations that best match their individual fuel consumption performance characteristics can achieve improved overall fuel consumption savings.

3.2.2 Miscellaneous Shaft Drive Systems. Adequate lubrication of shaft and thrust bearings, stern tubes, and reduction gears is essential to ensure reliable and efficient operation. Reduction gear oil should be purified and of the proper viscosity, and correct sump levels should be maintained. High levels will create foaming and drag. The gear teeth and clutch pads should be periodically inspected for wear.

3.2.2.1 Electric Drive Propulsion Motors. Electric drive propulsion motors must be kept clean to operate efficiently. Motor controllers and motor windings should be inspected and cleaned, as necessary. Ventilation systems and air coolers must be properly maintained to provide adequate cooling for the electric propulsion motors. Excess temperatures in motors will increase resistance (unusable power demand) and cause a reduction in overall insulation life.

3.2.3 Auxiliary Boiler Operation. Satisfactory sustained and efficient operation of auxiliary boilers contributes to overall fuel consumption savings, and depends on proper care and adherence to correct maintenance procedures. Specific attention should be paid to maintaining automatic regulating, control, and safety devices in proper operating condition. Inspections and operational checks should be conducted routinely. Feed consumption should be monitored and corrective actions taken if found to be excessive. Steam traps and drain orifices should be checked periodically and drains should be recovered, not diverted to the bilge.

3.2.3.1 Waste Heat Boilers. Some ships equipped with GTGs are also fitted with waste heat boilers to generate steam for heating laundry, galley, etc. The large amount of heat in the turbine exhaust would otherwise be lost to the atmosphere. Proper and efficient operation of these boilers contributes to overall ship energy consumption. Ship’s Force should ensure that the waste heat boilers are well maintained and fully operational to take full advantage of this energy saving design.

3.2.4 Water Production. In addition to water use reduction, the actual operation of water generators to produce fresh water is also very critical to energy conservation. Many ships are equipped with multiple stage flash type distilling, or Reverse Osmosis (RO) desalination plants. The flash units require clean heat transfer surfaces for maximum efficiency, along with proper feed temperature regulation. If the feed temperature is carried too high (above 175 °F), scale rapidly forms on the tubes and heating surfaces. Output of the evaporator will decrease significantly and extra fuel will be consumed. The proper operation of RO plants requires clean feed water. Silt and sediment can cause reduced output through the membrane. Limiting biological growth, proper use of anti-scalant chemicals, monitoring recovery rates, and monitoring for leakage are a few maintenance actions that will result in fuel savings if performed regularly.

3.2.5 Controllable Pitch Propellers (CPPs). The primary purpose of CPPs, especially with gas turbine plants, is to provide ship stopping and low speed astern operation in the most economical manner. Additionally, with diesel engine powered ships, the normal use of reduced propeller pitch is to maintain low ship speed operation (ahead and astern) below the minimum operating engine idle RPM condition. On average, the performance at the design pitch condition (similar to a fixed pitch propeller) is the most efficient approach since the amount of variance in ship displacement, fouling, sea and wind conditions (sea states), and overall ship resistance, have minor impact. However, the use of CPP pitch settings other than design can be energy effective. Using non-design CPP pitch settings can be accomplished in the single engine trail shaft mode in accordance with EOSS/EOP, which can result in an overall reduction of fuel consumption.

3.2.6 Generator Operations. The efficiency of an electrical power generator increases as its load is increased. Therefore, operating the minimum number of highly loaded GTGs, Ship Service Diesel Generators (SSDGs), or Ship Service Turbine Generators (SSTGs) necessary to satisfy the electrical requirements will save fuel. Generators should be loaded to no greater than 90 percent of rated capacity before paralleling another unit.

3.2.7 Generator Idling and Low Load Operations. Although it is not a recommended practice to continuously idle a generator in standby, some ships do idle one, and in some cases two, SSGs for emergency backup. Some surface ships are provided with an emergency generator capability which starts automatically when the on-line SSG(s) trip. With this additional emergency generator available, continuous idling of an SSG results in paying a high fuel consumption penalty in order to provide a double electrical casualty backup. Also, it is not preferred operating practice to idle a diesel engine for long periods if not necessary for mission requirements. Extended engine operation at any power less than about 40 percent of full load is likely to result in material condition degradation problems, such as intake and exhaust valve fouling, stuck piston rings, turbocharger fouling, lube oil dilution, and other symptoms related to incomplete combustion. Engine operation at no load, or very little load, will accelerate the development of these problems. To minimize wear and tear on diesel engines and reduce fuel consumption during restricted maneuvering, a typical gas turbine replenishment ship can operate on two SSDGs at 75 percent load each in ring bus configuration during restricted maneuvering, rather than four SSDGs at 37 percent load each in split plant configuration. This procedure saves fuel at a rate of 120 GPH. While it is understood that some special evolutions may require redundant generator operations as a safety measure, a more economical alignment shall be employed as soon as this redundancy is no longer required.

3.3 GAS TURBINE PROPULSION SYSTEMS.

The energy conservation techniques discussed in this section apply to surface ships powered by General Electric LM2500 gas turbine engines. Ships with multiple propulsion gas turbine engines can operate in various modes depending upon mission requirements, including maximum redundancy, most fuel efficient, and restricted maneuvering modes. As depicted in table 3-1, gains in efficiency result from operating fewer LM2500s at higher power levels rather than redundant engines at reduced, shared loads.

Table 3-1. LM2500 Operational Modes (4 GT/Ship).

Types of Operations	Plant Configuration	GTM's On-line	Gallons Consumed per Hour	Gallons Consumed per Day	Potential Gallons Conserved per Hour
Restricted Maneuvering	Minimum Risk - Full Plant	4 LM2500s	900-1200	21,600-28,800	None
Estimated Time @ Pwr 10%	Moderate Risk - Split Plant	2 LM2500s On-line 2 LM2500s in Stand-by	650-850	15,600-20,400	250-350
Underway Replenishment	Minimum Risk - Full Plant	4 LM2500s	1500	N/A	None
Assume 15 Knots	Moderate Risk - Split Plant	2 LM2500s On-line	1350	N/A	160
Ops: Box Trail Shaft	Minimum Risk - Trail Shaft	1 GTM On-line	230	5520	None
Ops: Box Drift	Moderate Risk - No GTMs On-line	1 or 2 GTMs in Stand-by	0	0	230
0-20 Knots Cruising	Minimum Risk - Split Plant	2 LM2500s On-line (split)	650-1900	15,600-45,600	None
Estimated Time @ Pwr 65.5%	Low Risk - Trail Shaft	2 LM2500s On-line (trail)	550-1700	13,200-40,800	100-175
20-28 Knots Cruising	Minimum Risk - Full Plant	4 LM2500s On-line	2150-4100	51,600-98,400	None
Estimated Time @ Pwr 14.5%	Low Risk - Split Plant	2 LM2500s On-line (split)	1800-3500	43,200-84,000	350-600
28-33 Knots Cruising	Minimum Risk - Full Plant	4 LM2500s On-line	6000	144,000	None
Estimated Time @ Pwr <10%	Low Risk - Tri Power	3 LM2500s On-line	5400-5700	129,600-136,800	300-600
Maximum Power	Full Plant	4 LM2500s On-line	6000	144,000	None
Battle Override	Full Plant	4 LM2500s On-line	6000	144,000	None

NOTE:

1. The purpose of this chart is to inform the ship's management, operations, and engineering staff of the most fuel-efficient modes available for standard LM2500 operating conditions. The chart is meant as general guidance in terms of possible fuel savings; exact fuel savings will vary by application. It should be mentioned and qualified that potential fuel savings are impacted by a number of tangential factors including, but not limited to, hull fouling, latent heating value of fuel, and propeller pitch. Aside from propulsion plant configuration, there are a host of maintenance-related practices that can assist ships in identifying symptoms and causes of reduced gas turbine performance. Corrective maintenance should be accomplished upon determination of performance degradation in order to optimize plant operating efficiency.

3.3.1 <u>Combustion Air/Intake System</u>. The LM2500 gas turbine engine requires large volumes of clean, ambient air to produce rated power. In the marine environment, the ambient air carries with it much entrained salt, salt water, airborne particulate matter, and soot. These contaminants can have as much as a 2-percent negative impact on gas turbine efficiency if left unaddressed, and can cause corrosion to occur in the engine's hot section. The gas turbine intakes are specifically designed to filter these contaminants, but require periodic maintenance. An opened Blow-In Door (BID) should trigger immediate maintenance actions within the inlet filtration system. Opening BIDs are caused by an excessive pressure drop in the duct housing, which allows unfiltered air to enter the engine. Ingestion of unfiltered air can drastically reduce the life of the gas turbine engine, with an immediate and noticeable loss in performance. In addition, unfiltered air greatly increases the possibility of Foreign Object Damage (FOD) to the gas turbine. Although the LM2500 has an FOD screen mounted directly upstream of the engine bellmouth, it is only effective at filtering large debris and does not prevent paint chips, shot peen, sand, and other contaminants from entering the gas path of the engine.

3.3.2 <u>Air Inlet Pressure and Temperature</u>. Gas turbine performance is significantly affected by ambient air conditions. A drop in overall ambient air pressure of 1 inch of mercury will result in a fuel flow increase of 3.2 percent in order to hold power output constant. This is caused by dirty demisters and clogged louvers, which can cause the BIDs to open, allowing for FOD. Similarly, an increase of 10 °F in ambient air temperature will result in a fuel flow increase of 2.5 percent in order to hold output power constant. To ensure maximum engine performance and efficiency, periodic maintenance to LM2500 Variable Stator Vane (VSV) system components needs to be performed routinely. Also, circuitry that provides for adjustment to inlet guide vanes, VSV, and main fuel control should be properly calibrated and periodically checked. It is imperative to follow all Planned Maintenance System (PMS) requirements for the intake system to ensure maximum engine performance and efficiency.

3.3.3 <u>Fuel Treatment</u>. To ensure reliable and efficient engine operation, fuel supplied to a gas turbine must be clean and free of water. Filters, purifiers, and coalescers are installed and operated to limit the size and quantity of particulate matter and water contained in the fuel supplied to an engine. It is also important that fuel temperature is maintained within a specified range in order to optimize fuel filtration and purification system performance. Filters, purifiers, and coalescers should be properly maintained, as free particulate matter can plug fuel nozzles and cause premature wear to hydraulic controls. The presence of seawater in the fuel can cause corrosion in engine hot section components. Special caution should be observed with seawater compensated fuel systems because the ever-present fuel/seawater interface within each tank increases the possibility of seawater contamination of the fuel.

3.3.4 <u>Water Washing Engines</u>. Periodic water washing of gas turbines is critical to the performance and long-term health of the engine. The water wash cycle calls for one cleaning cycle, with the use of approved detergents, followed by two rinse cycles to ensure all solution has been evacuated from the water wash system and all engine components have been adequately cleaned. Varying the speed of the compressor being motored during the wash cycle helps ensure a complete cleaning of the engine. Water washing effectively reduces compressor fouling and hot section corrosion while improving overall engine efficiency. Ships should ensure that they always stay up-to-date regarding PMS requirements for periodicity of gas turbine water washes.

3.3.5 <u>Single Engine Operations</u>. Naval ships that have multiple shafts powered by gas turbine engines are more efficient at low ship speeds, when the minimum number of engines is operated to sustain that speed. It is generally more economical to run one engine at a higher power level (higher corresponding thermal efficiency) than two engines, each at a lower power level. Operating in this single engine per shaft mode, gas turbine powered ships regularly accrue fuel savings of up to 25 percent as compared to operating two engines per shaft line at the same ship speed. Operating on the minimum number of engines may also reveal a need for maintenance on the engine with the higher fuel consumption rate. The engines with the lower fuel rate should be used until maintenance is performed on the degraded engine.

3.3.6 <u>Trail Shaft Operations</u>. In trail shaft mode, one engine can propel the ship at low speeds. The increase in thermal efficiency gained from having a single engine operating near its rated output more than overcomes the increase in ship resistance caused by the trailing shaft. The trailing shaft propeller pitch should be set at 100 percent of design pitch or greater to reduce the added (drag) resistance of the trailing propeller/shaft system. The more the propeller is pitched forward (design pitch or greater), the lower the drag resistance will be from the trailing shaft. Generally, the single driving shaft will operate more effectively (reduced fuel consumption) at a reduced propeller pitch. Control systems allow for driven shaft pitch reduction while reducing drive train torque and permit greater engine Brake Horse Power (BHP) and ship speed. Trail shaft operations shall always be conducted in accordance with the ship's EOP.

3.3.7 Bleed Air System Operations. Bleed air from the LM2500 gas turbine engine can be used to support Prairie/Masker systems as well as for anti-icing of the gas turbine intakes. The gas turbine bleed air is either energized or secured and does not offer modulated control. More than 10 percent of the compressed air from the LM2500 engine can be extracted as bleed, which severely compromises engine performance. An increase of more than 15 percent can be expected in specific fuel consumption while operating with Bleed Air Systems open. Operators should be aware of this efficiency penalty when operating Prairie and Masker systems, and should fix all leaks and minimize use of these systems, if possible.

3.3.8 Miscellaneous Operating Conditions. Operating conditions that are detrimental to gas turbine performance and reliability shall be avoided and corrected at the first opportunity, when possible. Unnecessary thermal cycling of the engines should be minimized to reduce stress on combustion system components, including the first stage (high-pressure turbine) nozzles and blades. Dirty or contaminated lube oil and excessive engine vibration are also detrimental to sleeve and roller bearing life. Borescope inspections should also be performed periodically and in accordance with PMS to monitor internal turbine components without disassembling the engine. These inspections can reveal existing or incipient problems such as burned combustors, damage to high-pressure turbine blades and nozzles, hot section corrosion, etc. Required maintenance actions or small repairs should be accomplished before catastrophic failure and associated expensive repairs occur. Engine life can be significantly extended with careful operating and maintenance practices.

3.4 DIESEL ENGINE PROPULSION SYSTEM.

The energy conservation strategies and techniques discussed in this section specifically apply to diesel ships. Because there are a number of different types and models of diesel engines utilized aboard ship by the U.S. Navy, some of these practices may not apply to every diesel engine powered ship.

3.4.1 Operation of Diesel Engines. The service life and maintenance requirements of a diesel engine are greatly influenced by its load profile during operation. In some cases, the particular requirements of an evolution or mission require that the installed diesel(s) be operated much of the time at speeds and loads either higher or lower than desirable from the standpoint of best fuel economy, least maintenance, and longest engine life. A ship usually has a considerable choice of speed and load factors that can be used to accomplish the mission. To optimize fuel economy, maintenance requirements, and engine life, the following should be considered:

a. An engine operated continuously at 100 percent rated (nameplate) power output will require much more frequent maintenance and major overhauls than an engine operated continuously at 80 to 90 percent of its rated capacity.

b. Diesel engines should be run at least 60-75 percent of their maximum rated load. Best thermal efficiency is at or about 75-80 percent of the maximum rated load.

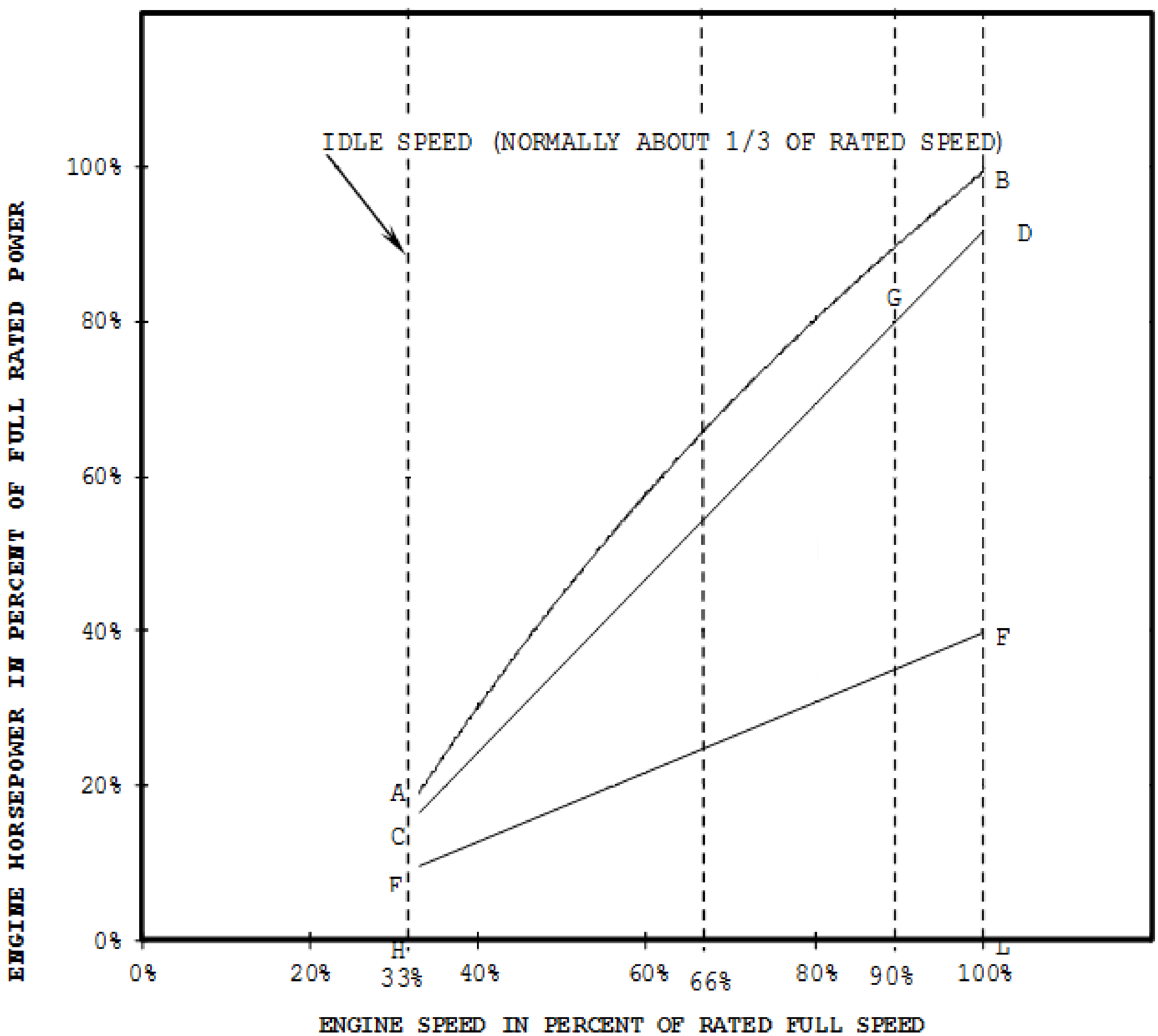
c. Prolonged or continuous operation of a diesel engine at its maximum Brake Mean Effective Pressure (BMEP), or maximum torque, should be avoided to the greatest extent possible.

d. Extended engine operation at less than approximately 60 percent of rated output shall be avoided when operational conditions permit, in order to prevent carbon formation, lube oil dilution, oil carry-over into the exhaust system, and other problems related to incomplete combustion. Short periods of low load are permissible, providing the engine is brought up to or close to full load on a regular basis. Extended periods of idling operation (e.g., rated speed/no loads) will accelerate the development of these problems.

e. Figure 3-2 presents typical recommended diesel engine operating limits and illustrates speed/load ranges that will produce the least engine maintenance and the most efficient engine utilization.

f. Whenever a cold engine start is required, the procedures outlined in the ship's EOP shall always be followed in order to ensure that the lube oil is brought up to design operating temperature using an approved procedure.

g. When a multiple-engine arrangement is installed so that various engine combinations may be employed, select the combination that operates with the fewest number of engines operating at the highest load to achieve maximum operating economy for any ship speed. Consistent with the need for split plant operation to ensure maximum reliability, every effort shall be made to maintain individual engine loading between 50 percent and 80 percent of rated power output.



KEY

A. FULL POWER OPERATION SHOULD NOT EXCEED THE LIMITS OF CURVE A-B.

B. WHERE ENGINE WEAR AND MAINTENANCE COSTS ARE IMPORTANT CONSIDERATIONS, LIMIT ENGINE LOAD AND SPEED COMBINATIONS WITHIN AREA BOUND BY C-G-D AND E-F. WHERE FEASIBLE, LIMIT ENGINE SPEED TO 90 PERCENT OF FULL SPEED AND AS CLOSE AS POSSIBLE TO LINE C-G FOR OPIMUM OPERATION.

C. OPERATION AS MAY BE NECESSARY OUTSIDE ABOVE OPIMUM AREA, BUT WITHIN UPPER LIMIT CURVE A-B PROVIDES SAFE OPERATION ALTHOUGH ENGINE MAINTENANCE REQUIREMENTS WILL BE INCREASED. PROBLEMS ASSOCIATED WITH OIL CARRYOVER, INCOMPLETE COMBUSTION, AND CARBON DEPOSITS WILL INCREASE AS CONDITIONS APPROACH LINE H-L.

Figure 3-2. Typical Diesel Engine Operating Limits.

3.4.2 Trail Shaft Operation. At speeds up to 8 knots, trail shaft operation on a diesel ship may provide fuel savings and could result in less maintenance. When operating in this mode, ensure that diesel torque limitations are not exceeded.

3.4.3 Engine Material Condition and Trend Analysis. Engine performance shall be monitored to ensure the engine is in top condition. Engine readings (temperatures and pressures) shall be logged by manual logs or automated log systems regularly, and fall within normal operating limits. Parameters falling outside of these limits shall be investigated and corrective actions taken before a malfunction and/or impending failure occurs, in accordance with NSTM, EOSS, and other instructions and directives. Two relatively straightforward indications of engine performance and condition are cylinder compression pressure and cylinder exhaust temperature. The recommended allowable deviation in compression pressure between any two cylinders should not exceed manufacturer's specifications. To ensure balanced loading of all engine cylinders, exhaust temperatures should also be monitored. Additionally, these two parameters provide a quick indication of the engine's material condition while it is in operation. On engines fitted with air cocks, indicator cards should also be drawn on a periodic basis to allow for a more detailed evaluation of engine performance.

3.4.3.1 Benefits of Engine Material Condition and Trend Analysis. Analysis of a diesel engine's combustion process has substantial benefits. Fuel savings is obtained by correcting fuel-related problems and providing for fine tuning combustion for maximum fuel economy. Lower maintenance costs are obtained by finding operational shortcomings and correcting them prior to catastrophic failure. Trend analysis also leads to less downtime by monitoring the condition of the engine to allow for scheduling routine maintenance at more opportune times, as well as giving a heads-up notice of an impending failure. Finally, a properly firing and balanced engine reduces shock loads and stress on the engine, which reduces wear and tear on the engine and its components.

3.4.3.2 Cylinder Exhaust Temperature. Generally, cylinder exhaust temperatures should not vary by more than 100 °F cylinder-to-cylinder and/or bank-to-bank for tandem applications of naturally aspirated engines. Turbocharged engine cylinder exhaust temperatures should not differ more than 150 °F. Temperature imbalances exceeding these limits should be investigated and corrected. Conditions such as improper valve/injector timing, fouled or worn injectors, leaky exhaust valves, worn rings, improper rack settings, etc., can cause pressure and temperature imbalance between cylinders. Overall, high exhaust temperatures are an indication of an overloaded engine. Cylinder exhaust temperatures should never be allowed to exceed manufacturer's limits or, if not specified, 900 °F.

3.4.3.3 Peak Cylinder Firing Pressure. The peak firing pressure in any cylinder should never be allowed to exceed the maximum value specified by the manufacturer. Continuous operation at peak cylinder pressures in excess of the engine manufacturer's recommended maximums can result in the following:

a. Increased thermal and tensile stresses in the cylinder heads, cylinder liners, cylinder head studs, piston heads, and exhaust valves.
b. High cylinder exhaust temperatures.
c. Fouled exhaust system components.
d. Burned injector nozzle tips.
e. Pounded out bearing material.
f. Ring failure and piston seizure.

3.4.3.4 Additional Material Condition Considerations. A systematic and regular inspection procedure that is applicable to each specific engine model installation, configuration, and operating cycle should be established. Performing scheduled preventative maintenance will keep the engine in optimum condition. Operational log sheets should also be maintained and retained until the next engine overhaul cycle. Operating irregularities, malfunctions, and impending failures are often discovered quickly by a comparative analysis of this data. Frequent lube oil samples should be drawn, tests performed, and results recorded in the "Diesel Engine Lube Oil Testing Log". Each engine should also be inspected by a certified diesel inspector at the intervals specified by the ship's maintenance schedule.

3.4.4 Combustion Air Systems. Engine air intake filters should be kept clean and the pressure drop monitored across the air filters. The charge air cooler airside should also be cleaned with an approved chemical at regular intervals in accordance with PMS procedures. For a typical marine diesel engine, fuel consumption will increase by 0.5 percent for every 5 °C (≈10 °F) rise in intake air temperature at a constant power output.

3.4.5 Blower/Turbochargers. Ensure that the blowers/turbochargers are properly maintained by cleaning the air and gas sides of turbochargers at the intervals recommended by the manufacturer. The temperature rise across the airside and temperature drop across the gas side of the turbocharger should be carefully monitored. These parameters generally provide a good indication of the efficiency of the unit and can alert the operator as to when cleaning should be performed. Additionally, the exhaust backpressure at the outlet of the turbocharger should be monitored. If this pressure increases, the engine(s) will operate inefficiently. Depending on the installation, an increase in backpressure of as little as 3 inches of H_2O can cause a 1-percent increase in fuel consumption. The lobe/housing clearances of blowers should be maintained within manufacturer specified limits to ensure maximum blower efficiency. Leaky oil seals should also be replaced immediately, as they are a safety hazard and increase lube oil consumption.

3.4.6 Fuel Injection. Regular maintenance and calibration of the fuel injection system is necessary to ensure that its operation is within manufacturer's specifications. Ideally, each cylinder should receive the same amount of fuel and produce very similar exhaust temperatures in a properly balanced engine loading. Fuel injection timing is also critical to good engine performance and fuel economy. A one or two-degree error in timing can cause a 2-percent increase in fuel consumption. Injector nozzle holes should also be checked periodically for size, as wear of only 0.0005 inch can cause a 0.5-percent increase in fuel consumption. Injectors should also be checked and cleaned in accordance with PMS procedures as fouled units will affect fuel oil spray pattern and burn rate, create unbalanced engine operating conditions, and result in increased fuel consumption.

3.4.7 Fuel Conditioning. Proper fuel oil conditioning and treatment is essential for reliable diesel engine operation and optimum performance. Because tolerances are very close in the injectors/injector pumps, any foreign particulate matter in the fuel could accelerate wear or plug nozzle holes. If fuel is contaminated by water, corrosion can also take place in these units, which can ultimately lead to injection pump seizures. Filters and coalescers should be properly maintained and changed as required to ensure maximum water removal rates from the fuel. Many installations have fuel filters directly mounted on the engines. These filters should also be changed according to the ship's PMS or when fuel oil supply pressure falls below the manufacturer's specified minimum value. Maintaining proper fuel temperature will result in the viscosity required to achieve effective filtration and efficient combustion.

3.4.8 Engine Cooling Water Systems. Cooling systems should be controlled at the engine manufacturer's specified temperature and pressure. The cooling water inlet and outlet temperatures need to be maintained within their respective acceptable design range. For most freshwater cooled engines, the jacket water outlet temperature should be maintained between 68 °C (155 °F) and 85 °C (185 °F). In addition to jacket water-cooling systems, some engines are also fitted with piston cooling water and/or injector cooling water systems. Proper maintenance and chemical treatment of cooling water systems will limit engine waterside corrosion and fouling, which can cause reduced coolant heat transfer and, ultimately, engine overheating.

3.4.9 Lubricating Oil Systems. Proper lubrication of the moving parts of a diesel engine is necessary to achieve maximum mechanical efficiency, engine fuel economy, and engine life. Clean lube oil at the proper temperature minimizes engine friction and wear. If lube oil temperature is too hot, it will evaporate faster, will be unable to remove as much heat, and will be consumed in larger amounts by the engine. Too low a lube oil temperature can cause increased friction and pumping power losses. The lube oil should be cleaned by changing filters on a regularly scheduled basis or by operating the lube oil purifiers continuously, when fitted. Lube oil samples should be drawn and tested for acidity, fuel dilution, and viscosity. Spectrographic analysis should also be conducted. All lube oil test results should be logged in the "Diesel Engine Lube Oil Testing Log".

3.4.10 Exhaust Systems. The exhaust system must be kept free of unnecessary restrictions in order to keep the exhaust backpressure as low as possible. This will ensure that maximum efficiency is derived from installed turbochargers. The results of high exhaust backpressure are detrimental and include higher exhaust temperatures, less air supplied for combustion, dirty exhaust, and less available power. Precautions should also be taken to prevent accumulation of excessive quantities of water and debris in the silencers and spark arresters.

3.4.10.1 Diesel Engine Exhaust Smoke. A diesel engine in good condition should produce no visible smoke from the exhaust under most operating conditions. A short puff of smoke when an engine is accelerated under load may be acceptable (turbocharger lag). This is common with older technology. Exhaust smoke is usually a good indicator of potential problems with the diesel engine.

a. Blue smoke: Worn piston rings, liners, guides, etc.

b. Black or gray smoke: Incomplete combustion, improper fuel, high exhaust backpressure, restricted air inlet, malfunctioning turbocharger, faulty injectors, etc.

c. White smoke: Light load operations, water in the diesel fuel, operation at low jacket water temperature, etc.

3.5 STEAM TURBINE PROPULSION SYSTEMS.

The energy conservation strategies and techniques discussed in this section specifically apply to steam ships. Several plant configuration changes have been analyzed using design heat balances as a basis to quantify savings. Subsequent trials and SECAT Team visits to individual ships have confirmed the validity of the analyses and quantified actual fuel savings aboard ship. It has been shown that individual components in each phase of the steam cycle play a key part in the overall efficiency of the steam propulsion plant. This section identifies economical propulsion plant alignments, as well as strategies that can be practiced for some of these individual components, for surface ships fitted with fossil fuel fired steam turbine propulsion plants. Because not all U.S. Navy steam plants are the same, some of these practices may not apply to every steam plant powered ship.

3.5.1 Steam Plant Optimization. The load (output) dependent performance characteristics of the various components comprising a typical steam turbine propulsion plant (boilers, main and auxiliary turbines, condensers, pumps, etc.) require heat balances for its thermodynamic analysis. However, a steam plant can be viewed in its simplest terms with regard to fuel consumption as the interaction of its producers and its consumers. The boilers are the steam producers and the starting point for the conversion of the chemical energy contained in the fuel (DFM) to heat and the production of the steam that is utilized by the plant consumers. As a result, proper operation of the boilers and their support and sub-systems (e.g., forced draft fans, combustion controls, etc.) is required to ensure that optimum boiler efficiency and final superheater outlet temperature are maintained for the required plant load to achieve minimum fuel consumption levels. Figure 3-3 presents typical relationships for final superheat temperature and boiler efficiency versus boiler evaporation rate (plant load). Achieving optimum boiler efficiency is also dependent upon minimizing stack losses by maintaining proper stack gas and economizer temperatures. Operating the boiler at or near design efficiency will ensure that only the minimum amount of fuel necessary to sustain a given boiler evaporation rate and plant load will be burned.

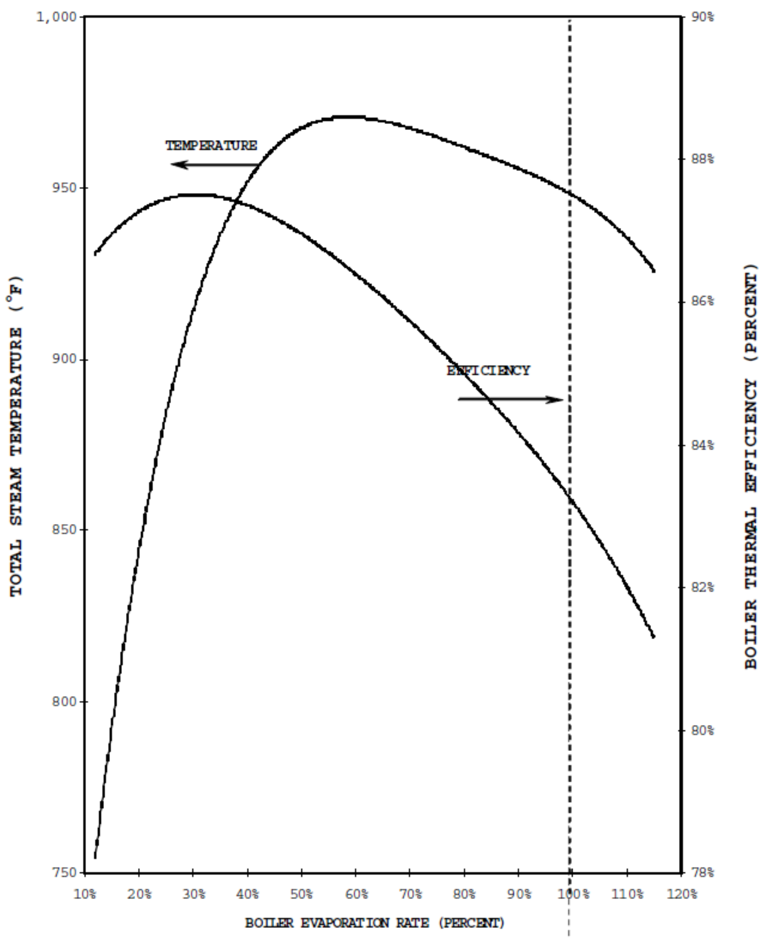


Figure 3-3. Typical Boiler Steam Temperature and Efficiency.

3.5.1.1 Turbine-Driven Machinery. For a typical steam turbine propulsion plant, almost all of the steam produced by the boilers is consumed by turbine-driven machinery. The bulk of this steam (80-90 percent) is consumed by the main turbine engines, with the remainder being consumed by the much smaller, less efficient SSTG, feed pump, forced draft fan, etc. For virtually all turbine-driven machinery, maximum efficiency (minimum steam consumption rate) occurs at or very near its maximum output (power or load) condition. This relationship is shown, both in terms of steam rate and efficiency, for a typical main propulsion turbine in figure 3-4. Because of these inherent turbine performance characteristics, many of the energy conservation strategies and techniques discussed in the following paragraphs are based on, and/or stress the utilization of, the minimum number of highly loaded turbine-driven machinery components necessary to achieve reliable and efficient plant and ship operation.

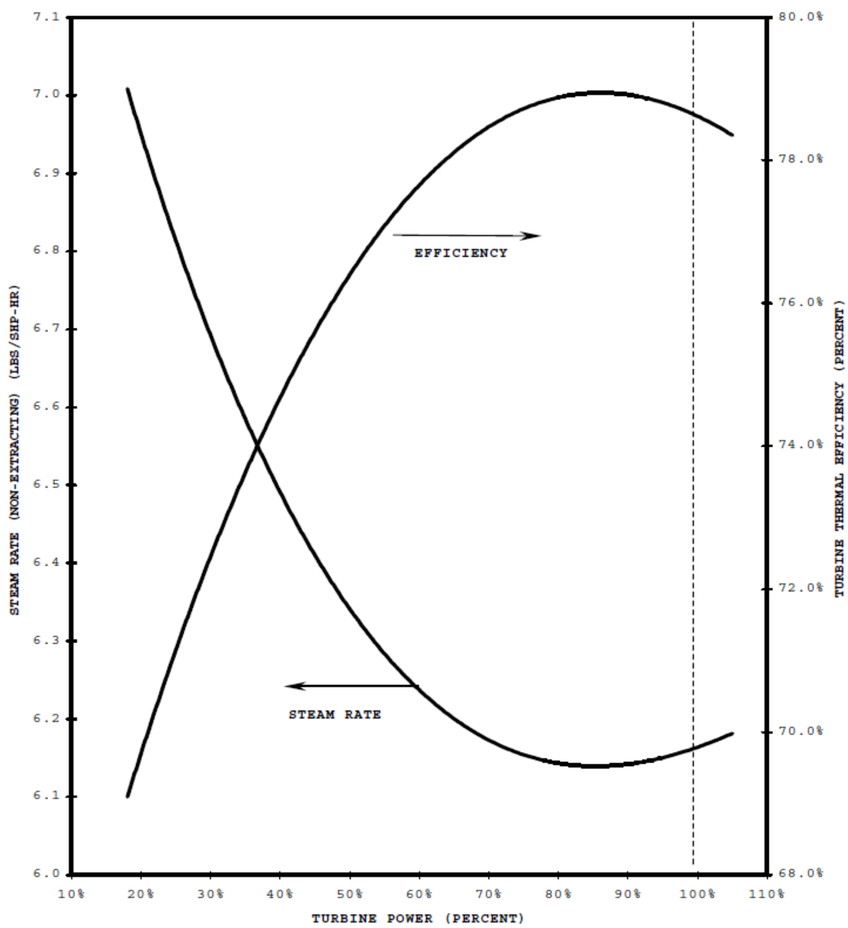


Figure 3-4. Typical Main Propulsion Turbine Steam Rate and Efficiency.

3.5.2 Boiler Light-Off. EOSS procedures shall be followed when lighting-off and securing boilers. Improper pre-light-off checks and rapid light-offs, even if operationally necessary, often result in one or more of the following:

a. Improper fuel-air mixture resulting in termination of light-off, pollution (excess fuel), or in the worst case, a boiler explosion (from improper purging, excess air or fuel).

b. Boiler stress, due to excessive thermal induced stress, excessive sooting on tubes and in the stack, etc.

c. Use of unnecessary auxiliary equipment, resulting in wear or possible failure.

d. Excessive steam generation, resulting in lifting of relief valves and loss of steam.

3.5.3 Steaming Auxiliaries in Port. When the ship is in port and shore power/services are not available, it provides its own services (electricity, steam, etc.) by "steaming auxiliaries" or "steaming modified main." The term "steaming auxiliaries" means that the main condenser is secured and excess auxiliary exhaust is unloaded to a turbine generator condenser (auxiliary condenser). This is in contrast to "steaming modified main" where the main condenser has been placed under vacuum and lined up to receive excess auxiliary exhaust. Steaming modified main requires that the systems associated with the main engine are in operation (i.e., main circulating pump, main condensate pump, main air ejectors, gland sealing steam, and main lube oil system and the jacking gear) in addition to those required to steam auxiliaries. Steaming auxiliaries versus modified main has been measured to produce from 50 to 150 GPH savings on typical amphibious ships.

3.5.4 Steaming Modified Main in Port. Ships may be required to steam modified main to utilize the main engine as soon as possible (i.e., bad weather or combat readiness). Some ships steam modified main because operators believe it increases reliability. Others steam modified main because they produce more auxiliary exhaust than the auxiliary condenser and auxiliary condensate system can handle. In the latter case, the inability to steam auxiliaries could indicate a plant that is operating very inefficiently and requires corrective action to system components and/or system alignment. Steaming modified main permits the ship to ignore problems associated with inefficient or improperly selected equipment. In some cases, the auxiliary condenser appears to be "too small" to handle the excess auxiliary exhaust when the steaming auxiliaries alignment is attempted. When operating conditions permit, steaming auxiliaries shall be utilized since it decreases fuel consumption by operating the minimum number of machinery components required for reliable and efficient operation.

3.5.5 In-Port Machinery Alignment Recommendations. The following machinery alignments shall be utilized to obtain the lowest possible fuel rate while steaming in port, when conditions permit:

a. Operate only one boiler.

b. Use the smaller "port use" fuel oil service pump in lieu of the main service pump, if installed. This not only saves fuel (~2 GPH), it also reduces wear on the main fuel oil service pump.

c. Operate the in-port forced draft blower, if installed.

d. Maintain the minimum required forced draft blower speed for a just clear stack by trimming excess combustion air.

e. Align the auxiliary exhaust excess pressure dump system to the auxiliary condensers and steam auxiliaries vice modified main.

NOTE

Under no conditions should the auxiliary exhaust dump and augment valves be open at the same time. Elimination of simultaneous making-up and dumping of auxiliary exhaust can frequently save 50 to 100 GPH on most steam turbine-powered amphibious and auxiliary ships.

f. Use electrically driven in lieu of steam driven auxiliaries.

g. Ensure that the main feed pump is operated in accordance with EOP, and the discharge pressure is properly maintained and does not exceed specified limits (usually set 150 PSIG higher than steam drum pressure; refer to EOP for limits).

h. Do not operate a standby main feed pump in port.

i. Secure all hand nozzle control (overload) valves on turbine-driven auxiliaries.

j. Operate the minimum number of SSTG sets required to maintain electric load and secure any standby units.

k. Secure all main propulsion related auxiliaries until preparation for getting underway commences.

l. When the ship is on shore power, energy conservation shall be practiced (e.g., observe A/C boundaries, reduce the number of A/C plants on-line, cut unnecessary electrical consumption by reducing equipment on-line, lighting in unmanned spaces, raising thermostat temperatures in unmanned spaces, ensuring thermostats are set properly for the season, coolers, heater, and ranges, etc.).

3.5.6 Split Plant Operation. Split plant alignment operation is a common mode of operation on multi-shaft ships. Split plant refers to an alignment in which steam from the boiler(s) of one fireroom is directed only to one engine while other firerooms provide steam individually to other engines. In the event of a boiler casualty, only one engine would be affected so the other engine(s) that receive steam from a separate boiler(s) could maintain propulsion. Split plant operation requires each fireroom to be self-sustaining. This increases the number of support auxiliaries required as compared to cross-connected operation. Situations such as sea and anchor details, restricted maneuvering, Underway Replenishments (UNREP), etc., warrant utilizing this somewhat more reliable propulsion alignment. However, the penalties associated with this operating mode include additional equipment in operation, greater fuel consumption, and related maintenance costs.

3.5.7 Cross-Connected Operation. The alternative to split plant operation is cross-connected operation. In this mode, boilers in one fireroom provide steam to more than one main machinery space. In the case of all amphibious steam ships, one of the two firerooms can be aligned to provide steam to both main engines. The advantage of cross-connected operation is that less equipment is needed than would be the case when operating firerooms separately. This alignment eliminates the operation of a fuel oil service pump, main feed pump, main feed booster pump, forced draft blower, and freshwater drain collecting tank pump that would otherwise be required for multiple boiler, split plant operation.

3.5.7.1 Use Cross-Connected Alignment with Caution. Cross-connected alignments are not usually practiced because they are sometimes difficult to align initially (cross-connecting drain lines, condensate, feed, etc.) and if a boiler casualty occurs, it could affect all machinery spaces. Cross-connected operation is normally utilized when recovering from an engineering casualty. However, it can also be employed during independent transits, open water steaming, i.e., when a normal level of reliability is acceptable, to save significant amounts of fuel. Additional benefits from cross-connected operation include reduced watch standing requirements, since only one fireroom is operating and manned; reduced wear and tear on equipment; and increased maintenance availability for the secured fireroom.

NOTE

Trail shaft operation is not recommended for steam ships because the propulsion system was designed for partial power efficient operation. A single boiler cross-connect configuration provides a more energy efficient mode of operation than trailing one shaft. Steam ships will normally operate in the trail shaft or locked shaft condition when required because there has been a casualty in the propulsion plant.

3.5.8 Single Boiler Operations. Single boiler operation is a common method of improving fuel economy at low speeds. By securing one boiler, the unit remaining on-line operates at a higher load with higher superheat temperatures (see figure 3-3). The higher superheat temperature reduces the required steam flow to the main propulsion turbine(s), turbine generators, and main feed pump(s) since the steam has a higher available energy for work. Single boiler operation also reduces the number of auxiliaries on-line and increases their load, thereby improving their efficiency. There may be sufficient feed flow to close the main feed pump recirculation valve, which reduces feed pump load and thus steam flow. Also, there is often a ship speed at which fuel consumption for single boiler operation is equal to that for two-boiler operation, whereupon two-boiler operation becomes more efficient. This speed (crossover point) varies from ship to ship. For a typical amphibious assault class ship shown in figure 3-5, the crossover point where two-boiler operation becomes more efficient is about 18.5 knots. Obviously, operating for a sustained period above this speed with a single boiler is not economical. Conversely, large savings will accrue if a ship spends considerable periods of time below the crossover point. The fuel measurement methodology provided in Appendix B shall be utilized to determine the specific crossover point for most efficient operation for one to two boilers.

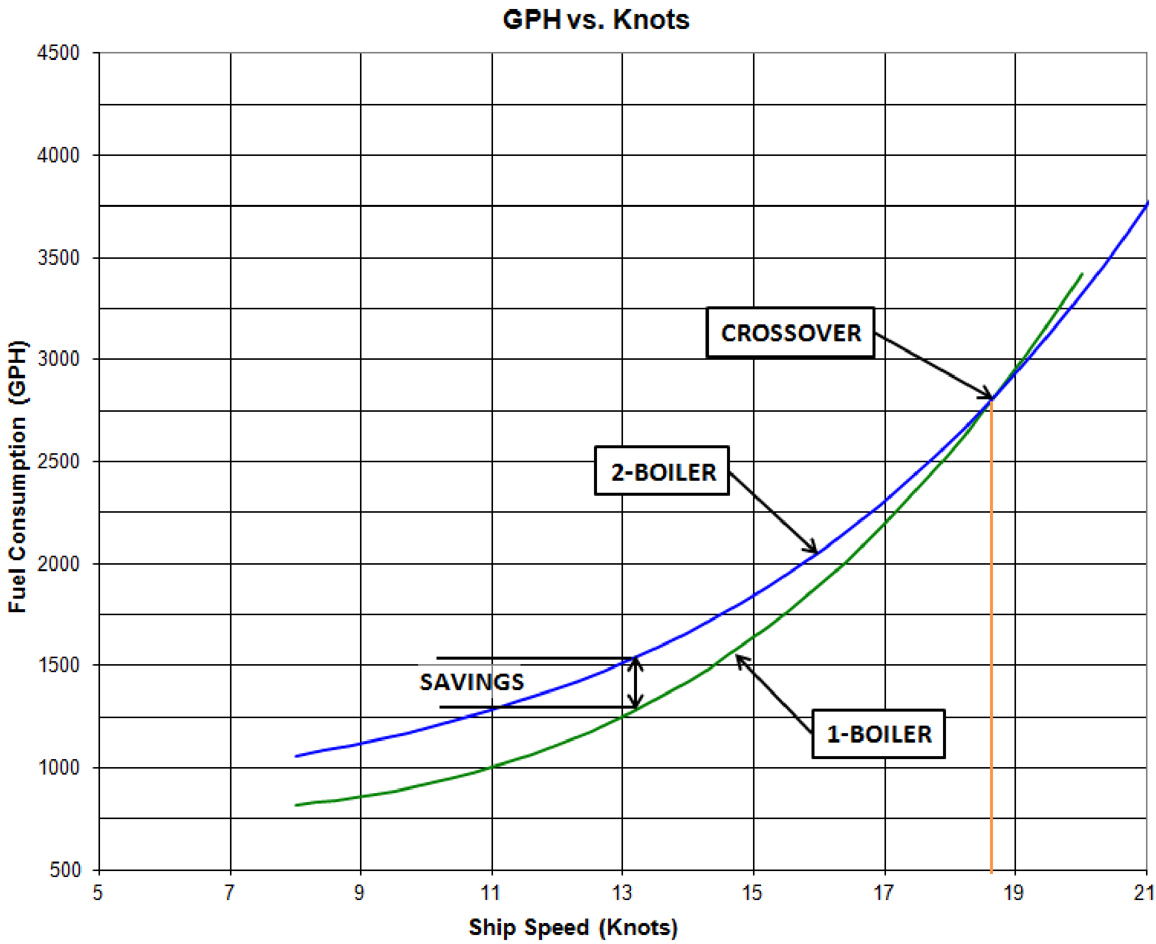


Figure 3-5. Economical Alignment Fuel Curves.

3.5.9 Maximizing Boiler Efficiency. Since the boiler is the point in the cycle where the chemical energy of the fuel is converted into thermal energy for the steam plant, its efficient operation is crucial to good fuel economy. Maximum boiler efficiency occurs when the heat absorbed by the steam approaches the amount of heat available during the combustion of fuel. Navy boilers typically have maximum boiler efficiencies of 86-88 percent. Many factors will reduce boiler efficiency. Among them are the presence of scale or soot, air casing leaks, refractory problems, improper fuel/air ratio, poor material condition of automatic combustion controls, defective burners and atomizers, and improper plant light-off procedures.

3.5.10 Boiler Material Condition. The following boiler material deficiencies will cause increased fuel consumption if not corrected:

a. Damaged and missing furnace refractory and pipe lagging increase radiation and convection losses, thus wasting fuel. The ambient temperature of the space may increase, thereby placing an additional burden on space ventilation.

b. Any steam leak, whether internally to a piping system or to atmosphere, represents a loss of energy, which increases fuel consumption.

c. Any condition that interferes with heat transfer is costly in terms of fuel oil consumption. Dirty boiler firesides and dirty watersides cause serious interference with heat transfer and thus result in high fuel oil consumption. High stack gas temperatures, low superheater outlet temperature, and low economizer outlet temperatures can indicate soot build-up and the need to blow tubes. Proper boiler water/feedwater chemistry and cleaning will minimize scale build-up.

d. Air leakage from the inner casing into the furnace increases stack heat losses and wastes fuel. Air leakage from the outer casing into the fire room requires that the forced draft blowers be operated at a higher speed, placing an additional burden on space ventilation and further increasing auxiliary steam and fuel oil consumption.

e. A number of burner defects lead to poor fuel oil atomization and the impingement of oil, soot, or carbon deposits, as well as other conditions that result in high fuel oil consumption. The following burner components and settings shall be checked to ensure complete combustion through proper fuel atomization and complete mixture with combustion air:

(1) All sprayer plates are the same size and not worn or damaged (use GO/NO-GO gauge).

(2) Overload sprayer plates are not used for normal cruising (if applicable).

(3) Fuel oil burner barrels are the same length.

(4) Diffusers are clean, not worn or damaged, and properly aligned.

(5) Throat rings are clean, not worn or damaged, and are concentric.

(6) Diffuser withdrawal settings are within tolerance.

(7) Tip protrusion settings are within tolerance.

(8) Register doors open to the proper position and close fully and properly.

(9) Fuel and steam valves are full open and not throttled.

(10) Atomizing steam is at the proper pressure and temperature.

3.5.11 Selective Use of Boilers. The ship can save a significant amount of fuel by operating the more efficient boiler(s) as much of the time as possible until maintenance can be performed on the boiler that is in poor condition. The ship can determine which boiler is burning more fuel by monitoring single boiler fuel consumption rates and recording other operating performance data, such as pressures and temperatures of steam, economizer inlet and outlet temperatures, stack gas temperatures, SGA readings, and fuel pressures at the burner header. The same performance data can then be recorded for the other boiler(s) with the same machinery alignment and steam load (i.e., same speeds, kW load, etc.) as used during the initial boiler test. Comparison of the recorded performance results will reveal which boiler(s) has the superior operating characteristic(s) and fuel consumption rate(s). Once the material condition of the boiler with inferior operating characteristics and high fuel consumption is corrected, the number of operating hours should be brought into balance with those of the other boiler(s). Note that no two boilers will have identical consumption rates even under virtually identical conditions.

3.5.12 Burner Management. Proper burner management entails the use of the minimum number of properly maintained burners in each boiler to provide the most efficient operation for a given boiler load while maintaining allowable fuel oil supply header pressure. If there are no operational restrictions and rapid bell changes are not planned, burner management shall be practiced. For maximum fuel savings, unused burners should be removed to further reduce atomizing steam demand. Burner management demonstrations during SECAT visits have resulted in savings of up to 70 GPH. For ships equipped with Electronic Automated Boiler Control (EABC) systems, burner management is performed automatically and allows for burner operation at low header pressures because of optimized air flow control.

3.5.12.1 Sprayer Plate. Proper burner management also includes verifying that correct and consistent size sprayer plates are used. Never mix tip sizes in the same boiler. In a case where overload and full power tips were used in the same boiler, the proper air flow could not be obtained since the larger sprayer plates fired approximately 17 percent more fuel than the full power sprayer plates for the same fuel oil header pressure. Any modification to the burner system must be integrated with the EABC for optimum combustion.

3.5.13 Operation of One Forced Draft Blower per Boiler. Although the Propulsion Operating Guide (POG) may specify one blower per boiler up to cruising speed, many ships routinely operate two blowers per boiler throughout the ship's operating range. Use of only one blower per boiler will allow the unit (both the blower and its steam turbine driver) to operate nearer its rated capacity and highest efficiency and eliminate the powering requirements of the second blower, thereby using less energy. Operation of one blower per boiler also makes it easier to trim excess air at low loads, particularly while in port. To realize the lowest possible fuel rate while operating forced draft blowers, all drive turbine overload nozzle valves must be shut. Additionally, when operating one forced draft blower per boiler, discharge shutters on the secured forced draft blower should be closed. Operation of forced draft blowers shall always be in accordance with EOP.

3.5.14 Trimming Excess Combustion Air. An average of 4 to 7 percent fuel savings can be realized through proper adjustment of the fuel-air ratio on the forced draft blower master controller to maintain combustion with minimum excess air levels in ships with automatic combustion controls. This process is now automated via the EABC system which is installed on all remaining steam ships.

3.5.14.1 Effects of Excess Combustion Air. Operating with above design excess combustion air levels in boilers causes the following:

a. Higher than design superheater outlet temperature which increase superheater tube metal temperatures and shortens tube life.

b. Increased stack gas temperature, presenting the ship as a greater infrared target.

c. Higher force draft blower speeds than required, causing additional wear and increased steam and fuel consumption.

d. Fuel waste, as the excess combustion air carries un-recoverable heat energy out of the stack.

3.5.14.2 Black and White Smoke – Indicators of Possible Boiler Explosion. Heavy white or black smoke conditions can indicate boiler explosions, because large quantities of unburned fuel are present. All that is needed is an ignition source (i.e., a hot piece of carbon) and sufficient air. Black smoke is generated during smoking conditions because of insufficient air to support combustion (unburned hydrocarbons and partial conversion to CO instead of CO_2). White smoke, however, results from large quantities of excess air that carry unburned hydrocarbons up through the economizer to the atmosphere where they condense and form a white (vapor) mist, referred to as white smoke. S9086-GY-STM-010/221, NSTM Chapter 221, discusses the potential causes of boiler explosions and provides guidance for minimizing these risks.

3.5.14.3 Stack Gas Analyzer (SGA). All U.S. Navy steam ships are equipped with an SGA. The SGA is used to effectively monitor boiler exhaust gas oxygen content as an indication of excess air supplied. The SGA consists of a probe, an electronics enclosure, and a display. The probe protrudes into the uptakes of the boiler and continuously measures excess oxygen contained in the stack gases. The display presents a digital readout of the percent oxygen content in the flue gases. As the amount of excess air increases, so too does the percentage of oxygen in the stack gases, as shown in figure 3-6. Through its use, the SGA can pay for itself in a very short time by allowing the watch stander to operate the boilers more efficiently. These fuel savings occur over the entire range of speeds normally used in Fleet maneuvers and transits. Trimming excess air has been demonstrated to provide between 15 to 65 GPH fuel savings during SECAT visits to typical amphibious ships. Trimming air does not reduce ships' operational capabilities.

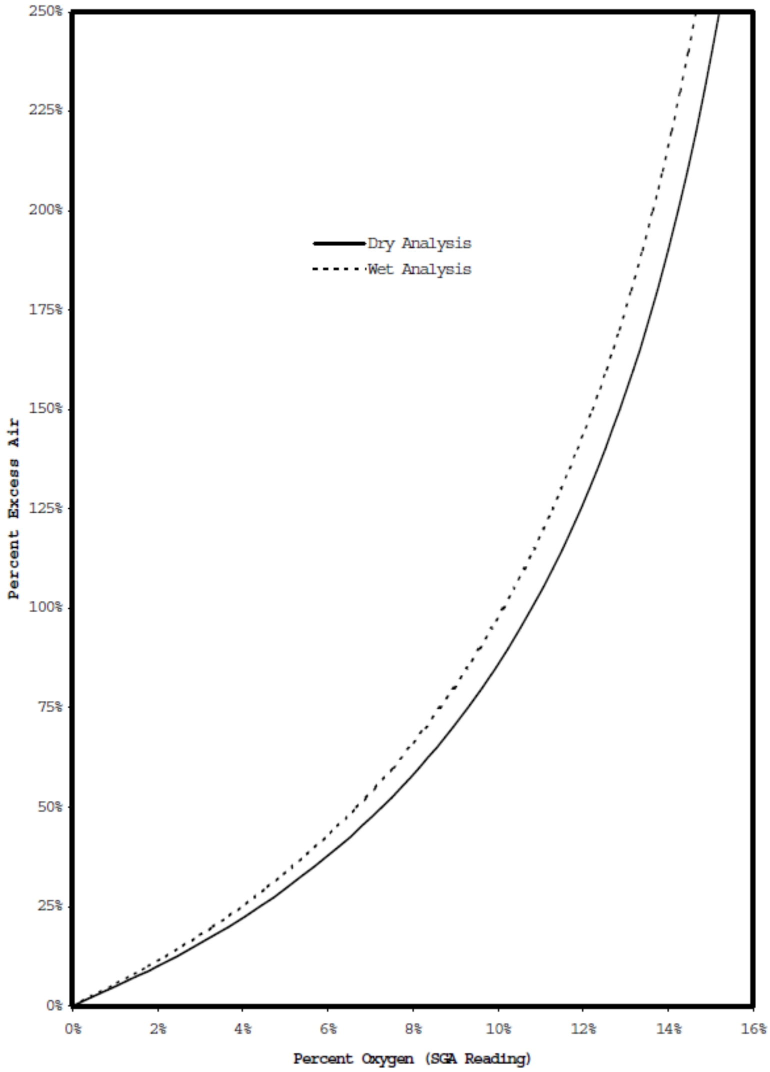


Figure 3-6. Stack Gas Oxygen Content and Excess Air Equivalent.

NOTE

If a significant speed change order is received or if speed maneuvers are anticipated, the fuel/air ratio manual adjustment must be returned to the normal setting to preclude smoking during maneuvers because there may be an inadequate supply of combustion air to meet the additional demand for air during these changes. As soon as the plant settles out at the new speed, combustion air should again be trimmed by increasing fuel/air ratio.

3.5.14.4 Excess Air Levels. Excess air levels generally vary indirectly with boiler firing rate. At minimum firing rates, excess air may be as high as 100 percent, and require a considerable amount of trimming (increasing the fuel/air ratio relay setting from the reference mark). At higher firing rates, excess air may be as low as 15 percent, which is close to optimum. The relationship between boiler efficiency, stack gas oxygen content, and stack gas temperature during the combustion process is shown in figure 3-7.

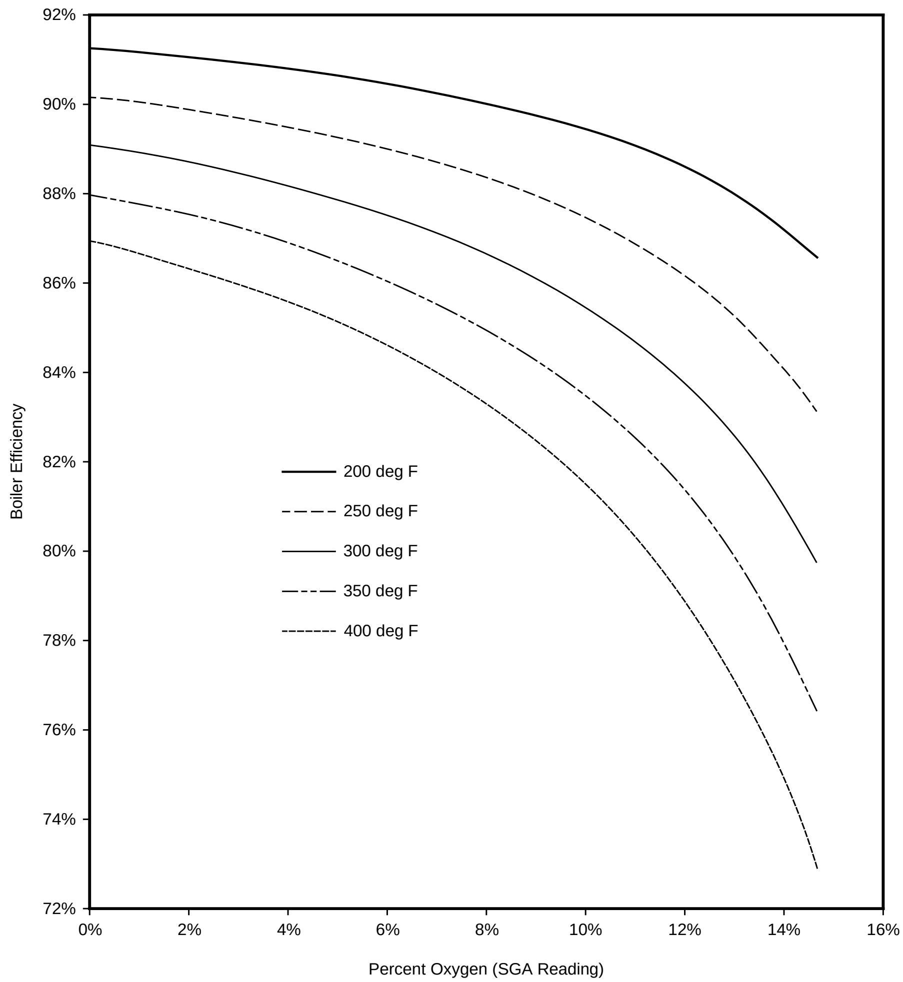


Figure 3-7. Stack Gas Conditions vs. Boiler Efficiency.

3.5.15 Superheater Outlet Temperature. It is important to operate the boiler as close to design conditions as possible to allow steam cycle consumers (main and auxiliary turbine-driven machinery) to extract the maximum available energy from the steam possible, thereby reducing plant fuel consumption. Operating with higher than design superheater outlet temperatures can cause additional thermal stress to the superheater. Lower outlet temperatures increase plant fuel consumption. High superheater outlet temperatures can be caused by failure to use deceleration tables, low feedwater inlet temperature, or operating with too much excess air. Monitoring the SGA and proper boiler controls adjustment can help prevent this condition and save fuel in the process. Low superheater outlet temperatures can be caused by fouled gas side tube surfaces, failure to follow acceleration tables, or high feedwater inlet temperature.

3.5.16 Steam Turbines. The following are a few main and auxiliary turbine-operating tips for economical propulsion plant operation.

a. The most economical way to operate the engineering plant is to use the minimum number of auxiliaries required to maintain speed and services. This will result in system operation at designed loads where they are most efficient (refer to figure 3-8 and figure 3-9). The plant alignment status boards in Appendix C will assist watch standers in maintaining the most economical plant alignment.

b. Ensure that the individual at the throttle is following the standard acceleration and deceleration tables.

c. Turbine gland seal steam pressure should be kept as low as possible, within design limits, while still maintaining vacuum.

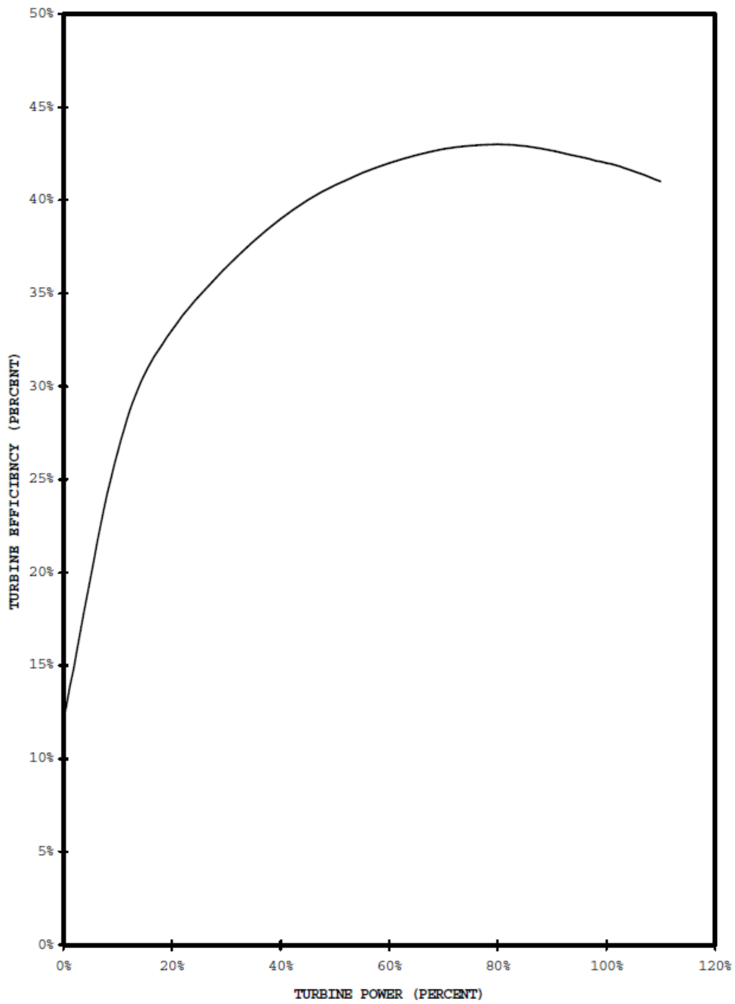


Figure 3-8. Typical Auxiliary Steam Turbine Efficiency.

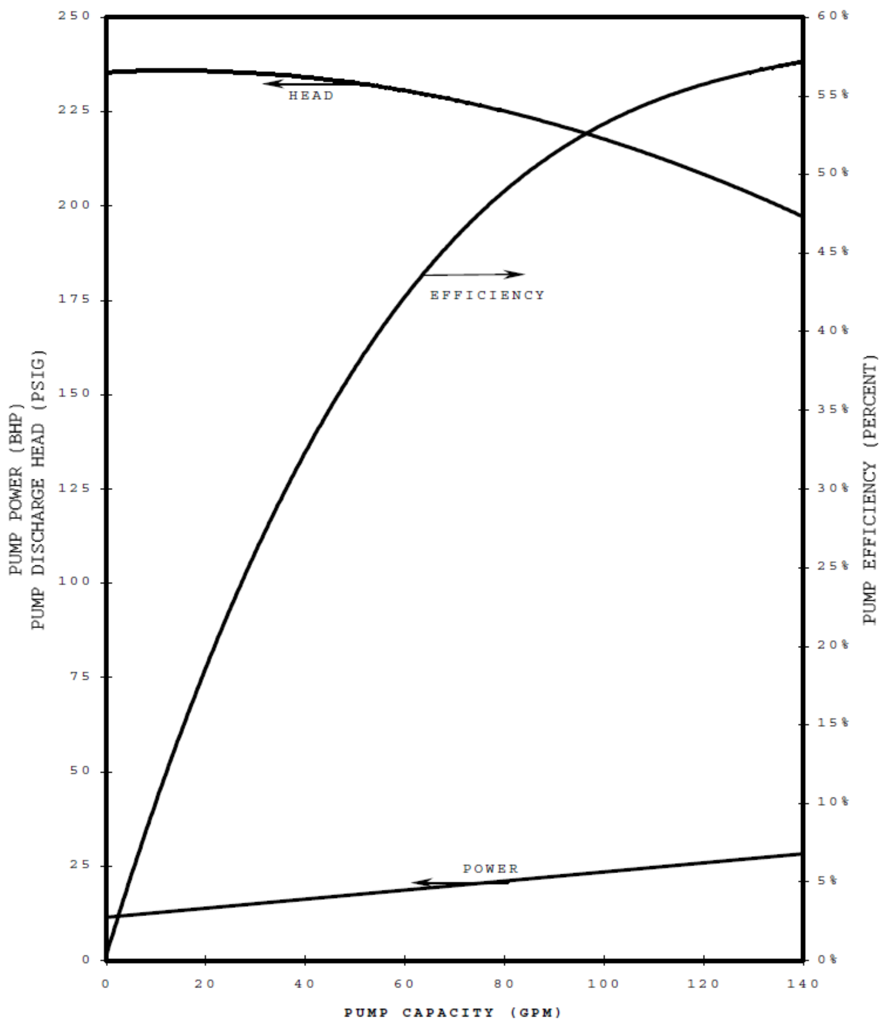


Figure 3-9. Typical Centrifugal Pump Performance.

3.5.17 SSTG Operations. The efficiency of a steam turbine-driven generator increases as its load is increased. Therefore, fuel will be saved by operating the minimum number of generators to satisfy electrical load requirements. Ships operate two service generators in parallel with multi-ship transits, UNREP, sea detail, etc. Events that can increase electrical load substantially (UNREP, flight operations, weapons exercises, etc.) are usually planned in advance so the electrical plant can be adjusted when needed. Normally, steam turbine-driven generators require up to half an hour to be started and placed on-line.

3.5.17.1 Generator Idling. Although it is not a recommended practice to idle a generator on standby unless required to meet specific mission needs, some ships do idle one generator, and in some cases two SSGs for emergency backup. Most naval surface ships are provided with an emergency diesel generator that starts automatically in case the ship's service generator trips. With this additional emergency diesel generator available, idling a SSG results in an excessive fuel penalty in order to provide a double electrical casualty backup. Aboard typical amphibious assault class ships, approximately 25 GPH of fuel is typically required to keep a backup SSTG idling in addition to two operating SSTGs. If required to idle a generator to maintain mission readiness, Ship's Force should refer to EOP and CO's standing orders for proper operation, and once the idling generator is no longer required to meet the mission requirements, it should be secured.

3.5.18 Electric Versus Steam Driven Pumps. The fuel savings achieved by utilizing electrically driven auxiliary machinery versus steam-driven machinery is due primarily to better thermal efficiencies achievable by the SSTG than by small auxiliary non-condensing drive turbines. The SSTGs have several stages of blades for energy conversion via thermal expansion into a condenser under a vacuum. This provides a much higher thermal efficiency than that achievable by the small auxiliary non-condensing turbines with a single stage of blading and thermal expansion of the steam to a backpressure of about 15 PSIG. In addition, any excess auxiliary exhaust created by these non-condensing turbines that is not used by the deaerating feed heating tank and distillers is dumped to the main and/or auxiliary condensers. Even with the introduction of generator, motor, and line losses, the combined efficiencies of electrically driven equipment are significantly better than those of steam-driven equipment, particularly at other than design operating loads. For instance, during a SECAT Team visit onboard a typical amphibious transport dock class ship, a fuel savings of 62 GPH at 8 knots was quantified as a result of securing two turbine-driven fire pumps while starting one motor-driven fire pump of equivalent capacity. A common opinion held by many operators is that the fuel cost benefits of using electric auxiliaries versus steam are outweighed by the possibility of losing the SSGs. It is a remote possibility that all of the operating SSGs would fail at once. This would have a more far-reaching impact on the ship than just shutting down motor-driven pumps. It should also be noted that there are entire classes of ships with only electrically driven fuel oil service pumps, main feed booster pumps, and main condensate pumps.

3.5.19 Condensate and Condensate Systems. The latent heat in turbine exhaust steam is transferred to the seawater in the condenser, causing the vapor to condense into water. This condensate is then pumped to the Deaerating Feed Tank (DFT), where it is scrubbed of corrosive entrained oxygen. The proper operation of this heat sink and pumping system is essential to maintain the design efficiency of the steam cycle. There are many economical strategies that can be employed in the operation of both the main and the auxiliary condensate system. Operational and maintenance-related strategies include:

a. The main condenser should be maintained at the highest possible vacuum. This increases the amount of energy available from the steam. A 1-inch decrease in condenser vacuum increases fuel consumption by 3 percent. Locate and stop air leaks.

b. The freshwater drain collecting tank pumps should be utilized instead of vacuum drag. The use of vacuum increases fuel consumption by approximately 1 percent due to flashing in the condenser and the subsequent heat loss.

c. If the condensate recirculating valve is continuously open, condensate will be cooled unnecessarily. This wastes fuel because additional heat is needed later in the cycle to reheat the condensate.

d. Fouling of the seawater side of condensers decreases cooling water flow and reduces heat transfer. Indications of this problem are a decrease in vacuum and an increase in the temperature rise across the seawater side of the condenser.

e. Air ejectors should be routinely inspected and worn or clogged nozzles should be replaced. The steam should be dry and slightly superheated to reduce nozzle erosion.

3.5.20 Steam and Water Losses. Steam and water losses may seem insignificant when considering an individual valve or pump packing leak, but there are numerous valves and pumps aboard ship and the losses add up quickly. Steam and water leaks of only 100 GPH can increase daily fuel consumption from between 60 to 90 gallons per day (GPD) of DFM. When all steam and water leaks are totaled, the losses can become significant and costly, especially in the case of carriers. While the examples below are primarily for carriers, the strategies discussed for reducing steam and water losses apply to all steam ships.

3.5.20.1 Auxiliary Exhaust System Steam Line Valves. Valves on steam lines to the auxiliary exhaust system may leak if not closed properly or if they have worn discs and/or seals. Superheater protection, bleed steam isolation, and live steam augment valves may leak into the auxiliary exhaust system. This will cause the energy in the leaking steam to be lost to the sea if auxiliary exhaust is being unloaded to the main or auxiliary condensers. All steam chest drain valves should also be carefully checked. Stethoscope type listening or other types of leak detection devices can help to quickly locate leaks.

3.5.20.2 Perform PMS on All Valves. Each ship should perform required PMS judiciously to ensure correctness and uniformity in the maintenance and preservation of valves throughout the engineering plant. S9086-RK-STM-010/505, NSTM Chapter 505, Section 9, Valves, can be utilized to develop such a program.

3.5.20.3 Estimate of Fuel Consumed for Excess Make Up Feed. The following equation provides an estimate of equivalent fuel consumed for excess make up feed (losses).

$$Q_{FUEL} = \frac{530 * MUF}{HHV * \eta_{BOILER}}$$

Where:

Q_{FUEL}	=	Fuel consumed due to additional make up feed requirements due to excessive steam, feed water, and condensate leaks, LB/HR
530	=	Heat required per pound of distillate, BTU/LB
MUF	=	Make up feed consumption, LB/HR
HHV	=	Higher heating value of fuel, BTU/LB; (DFM = 19,500 BTU/LB)
η_{BOILER}	=	Efficiency of boilers, % (typically 85%)

NOTE

The above equation assumes one-third of losses that require MUF are from steam, one-third from feed, and one-third from condensate systems.

3.5.20.4 Maintain Proper Boiler/Feedwater Chemistry. Proper boiler/feedwater chemistry is necessary to maintain water within limits. Dumping and flushing boilers or feed tanks can consume tremendous amounts of water. Drain systems should be maintained to prevent water loss. Contaminated drains should be isolated from the collection system and the source of contamination corrected.

3.5.20.5 Distillation Units. Many steam ships are configured so that the heating steam for the distilling units can be supplied either from auxiliary exhaust or live steam from a 150/15 PSI reducer. Some ships have made it a practice to use the 150/15 PSI reducer to supply heating steam at all times with the supply valve from the auxiliary exhaust system secured. When operating the distilling units using only auxiliary exhaust, the energy to heat the water can be considered free, since it would otherwise be dumped via the condenser. For a typical amphibious transport dock class ship with two 30,000-GPD distilling units operating on live steam, fuel consumption equates to approximately 52 GPH or about 1 gallon of fuel per 48 gallons of water distilled.

3.5.20.6 Distilling Plant Efficiency as it Relates to Feed Temperatures. The most common distilling plant installed in steam ships is the flash type. For this type of distilling plant, improper feed heater operation can result in reduced distillate production rates. Frequently, operators believe they will increase distiller output by operating at a feed temperature 10 to 15 °F higher than design (usually 165 to 175 °F). These higher feed temperatures increase scale formation on the feed heater and condenser surfaces. As scaling occurs, freshwater production is reduced rapidly, leading to the need to acid clean the distilling unit before it can be returned to full capacity.

3.5.21 Main Circulating Pump. Main circulating pump operation is required when, due to reduced ship's speed, the water flow through the main condenser via the scoop is inadequate to maintain condenser vacuum. At low speeds, the power required to drive the main circulating pump represents a significant percentage of the total steam flow delivered by the boiler. Therefore, using a main circulating pump only when needed will result in improved fuel economy. There are steam turbine-driven ships that have been able to secure the main condenser circulating pump at as low as 4 knots, while still maintaining design vacuum. The point at which the main circulating pump can be secured will vary with seawater temperature, ship's speed, condenser condition, and other factors. When operating in cold water, scoop injection can provide adequate cooling seawater at speeds lower than 12 knots. This can best be ascertained by the ship in a series of trials to determine the speed at which the pump can be safely secured for a given seawater temperature, as long as vacuum is maintained during steady state steaming. During maneuvering, the fuel savings from securing this pump would be negligible and waiting for vacuum to drop before starting the main circulating pump could lead to operational difficulties. From a fuel economy point of view, in cooler water the main circulating pump can be secured at lower speeds (8 knots is generally a conservative number for most ships) and still maintain vacuum by the scoop injection, versus a hard policy of 12 knots. Where installed, electrically driven circulating pumps should be operated on low speed to provide the minimum achievable condenser circulating water flow rate while still maintaining condenser vacuum at design levels. Typical amphibious ships have measured 30 to 35 GPH fuel savings by securing the main circulating pump when it is not needed.

3.5.22 Proper Maintenance of Centrifugal Pumps. Timely and proper maintenance of all centrifugal pumps is essential. A badly worn pump (both driver and pump ends) requires more energy to pump the same volume of fluid than a pump with proper clearances.

3.5.23 Operation of Auxiliary Exhaust Augmenting and Unloading Valves. Proper operation, maintenance, and settings on both auxiliary exhaust augmenting and unloading valves are essential to avoid wasting significant amounts of fuel. The auxiliary exhaust system should be maintained at design pressure for proper operation of the DFT. At high loads, excess pressure is unloaded to the condensers via the dump valve, while at low loads the augmenting valve opens. Improper settings or malfunction of the auxiliary exhaust augment and dump valves can result in a condition in which live steam is admitted to the auxiliary exhaust system only to be dumped to the main or auxiliary condenser. This condition is quite common and typically has an associated fuel penalty of more than 50 GPH. Proper settings and maintenance of the augment and dump valves and their pilot controllers are essential to economical plant operation. Typical valve regulator settings should be available in EOSS/EOP.

3.5.24 Main Feed System. The feed system is a critical phase of the steam cycle. At the pump, work and heat are put into the process in order to provide feedwater to the boiler at proper operating conditions. Some notes on proper operation of the feed system are listed below.

a. Excessive feed pump discharge pressures should be avoided. Boiler feedwater regulator settings should be in accordance with On Line Verification (OLV) procedures. Excessive feed pump discharge pressure will result in using additional steam to drive the pump.

b. Extra nozzles (if equipped) on main feed pumps should be opened only at high powers.

c. Gland cooling water for the main feed pumps is supplied from the condensate system and returns to the freshwater drain tank. On some ships, an unauthorized alteration diverts this water to the bilge versus the freshwater drain tank. The gland design flow rate is 5 GPM per pump, but actual flows can be much higher, particularly if flow control orifices have been removed. This water flow is typically 300 GPH, or 7,200 GPD, of lost feedwater per pump.

d. If the temperature of the feedwater supplied to the boilers is lower than design, more heat will be required to generate steam. Consequently, more fuel oil will be used to maintain the required rate of steam generation. Low feedwater temperature is sometimes caused by incorrect operation of the DFT and feedwater heaters (if equipped).

3.5.25 Operation of Standby Main Feed Pump. Routine operating practice for many ships includes the idling of a main feed pump in a standby mode for emergency use. This idling main feed pump is one of the largest energy wastes aboard ship. Review of the technical manual for any main feed pump will show that it is very inefficient at low loads. A typical idling main feed pump consumes about 3,600 pounds of steam flow per hour. Further, this increased steam demand also increases the steam demand for the main feed pump on the line, the fuel oil service pump, and the forced draft blower(s). When all of these effects are considered, an idling main feed pump can increase fuel consumption by about 40 GPH. The need to have such an energy consumer in standby must be evaluated in light of the tactical or safety requirements at hand and should be secured when an operating scenario does not warrant this redundancy. If a standby main feed pump is essential, lowering the idling main feed pump discharge pressure to 300 PSI can eliminate a substantial portion of this additional fuel consumption. SECAT Team experience aboard several ships has shown that, simply by maintaining the idling main feed pump discharge pressure at about 300 PSI on 600 PSI, plants can reduce this excess fuel consumption by approximately 20 GPH. The recirculation valve (if equipped) should be fully open at this low flow to prevent overheating. In contrast, a reciprocating emergency feed pump, such as that used on some 600 PSI propulsion plants, does not waste energy while on standby. Main feed pumps that are on-line (not standby) should be checked to ensure proper operation of the recirculating valves.

APPENDIX A
ENERGY SURVEY CHECKLIST FOR IMPROVED FUEL ECONOMY

A.1 PURPOSE.

The ENCON checklist provides a periodic qualitative self-assessment of ship progress in following good energy conserving practices. Ships can use the checklist to identify the areas where a ship needs better energy conservation practices for improved fuel economy.

A.2 CHECKLIST.

a. **Strong Command Commitment**

(1) Is your CO committed to ENCON? Strong Command commitment is necessary for successful shipboard energy conservation.

(2) Did your ship participate in ENCON training events? This aids your ship in attaining the highest marks for the SECNAV Annual Energy Award evaluation.

(3) Does your ship have an established energy conservation plan?

(4) Does your CO check the iENCON website (www.i-encon.com) regularly for updated ENCON data and information?

(5) Are your CO, XO, and department heads reviewing MOCK bills provided by Energy Advisors to assess ship's energy demand and conservation practices monthly when in port?

b. **Top Five (5) ENCON Practices**

(1) Drifting Mode or Anchoring Underway (up to 70 percent less fuel)?

(2) Trail Shaft (up to 50 percent less fuel)?

(3) Clean Hull/Propeller (up to 18 percent less fuel)?

(4) Good Navigation (use OTSR & TESS data)?

(5) Good Machinery Maintenance?

c. **ENCON Management**

(1) Does your ship have an established Shipboard Energy Manager (SEM)?

(2) Does the SEM chair the Energy Conservation Board and does the board meet regularly?

(3) Does the SEM announce the Energy Tips on POD and 1 Main Circuit (1MC) for all-hands' energy awareness?

(4) Does your ship follow the latest Fleet instructions for energy conservation?

(5) Does the SEM check the iENCON website (www.i-encon.com) quarterly?

(6) Does the SEM submit the SECNAV Annual Energy Award package?

(7) Has your ship submitted best energy and pollution abatement lessons learned as part of ship submittal for consideration for the EPEC award initiated in February 2012?

(8) Does the SEM recognize individuals when important energy savings initiatives are achieved?

(9) Does your ship have an ENCON Review Board?

(10) Are Division-in-the-Spotlight (DITS) and regularly scheduled command-wide zone inspections conducted to stress energy conservation?

(11) Are members of the ship energy conservation team embedded with Zone Inspection Teams to identify energy impacting deficiencies such as leaking faucets and lights on in unoccupied spaces?

d. **Training & Awareness**

(1) Did your ship's senior officers attend an ENCON training event? Training schedules can be obtained from www.i-encon.com.

(2) Has the ship acquired the most recent version of the Ship Energy Conservation Assist Training (SECAT) Tool? The SECAT Tool helps to develop fuel consumption curves, optimum transit curves, and replenishment requirements.

(3) Is energy conservation included in Planning Board for Training (PBFT) sessions to schedule periodic energy conservation training for the ship?

4) Does your ship cover energy awareness during Indoctrination Division for all new personnel as required by Standard Organization Regulation Manual (SORM)?

e. **Fuel Consumption & Optimum Transit Curves**

(1) Does your ship have Fuel Oil Meters (FOMs) installed on all main engines? If not, contact your port engineer to install MACHALT 370a (GT & diesels) or MACHALT 370 (steam).

(2) Are FOMs in good operating condition?

(3) Are FOMs calibrated regularly?

(4) Do your ship service generators have FOMs? If not, you can use nomograms provided in the SECAT Tool and ENCON Guide to determine fuel usage per kW.

(5) Are fuel consumption curves maintained to reflect current performance?

(6) Are fuel consumption curves posted in the bridge, Main Engine Room, and Engineering Control Center?

(7) Are fuel consumption and optimum speed curves used for planning ship's daily operations?

(8) Has your ship utilized the SECAT Tool to identify fuel profiles and most efficient speeds for transit?

(9) For ICAS energy dashboard ships, are actual equipment profiles and fuel consumption monitored and compared to SECAT Tool projected fuel consumption for recommended configurations and recommendations for most efficient speeds?

f. **Navigation & Ship Handling**

(1) Is energy considered when charting navigational routes?

(2) Does your ship use OSTR & TESS data?

(3) Does your ship avoid shallow waters if possible?

(4) Does your ship attempt to minimize speed change whenever possible while maintaining station (frequency and magnitude)?

(5) Does the helmsman use minimum rudder angle to keep on track (3 degrees or less)?

(6) Does your ship attempt to operate at or near economical speed as much as possible during independent operations or long transits?

(7) If conditions permit, are the ship's autopilot features used to reduce fuel consumption?

(8) Does the ship optimize winds and currents while operating in the open ocean or night steam boxes?

g. **Hull/Propeller Cleaning**

(1) Does your ship regularly coordinate with TYCOMs to inspect the hull and propeller in order to ensure that hull and propeller cleanings are being scheduled and performed as required?

h. **Engineering Plant Operation**

(1) Is an energy-efficient plant alignment consciously selected for each day's operations (i.e., anchoring underway or drifting at night, and trail shaft)?

(2) Is bleed air secured regularly when it's not needed?

(3) Is the minimum number of fire pumps used whenever possible?

(4) Are motor-driven pumps vice turbine-driven pumps operated when possible?

(5) Are main circulating pumps secured as soon as main condenser vacuum permits?

(6) Are main boilers excess air controlled for just haze condition?

(7) Is idling main feed pump secured for improved fuel economy?

(8) Is a machinery alignment status board (found in the SECAT Tool and ENCON Guide) conscientiously maintained?

(9) Is permission obtained from the EOOW for all equipment status changes?

(10) Is EOSS validated, properly maintained, and routinely used?

(11) Does your ship use acceleration/deceleration tables?

(12) Is there a program to minimize freshwater usage, such as daily announcements?

(13) Are low-flow shower heads installed and in good operating condition?

(14) Are faucets in heads spring-loaded or of the metering type, and in good operating condition?

(15) Does your ship minimize freshwater leaks throughout ship (laundry, showers, and galley)?

(16) Is there a program to promote electric load reduction?

(17) Does your ship secure electrical/electronic equipment when not required to meet the ship's operational requirements?

(18) Is the minimum number of ship service generators operated when the total electrical load is below 90 percent rated capacity of the generators in operation?

(19) Is the minimum number of A/C units operated when conditions permit?

(20) Are lights turned off in unmanned spaces?

(21) Does your ship adjust liquid load for slight trim by bow prior to getting underway, and does the engineering department assure maintenance of trim by the bow (DDGs, CGs, and FFGs only)?

(22) Is fuel and water usage documented for trend analysis?

(23) Is fuel and water usage published in the POD?

(24) Does the ship utilize shore services: Electric power? Water? Does the ship minimize electrical usage while on shore power, particularly during times of local utility peak power demands?

(25) Are the freshwater risers topside locked while not in use?

(26) Does the ship maintain a daily Fuel Oil and Water Report that is accessible to key personnel?

(27) Do you strategically plan aircraft usage to ensure that minimal freshwater wash downs of aircrafts are required?

(28) Do you use the "SUNBURST" door program which limits access to the weather decks, thus keeping internal temperatures cooler and reducing the formation of condensation?

(29) Do you use electronic filing and messaging as much as possible to reduce paper and ink consumption and printer/copier power usage?

(30) Has your ship implemented a "Trouble Call Program" where ship's force can call a Trouble Call number to identify and report equipment and material issues so they can be repaired? Do energy efficiency related trouble calls receive the highest priority with same day repairs?

(31) Do you use bleed air starts for normal operation on GTGs and GTMs in order to reduce the run time for the on-line High Pressure Air Compressor?

(32) Are drills utilizing common systems combined whenever possible (e.g., Damage Control drills and Command Systems Training Team scenarios)?

(33) Is diesel engine wear minimized by conducting 1-hour carbon burn off for every 4 hours of light loading?

(34) Are open loop and split loop chill water alignment used?

(35) Are bleed air starts used to reduce run time/energy for High Pressure Air Compressor (HPAC)?

(36) Are casualties combined with same controlling action?

(37) Are DC drills combined with CSTT scenarios?

i. **Engineering Plant Maintenance**

(1) Are Gas Turbine Water Washes conducted based on condition?

(2) Are intake and exhaust systems for Gas Turbine Engines (GTEs) properly maintained to design conditions?

(3) Are diesel engine fuel injectors properly maintained?

(4) Are all gears and shaft bearings properly lubricated and maintained?

(5) Is lagging and piping insulation maintained in good condition?

(6) Does your ship have personnel trained and certified in gauge calibration?

(7) Are all gauges critical to plant performance properly calibrated?

(8) Does the engineering department have a valve maintenance program?

(9) Are A/C boundary doors in good condition and identified with posted signs?

(10) Are light fixtures cleaned and well maintained?

(11) Do you have a Propulsion Load Management Unit (PLMU) that enables main propulsion diesel engines to operate at their most efficient level by adjusting the throttle position to match the load?

(12) Do you periodically check systems for air leaks?

(13) Do you conduct infrared grooming of all electrical controllers and switchboards to minimize needless power loss through heat loss on loose contacts and cable connections?

(14) Do you conduct regular condenser and Fan Coil Unit cleanings to improve chill water flow through the A/C system to increase its efficiency and reduce energy usage?

(15) Are GT Intake Agglomerators cleaned?

j. **<u>Shore Power ENCON</u>**

(1) Do you follow all actions relating to shore power/water usage listed under items h. and i. above while in port?

(2) Does your CO make all-hands announcements to be energy conscious while using electricity and water when in port?

(3) Do you include shore power energy savings accomplished in your SECNAV Annual iENCON Award submittal?

(4) Are there spaces not normally manned in port where the lighting and ventilation can be turned off?

(5) Can you use embedded training devices [such as AEGIS Combat Training Systems (ACTS), Onboard Trainer (OBT), Training In-port Watchstander Simulator (TWIS), or Training Imbedded Work Station (TIWS)] while pier-side to conduct Combat System training scenarios without being required to be underway?

(6) While in port, can you prepare all food in the main galley, and secure all other galleys (such as the wardroom galley and Chief's Mess galley) and ancillary scullery equipment not needed?

(7) Can red lighting be used at night and in port to further reduce the lighting load on the electric plant?

(8) Does your ship know what the average in-port energy usage baseline is for your class of ship?

APPENDIX B
SECAT TOOL

B.1 SECAT TOOL OVERVIEW.

NAVSEA developed the Ship Energy Conservation Assist Training (SECAT) Tool to enable fossil-fueled U.S. Navy surface ships to independently generate fuel consumption curves and fuel requirements specific to their vessel's particulars. The SECAT Tool is comprised of two interrelated programs: fuel curve development and Optimum Ship Transit Planning (OSTP). The objective of this tool is to encourage ships to self-monitor their fuel consumption and develop their own ship-specific fuel consumption curves, which are then used to make smart, energy efficient transit planning decisions including optimum plant alignment, transit speed, and fuel replenishment requirements and scheduling. The most recent complete tool package instructions are provided on the iENCON website (www.i-encon.com) and can be requested on a CD or via email. This tool is applicable for all steam turbine, gas turbine, and diesel engine powered ships.

B.2 SECAT TOOL USER GUIDE.

This appendix provides a step-by-step user guide for the SECAT Tool with screenshots to help familiarize the user with the tool.

B.2.1 Computer Requirements to Run Tool. The SECAT Tool was developed using Microsoft Excel; it should be compatible with any government laptop onboard a ship or pier-side as long as Microsoft Excel is installed. An internet connection is not required to run the tool.

B.2.2 SECAT Tool Setup. When the tool is first extracted from a SECAT CD, it may be in a zipped format. After saving the zipped folder to a local folder on the computer, the user must first "unzip" the tool in order for it to function properly. The process for unzipping a folder will vary slightly depending on the software installed on the computer. It is recommended to delete the zipped folder from the computer so that the user does not unintentionally use the tool contained in the zipped folder, as it will not function properly. Alternately, the software may be obtained via email in an unzipped ready-for-use format.

B.2.3 SECAT Tool Structure. Once the SECAT Tool has been properly unzipped, the folder can be opened and should appear as shown on figure B-1. The tool contains the following folders which will be discussed in more detail later in this appendix:

a. **BOSC XL Version 1.2 (*Date*)** – This is the additional tool provided with the SECAT Tool, which will be discussed in Appendix D. The date in the folder name is the date the tool was last modified.

b. **SECAT XL Version 1.3 (*Date*) - BLANK** – This folder contains an unpopulated (blank) version of the SECAT Tool which can be used by any ship at any time. This version is ideal for a ship that is prepared to gather and record fuel consumption data to develop a ship-specific set of fuel curves to accurately predict instantaneous fuel consumption as well as transit fuel consumption using OSTP. This folder also contains the trial data and fuel nomograms for all ship classes for which the data is currently available.

c. **SECAT XL Version 1.3 (*Date*) - SHIP CLASS** – This folder contains prepopulated versions of SECAT for each available ship class based on class trial data. This version is ideal for a ship looking for a quick estimate of their instantaneous fuel consumption as well as transit fuel consumption using OSTP; however, it should be noted that these may not be as accurate as fuel data recorded by each ship. These versions have been slightly modified from the "blank" version for each ship class; however, the instructions throughout this entire appendix generally still apply to these versions of SECAT.

NOTE

When the SECAT Tool is first opened, it will ask the user for a password. Open the file as "read-only." The SECAT Tool contains an abundance of imbedded equations and data; in order to eliminate the risk of unintentionally altering the imbedded equations and data and corrupting the tool, a password to modify has been added. Once the user opens the file as "read-only," they can then save a new copy of the file to their computer, leaving the original file intact to be used again in the future.

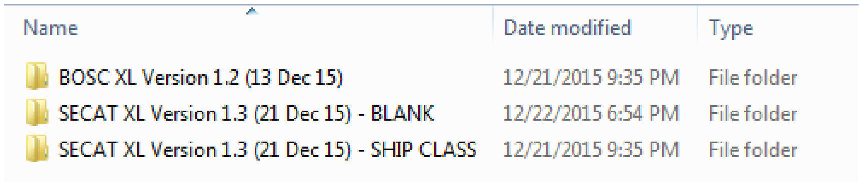


Figure B-1. SECAT Tool Folder Structure Screenshot.

B.2.4 Navigating the Tool. The SECAT Tool is meant to be extremely user friendly and easy to navigate. The tool is set up across multiple tabs in Excel, and is organized to start on the leftmost tab and end on the rightmost tab. The tool is also set up with internal hyperlinks so that the user does not have to scroll through the tool searching for help instructions, data entry forms, etc.

B.2.4.1 Using the Excel Tabs for Navigation. Figure B-2 provides a screenshot of the homepage of the SECAT Tool. Across the bottom are eight tabs: Instructions, Agenda, Trip Particulars, Nomograms, Fuel Consumption Data, GPH vs. Knots, GPNM vs. Knots, and OSTP. Each of these tabs will be discussed in more detail later in this Appendix. For now, it should be noted that these tabs are the primary method for navigating through the SECAT Tool. The user will start from the leftmost tab and work their way right, ending on the OSTP tab.

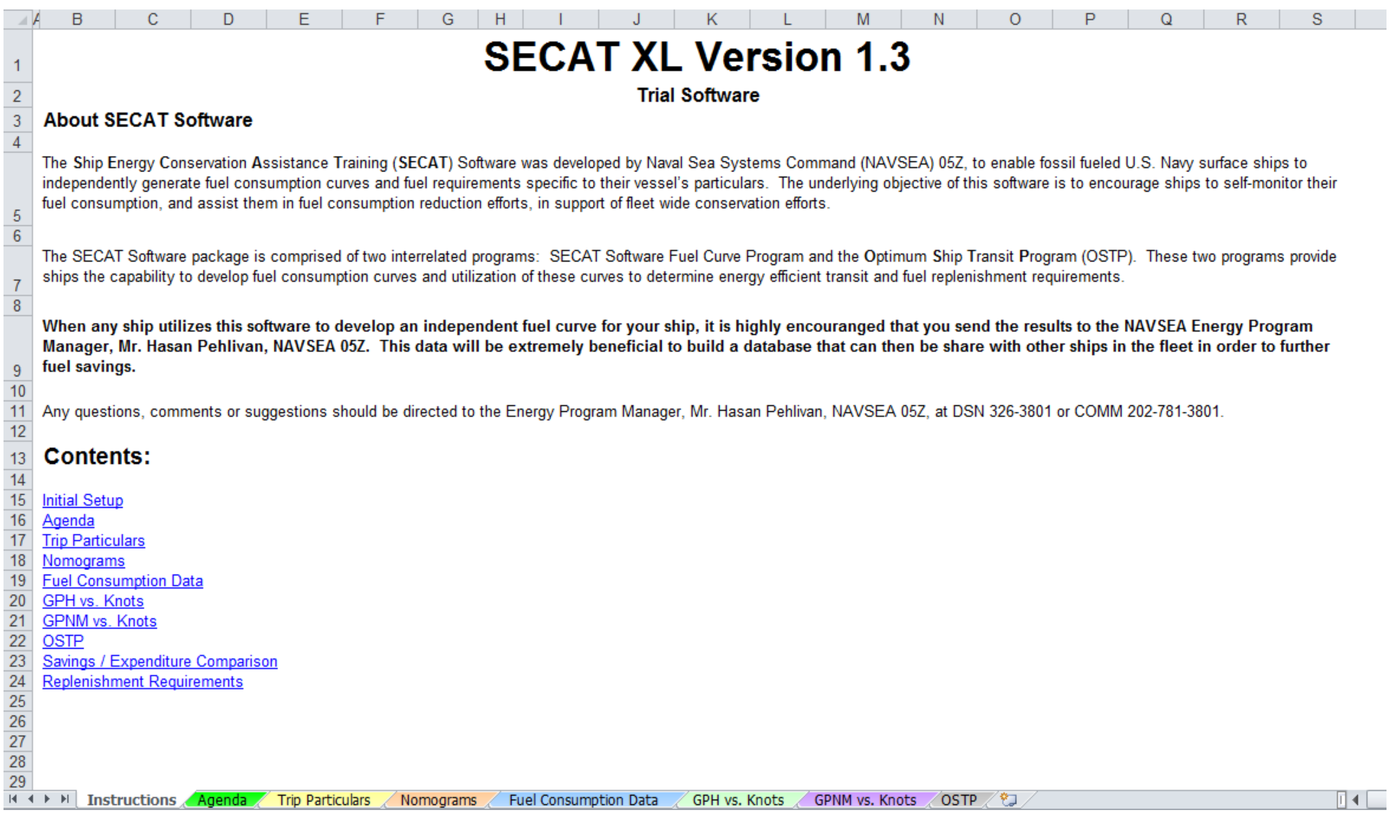


Figure B-2. SECAT Tool Homepage Screenshot.

B.2.5 <u>Using the Tool</u>. After the SECAT Tool has been properly downloaded to the computer, unzipped, and the user is familiar with the structure, homepage, and how to navigate the tool via the eight tabs located at the bottom of the Excel spreadsheet, the user is ready to begin utilizing the tool to develop fuel curves, determine optimum transit speeds, and determine useful transit planning information for making smart, energy efficient decisions.

B.2.5.1 <u>Instructions Tab</u>. The Instructions tab (see figure B-2) contains a Table of Contents with hyperlinks that provides the user supplemental instructions and information pertaining to each tab and subsection of the SECAT Tool. It is optional, though recommended, that the user read through each of these sections prior to using the tool. When the user clicks on one of the items in the Table of Contents, it will bring the user directly to the location to view the instructions. For example, if the user clicks "Trip Particulars," the screen should appear as shown in figure B-3, providing additional information and instructions on how to use the Trip Particulars tab in the tool. At the end of the instructions, the user has two options: Back to Software or Back to Table of Contents. If the user selects Back to Software, the hyperlink will bring the user to the location in the tool pertaining to the instructions. In this example, it would bring the user to the Trip Particulars tab. If the user selects Back to Table of Contents, it will bring them back to the homepage screen where they can then select a different topic to read about, or move on to the Agenda tab in the tool.

NOTE

If at any time while using the tool the user needs to find the instructions, rather than navigating back to the Instructions tab and clicking on the appropriate Contents hyperlink, the user will find a grey box at the top right corner of each tab labeled "Need Help?" This will automatically send the user to the appropriate location in the Instructions tab.

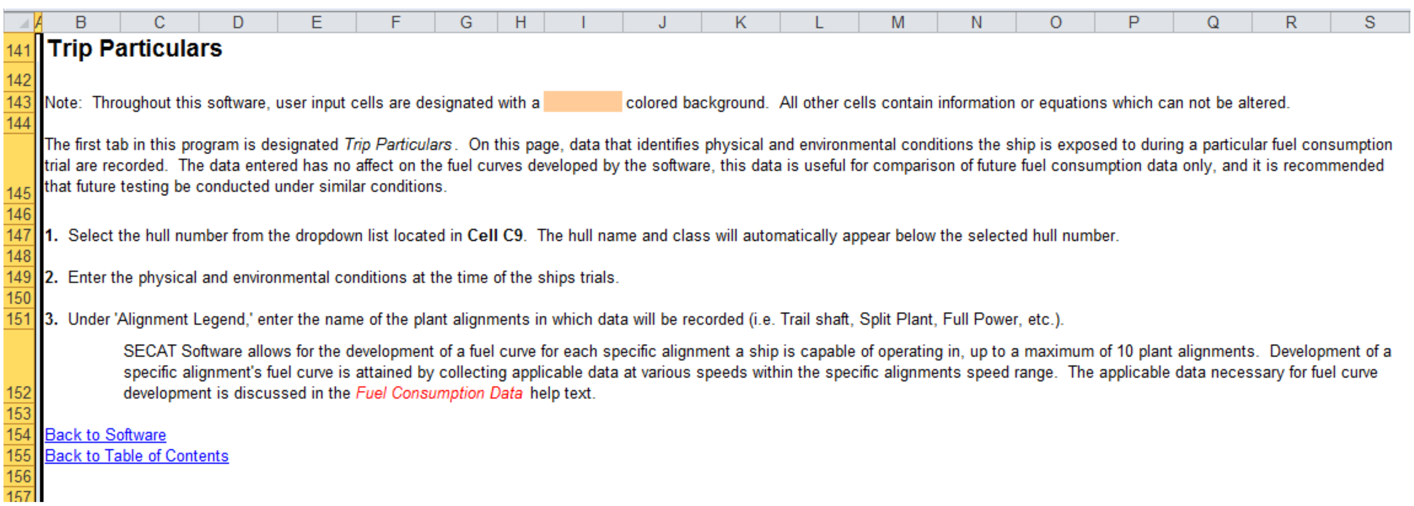


Figure B-3. Trip Particulars Instructions Screenshot.

B.2.5.2 <u>Agenda Tab</u>. The Agenda tab provides instructions on how to plan and execute speed runs to obtain all the information necessary to develop fuel curves for the ship. It provides information on how to prepare for the speed runs, example plant alignments, speeds, time per run to reach steady state operations, and additional recommendations once the data is collected. It is highly recommended that the Agenda be read by the user before executing any speed runs for collecting fuel consumption data.

B.2.5.3 <u>Trip Particulars Tab – Overview</u>. The Trip Particulars tab is the first tab that requires user input. The remainder of the tool is set up so that all the peach-colored cells require user input, and all the blue cells are automatically calculated or generated by the tool. The data provided on the Trip Particulars tab is used as a reference only – the data entered on this tab will not affect the ship fuel curves developed by the tool. The purpose of this data is to record some of the environmental (i.e., wave height, air and sea temperature) and ship conditions (i.e., displacement, electric load, time since last hull cleaning) so that, in the future when the ship is revisiting its fuel curves in order to estimate their current fuel consumption rate, they will know whether the previously developed fuel curves were developed under similar conditions. In the event that the environmental and ship conditions are drastically different from when the fuel curves were developed, then the curves may not provide for the most accurate estimate of the ship's fuel consumption with its current environmental and ship conditions. It is therefore recommended that ships develop multiple sets of fuel curves based on different environmental and ship conditions, such as arctic temperatures vs. tropical temperatures, light displacement vs. full load displacement, or clean hull and propeller vs. dirty hull and propeller, so they have several baselines to compare to when estimating fuel consumption. Figure B-4 provides a screenshot of the Trip Particulars tab.

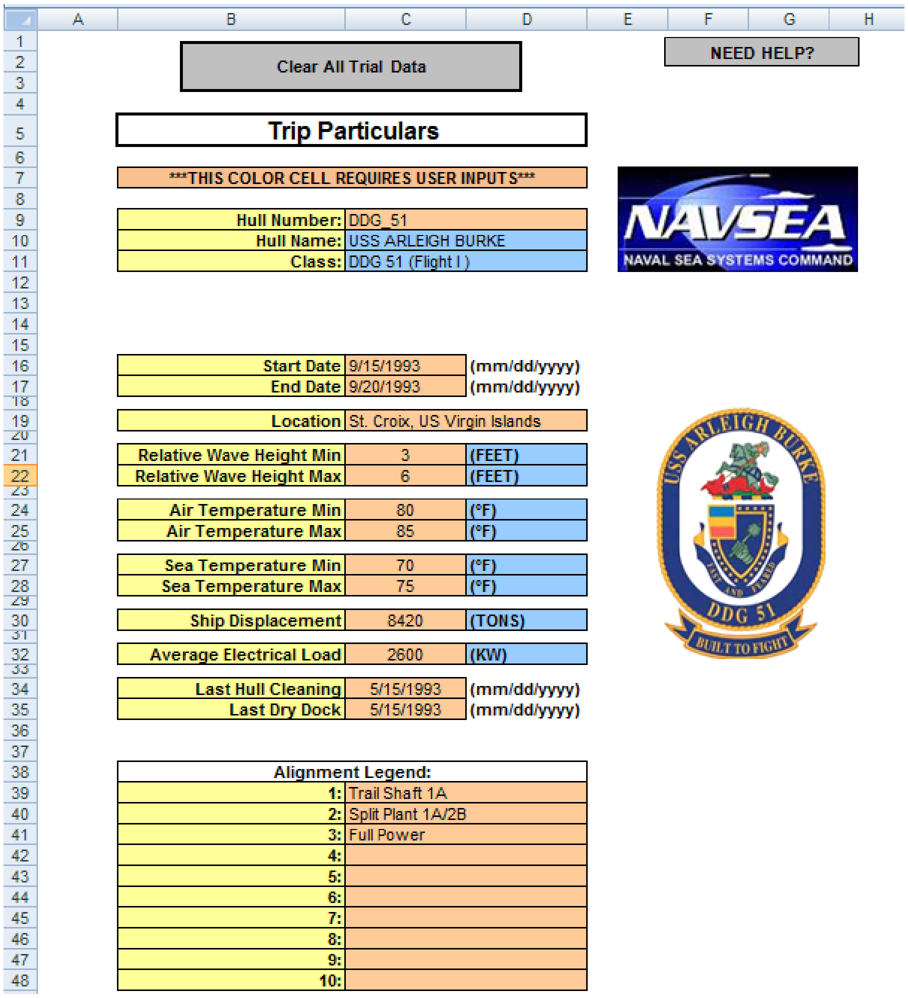


Figure B-4. Trip Particulars Tab Screenshot.

B.2.5.3.1 Trip Particulars Tab – Data Entry. The following information should be entered into the Trip Particulars tab:

a. **Hull Number** – After selecting the peach-colored cell to the right of Hull Number, a dropdown icon will appear on the right hand side of the cell. Click on this icon and then select the ship's Hull Number. After the Hull Number is selected, the Hull Name and Class will appear just below the Hull Number, and the ship's Coat of Arms will appear on the right side of the data form.

b. **Start Date** – Start date when the ship began recording fuel consumption data.

c. **End Date** – End date when the ship finished recording fuel consumption data.

d. **Location** – Location where the fuel consumption data was recorded.

e. **Relative Wave Height Min/Max** – Minimum and maximum wave height to indicate sea state during the period the ship was collecting fuel consumption data.

f. **Air Temperature Min/Max –** Minimum and maximum air temperature during the period the ship was collecting fuel consumption data.

g. **Sea Temperature Min/Max –** Minimum and maximum seawater temperature during the period the ship was collecting fuel consumption data.

h. **Ship Displacement** – The tool contains default ship displacement values once the user selects a ship. If known, it is recommended that the user update this displacement value to reflect the actual displacement of the ship during the period the data was collected.

i. **Average Electric Load –** This value can be used in conjunction with the nomograms to determine the fuel consumption of the generators if FOMs are not installed on the ship.

j. **Last Hull Cleaning –** Date of last hull cleaning (will help indicate whether the ship has a clean or dirty hull).

k. **Last Dry Dock –** Date of the last dry dock.

l. **Alignment Legend –** The SECAT Tool is set up to allow up to ten plant alignments. For the case of a DDG or CG for example, there are up to nine possible plant alignments: four trail shaft alignments, four split plant alignments, and one full power alignment. It is recommended that the engine number be included in the name of trail shaft or split plant alignments so that the user knows which engines were online for those fuel curves. For example, if a DDG is recording trail shaft data using the 1A gas turbine, the alignment title should be labeled "Trail Shaft 1A" (see figure B-4).

B.2.5.4 Nomograms Tab. The Nomograms tab contains links to the available nomograms for most ship classes. For the ship specific SECAT forms, the nomogram(s) have been provided directly within the tool, if available. Nomograms are used to determine the fuel consumption of boilers and generators when Fuel Oil Meters (FOMs) are not installed. For diesel and gas turbine generators, nomograms plot electric load (kW) vs. fuel rate (GPH) in order to determine the generator's fuel consumption. For steam turbine generators, boiler nomograms are used to convert burner fuel pressure (PSIG) into fuel flow rate (GPH). These nomograms are based on the boiler's sprayer plate capacity curves. All available nomograms can also be found in Appendix C of this Guide.

B.2.5.5 Fuel Consumption Data Tab – Overview. The Fuel Consumption Data tab is where the user records the necessary information to develop fuel curves, i.e., ship speed and fuel consumption rates. This tab also provides data entry for propeller RPM and pitch. Though not required for the tool to develop curves, propeller RPM and pitch are recommended to be recorded so that this information is readily available when referencing the fuel curves in the future. Figure B-5 provides a screen shot of the Fuel Consumption Data tab for one plant alignment. This tab is set up with a total of ten data entry tables, one for each of the plant alignments specified on the Trip Particulars tab alignment legend. For each alignment, the user can enter up to 15 data points (i.e., 15 speeds). The minimum number of data points necessary to create a fuel curve is three; however, it is highly recommended that a minimum of five to eight data points throughout the entire speed range for the given alignment be used to improve accuracy. If time is limited and less than five data points are obtained, the user should be aware that the accuracy of the fuel curve will be reduced and could result in noticeable differences between the actual and predicted fuel rates.

	A	B	C	D	E	F	G	H	I
1	**Enter Fuel Consumption Data**								
2									
3	**Alignment 1: Trail Shaft 1A, Data**								
4	**Trial #**	**SPEED**	**PRPM**	**PITCH**	**GEN GPH**	**ME GPH**	**BLR GPH**	**TOT GPH**	**GPNM**
5	**1**	8	36	70	380	274.4		654	82
6	**2**	10	43	70	380	303.8		684	68
7	**3**	12	52	70	380	368.6		749	62
8	**4**	15	66	70	380	533.5		914	61
9	**5**	18	79	70	380	748.8		1129	63
10	**6**	20	89	70	380	940.8		1321	66
11	**7**								
12	**8**								
13	**9**								
14	**10**								
15	**11**								
16	**12**								
17	**13**								
18	**14**								
19	**15**								
20									
21	Fuel Curve **Min** (knots):		8		**Optimum Speed [knots]:**			15.5	
22	Fuel Curve **Max** (knots):		20		**Optimum GPNM:**			59.1	
23	(Default = Raw Data Min/Max)								

Figure B-5. Fuel Consumption Data Tab Screenshot.

B.2.5.5.1 Fuel Consumption Data Tab – Data Entry. The following information should be entered into the Fuel Consumption Data tab:

a. **Speed** – A repeatable speed, such as speed through the water measured with a Doppler type speed log or the RPM/speed relationship on fixed pitch propeller ships, should be recorded. Speed over ground is not recommended for fuel curve development since it does not account for the effects of water current speed and direction.

b. **PRPM** – Propeller RPM.

c. **Pitch** – For CPPs, the pitch should be recorded for each speed point.

d. **GEN GPH** – Generator fuel consumption rate. This value can either be found from the FOMs, or by plotting the electric load on the nomograms provided in the SECAT Tool and Appendix C. For steam ships, this column is not applicable and can be left blank.

e. **ME GPH** – Main engine fuel consumption rate. The fuel consumption rate at each speed should be recorded when the reading appears relatively stable. If the rate appears to be fluctuating slightly, the average between maximum and minimum should be recorded. Large fuel rate fluctuations are an indication that the plant has not stabilized and additional time at that speed is necessary. For steam ships, this column is not applicable and can be left blank.

f. **BLR GPH** – Boiler fuel consumption rate. Similar to the main engine fuel consumption rate above, the boiler fuel consumption rate should only be recorded once the reading appears relatively stable. The boiler fuel consumption rate can be found utilizing the nomograms provided in the SECAT Tool and Appendix C. For diesel and gas turbine ships, this column is not applicable and can be left blank, unless the ship still utilizes an auxiliary boiler, in which case its fuel consumption can be entered in this column.

g. **Fuel Curve Min/Max (knots)** – The SECAT Tool default setting is to plot fuel consumption curves between the minimum and maximum speed entered in the table for each plant alignment. In the event that the ship was not able to collect data across the entire speed range of the plant alignment, the tool provides the user the opportunity to extrapolate the fuel curve below the minimum recorded speed data, or above the maximum recorded speed data. In order to use this feature, the user overrides the value in these cells and the tool will plot the curves based on the new minimum and/or maximum speed.

NOTE

This extrapolation feature should be used with extreme caution. The data extrapolated beyond the original minimum or maximum loses accuracy quickly, and should only be used for rough approximations. Therefore, the use of this function should be limited to extrapolating only one to two knots above/below the original maximum and minimum speeds, respectively. It is instead recommended that the ship perform additional speed runs when time becomes available in order to validate the fuel consumption at those speeds, rather than using the extrapolation feature.

B.2.5.5.2 Fuel Consumption Data Tab – Calculations. For each speed run, the tool will calculate the total fuel consumption in GPH and GPNM. The total GPH is simply the sum of the generator, main engine, and boiler fuel consumption. The GPNM for each speed is the total fuel consumption (GPH) divided by the speed. This fuel consumption value is used to determine the optimum transit speed for each alignment. The optimum transit speed is the speed at which the least amount of gallons are burned per nautical mile travelled, and, thus, the most efficient transit speed for that alignment. The optimum transit speed and corresponding GPNM fuel consumption is automatically calculated and provided below each data table (see figure B-5) for each plant alignment.

B.2.5.6 GPH vs. Knots Tab – Overview. Once all the necessary data has been entered into the Trip Particulars tab and the Fuel Consumption Data tab, the SECAT Tool has already developed the ship's total fuel consumption in GPH vs. the ship speed curve for each alignment identified in the alignment legend, shown in figure B-6.

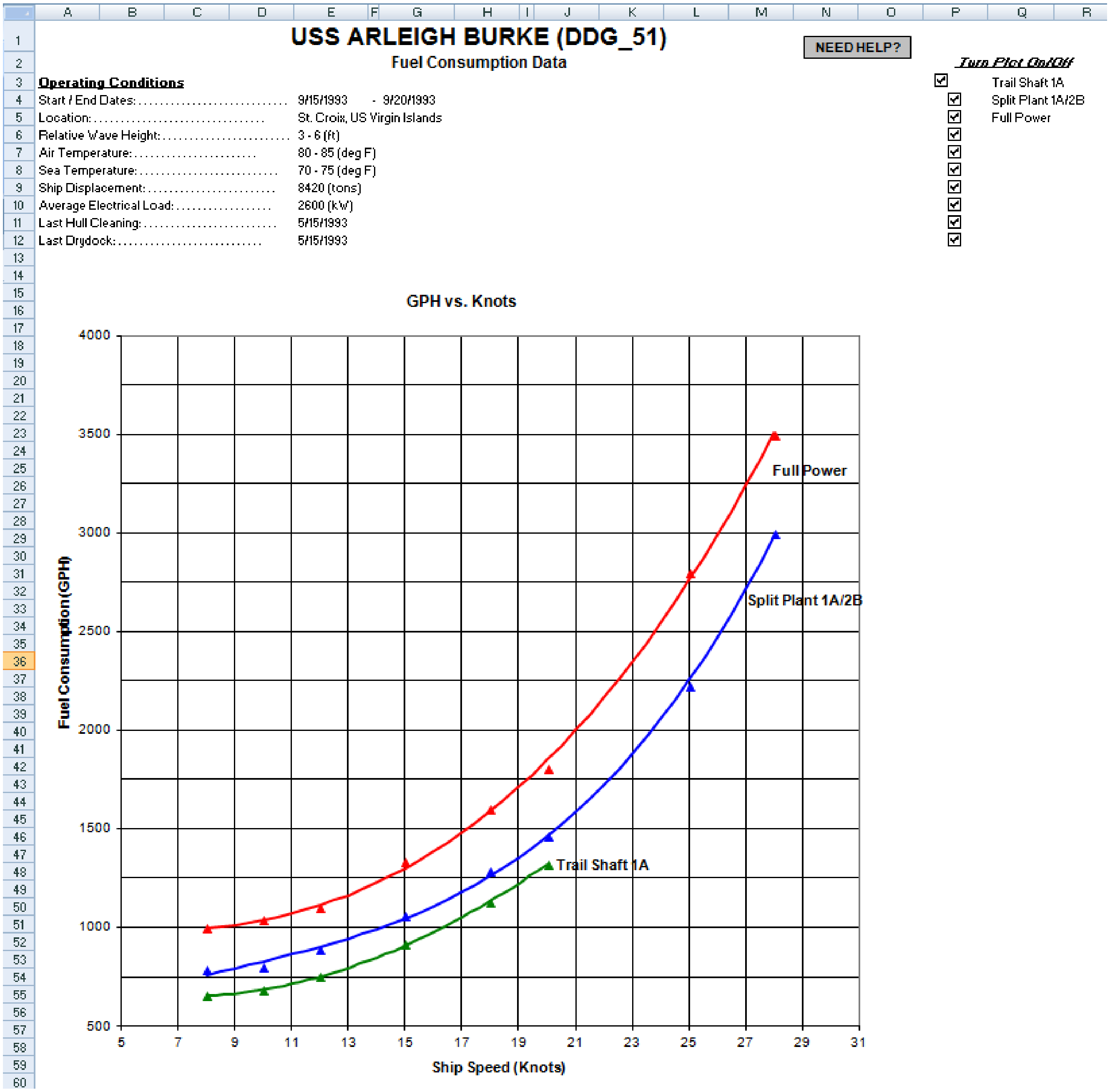


Figure B-6. GPH vs. Knots Tab Screenshot.

B.2.5.6.1 GPH vs. Knots Tab – Plot Features. There are several key features to discuss in regards to modifying and interpreting the fuel consumption curves.

a. **Adjusting x- or y-axis** – Just like any typical Microsoft Excel chart, the user has the ability to modify the x- or y-axis minimum and maximum values, and unit step values to adjust the curve as to their own preference.

b. **Using the trend line to interpret fuel rate** – In Microsoft Excel, the user can click anywhere on the chart area to access the plot and then move the cursor to a point along the trend lines. A little box will then appear next to the cursor which will provide a speed and corresponding fuel rate for that alignment. This is useful if the user is trying to determine the fuel consumption rate at one particular speed and alignment.

c. **Using the original data to determine trend line accuracy –** The triangular data points on the plot represent the data entered on the Fuel Consumption Data tab. It is important that the majority of the data points line up on or near the trend line. The closer the data points are to the trend line, the more accurate the fuel curve will be. If the data points are scattered significantly, then the data should be rerun in order to have an accurate fuel curve. Inconsistent and scattered data is likely a result of any combination of the following: time spent at each speed was too short to reach steady state, change in plant alignment, equipment deficiency, changing environmental factors, etc.

d. **Turning plots on and off –** Another feature of the tool provides the user the ability to “hide” various plant alignment curves on the chart. This is beneficial when there are multiple curves with extremely similar fuel consumption curves (i.e., plotting all four trail shaft alignments on the same chart) so that the user can interpret data effectively, and only view the plant alignments they are most interested in. In the top right corner of the tab, there are ten checkboxes – one for each of the ten possible plant alignments. By un-checking the box next to any of the plant alignments, that fuel curve will be hidden from the chart.

e. **Printing and posting fuel curves –** The tool has already been formatted to provide the trip particular information and the fuel chart on a single piece of paper. The user can simply go to file > print and make several copies of the fuel curves to post in the bridge, at the engineering control console(s), and anywhere else deemed necessary to assist key personnel in maintaining efficient plant operation.

B.2.5.6.2 GPH vs. Knots Tab – Utilizing the Fuel Curves. Developing and maintaining fuel curves has more benefits than just estimating the ship’s total fuel consumption at one speed for one alignment. It provides a powerful analysis tool to do the following:

a. Alert operators to adverse trends in plant performance.

b. Identify performance differences in major components (e.g., diesels, gas turbines, boilers, etc.).

c. Determine the effects of different machinery alignments.

d. Determine the effects of varying environmental conditions, including sea and air temperatures and sea state.

e. Determine the effects of varying ship conditions including displacement, electric load, change in plant alignments, and hull fouling.

f. Provide a baseline to assure that the most energy efficient machinery alignment is being used.

B.2.5.7 GPNM vs. Knots Tab – Overview. The next tab in the SECAT Tool plots the ship’s total fuel consumption in GPNM vs. ship speed. These curves are developed by dividing the fuel consumption in GPH by the ship speed. This typically causes the GPNM fuel consumption curves to take on a “bathtub curve” shape, as shown in figure B-7.

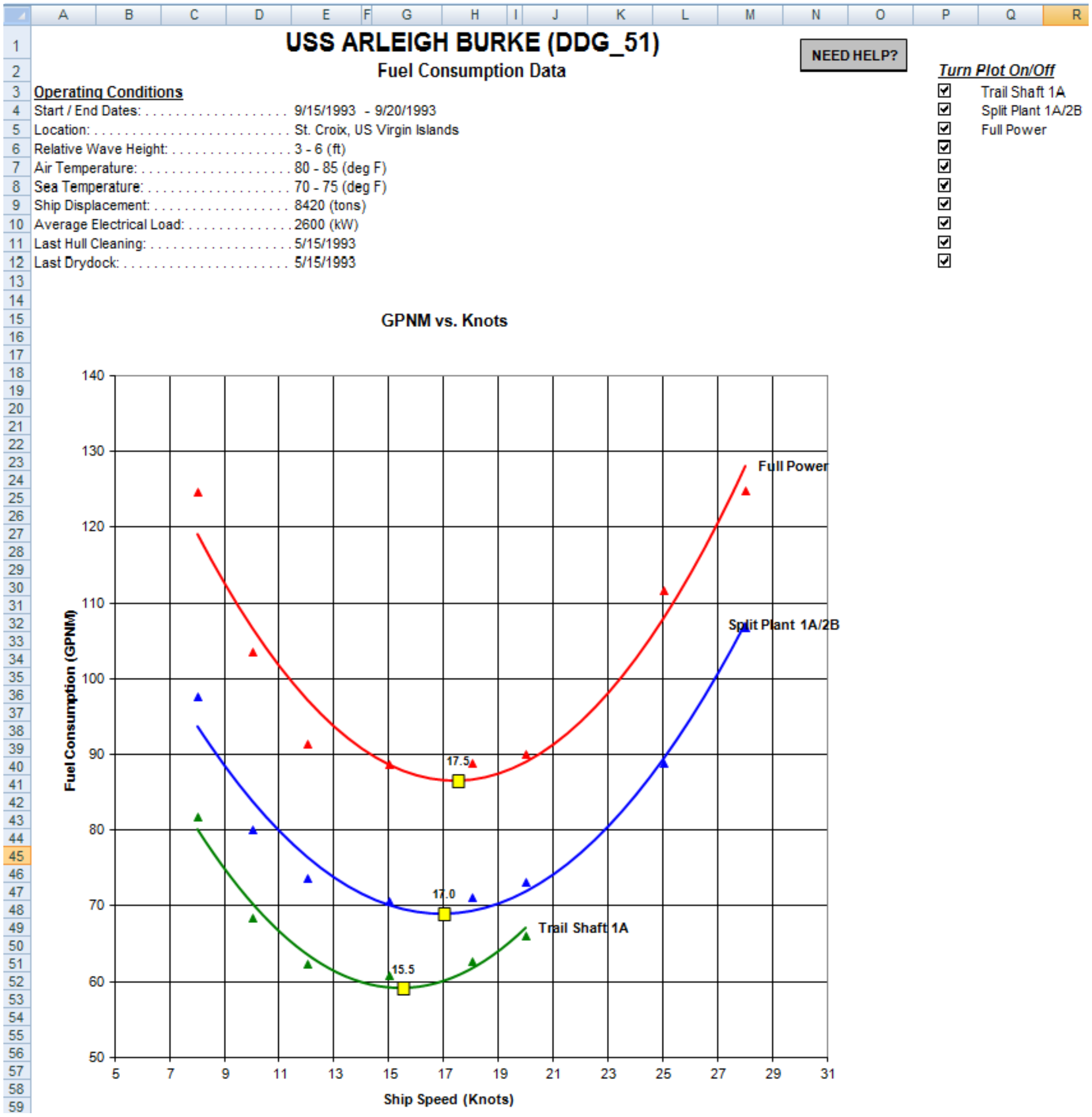


Figure B-7. GPNM vs. Knots Tab Screenshot.

B.2.5.7.1 <u>GPNM vs. Knots Tab – Plot Features</u>. The GPNM vs. Knots fuel consumption chart has all the same features as the GPH vs. Knots fuel consumption chart outlined in B.2.5.6.1.

B.2.5.7.2 <u>GPNM vs. Knots Tab – Utilizing the Fuel Curves</u>. The GPNM vs. Knots fuel consumption chart has all the same benefits as the GPH vs. Knots fuel consumption chart outlined in B.2.5.6.2. In addition to these benefits, the GPNM vs. Knots chart has one additional key benefit. This chart is used to determine the optimum transit speed for each plant alignment, depicted by a yellow square with the corresponding speed labeled for each plant alignment. This represents the speed with the lowest fuel rate, and thus the most efficient transit speed for the ship. This contradicts the belief that slowing down will always save fuel. The reason this statement isn't true is due to the electrical plant fuel consumption. While it is true that the propulsion plant fuel consumption will be reduced by operating the ship at reduced speeds, the generating plant will still burn fuel at the same rate, assuming no change in electrical load. Therefore, if a ship reduces their speed in half for a transit, the electrical plant will consume twice as much fuel to complete that same transit. For speeds below the optimum transit speed, this increase in fuel consumed by the electrical plant during the transit is greater than the decrease in propulsion plant fuel consumption, thus causing the "bathtub curve" effect. Therefore, it is recommended that ships operate as close as possible to their optimum transit speed to save the most fuel.

B.2.5.8 OSTP Tab – Overview. The final tab in the SECAT Tool is the Optimum Ship Transit Planning (OSTP) tab. This tab provides a variety of useful information to review prior to planning a transit. Taking into account proposed transit distance and time, amount of fuel onboard, and cost of fuel, the OSTP tab provides the user with information such as total fuel consumption and monetary costs of the proposed transit, selecting the optimal plant alignment and transit speed, determining the number of necessary replenishments at sea and when they need to be scheduled, the amount of fuel remaining onboard at the end of the transit, and more. OSTP is divided into three main sections: Optimum Ship Transit Results, Savings/Expenditures Comparisons, and Proposed Transit Replenishment Requirements.

NOTE

Macros must be enabled in Excel for the tool to function properly. If the macro security settings are too high, or macros are disabled, the tool will not function properly. As there will be several versions of Microsoft being used, consult the help feature to determine how to enable macros and adjust macro security settings if necessary.

B.2.5.8.1 OSTP Tab – Required Inputs. The OSTP portion of the tool requires only a few user inputs. The inputs required are:

a. **Transit Distance** – The distance, in nautical miles, of the proposed transit.

b. **Transit Speed or Time** – The user has an option of entering either a transit speed or a transit time (in either hours or days). It is important to note that the tool can only accept one input for transit speed or time. If the user tries to input more than one value into any of these cells, a warning measure will pop up directing the user to delete one of the inputs.

c. **Fuel Cost** – Enter the current cost of fuel, per gallon. If the current cost of fuel is not known, the standard fuel price can be found on the Defense Logistics Agency website (www.energy.dla.mil).

d. **Full Load Capacity** – The tool automatically populates this cell with a default full load capacity for each ship class. If the user has a more accurate number for the total capacity of the fuel tanks onboard their ship, they should override the default value in this cell.

e. **Fuel Onboard** – Enter the total gallons of fuel onboard the ship at the beginning of the transit.

f. **Minimum Threshold** – The minimum threshold represents the percentage of fuel onboard when the ship requires replenishment. The default value for this cell is 60 percent; however, the user has the ability to change this value to align with their ship's minimum threshold.

g. **Maximum Threshold** – The maximum threshold represents the percentage of the total fuel tankage volume to fill when replenishment is complete. Ships allow for a 5 percent safety buffer to account for thermal expansion of fuel and to reduce the risk of overflowing tanks during the refilling process. The default maximum threshold is 95 percent; however, the user has the ability to change this threshold value if necessary.

B.2.5.8.2 OSTP Tab – Optimum Ship Transit Results. The first portion of the OSTP tab is the Optimum Ship Transit Results. This section provides a tabular result for each plant alignment including: transit distance, time, and speed, fuel consumption rate in GPH and GPNM, total transit gallons required, projected fuel cost, and the projected fuel remaining on board if no underway replenishments were performed. A second table is also provided which summarizes the optimum transit speed and fuel consumption for each plant alignment. The most important feature of this section of OSTP is its ability to notify the user if there is an alternate plant alignment and transit speed which will save the ship even more fuel during its transit. Earlier in this Appendix it was pointed out that slower isn't always the most fuel-efficient method; in some cases a faster speed can actually save fuel during a transit. This is true anytime the proposed transit requirements entered by the user results in a transit speed which is less than the optimum transit speed. Refer to figure B-8 below for an example. The proposed transit is 2,500 nautical miles at 12 knots. Looking at the table, the user will notice the first row is highlighted green, which indicates a higher speed will consume less fuel and require less transit time than the most economical alignment for this transit. The table shows that if the ship were to complete the 2,500-nautical mile transit at 15.5 knots instead of 12 knots, it will burn about 11,000 gallons less fuel and the transit time can be reduced from 8.7 days to 6.7 days. If the tool determines that the ship has the ability to increase the transit speed to reduce fuel, it will indicate the new speed in the table so that the user can recognize the potential for additional fuel savings.

***** YOU MUST ENABLE MACROs FOR THIS SOFTWARE TO WORK!!!*****

Optimum Ship Transit Results

Create Transit Option

Transit Distance	2,500	NM
Enter ONE of the Following:		
Enter Transit Speed	12.0	Knots
OR Transit Time		Hours
OR Transit Time		Days

Hull	DDG_51
Name	USS ARLEIGH BURKE
Class	DDG 51 (Flight I)

Data Collected On:	9/15/1993
Today's Date:	9/7/2012

Speed	12.0	knots
Time	208.3	Hours
	8.7	Days
Fuel Cost	$ 3.81	$/gal
Full Load Capacity	454,252	gallons
Fuel Onboard	400,000	gallons
Fuel Onboard	88%	
Minimum Threshold	60%	
Maximum Threshold	95%	

Distance (NM)	Transit Time Hours	Transit Time Days	Transit Speed (Knots)	Machinery Alignment	GPH	GPNM	Transit Gallons	Projected Fuel Cost	Projected Gallons Remaining Onboard	Projected % Fuel Remaining Onboard
2,500	161.3	6.7	15.5	Trail Shaft 1A Optimal Speed	941.4	59.1	147,873	$563,398	252,127	55.5%
2,500	208.3	8.7	12.0	Trail Shaft 1A	750.4	63.6	159,056	$606,005	240,944	53.0%
2,500	208.3	8.7	12.0	Split Plant 1A/2B	901.7	76.5	191,290	$728,815	208,710	45.9%
2,500	208.3	8.7	12.0	Full Power	1,112.1	97.3	243,344	$927,139	156,656	34.5%

Indicates a higher speed will consume less fuel and require less transit time than the most economic alignment for this transit

Insufficient fuel onboard to complete transit without Replenishme

Optimum Transit Speeds

Alignment	Optimum Transit Speed [Knots]	Optimum GPNM
Trail Shaft 1A	15.5	59.1
Split Plant 1A/2B	17.0	69.0
Full Power	17.5	86.6

Figure B-8. OSTP Tab – Optimum Ship Transit Results Screenshot.

B.2.5.8.3 OSTP Tab – Savings/Expenditures Comparison. The second portion of the OSTP tab is the Savings/Expenditures Comparison. This portion of the graph provides a tabular comparison of the GPH, GPNM, transit gallons saved/expended, and transit cost savings/expended for each plant alignment. Values in black font represent potential fuel or monetary savings, while values in red font represent potential fuel or monetary expenditures required to complete the transit. The user must first select a proposed plant alignment for the transit from the dropdown box next to "Select Configuration." The table will then compare the other plant alignment options to the selected alignment to determine how much fuel can be saved or expended by operating in a different plant alignment. Take figure B-9 as an example. The proposed alignment selected is "Split Plant 1A/2B." Looking at the table, the first thing to notice is that every value is "0" next to Split Plant 1A/2B because that was the selected proposed alignment. Next, compare the Trail Shaft Optimal Speed alignment to the Split Plant 1A/2B alignment. This table shows that operating in trail shaft at 15.5 knots instead of split plant at 12 knots will burn an additional 39.6 GPH, hence the red font. Despite this increase of 39.6 GPH in fuel consumption, this optimal alignment actually has a 17.4 GPNM fuel consumption reduction due to operating at the optimum transit speed. This translates into a fuel savings of approximately 43,400 gallons of fuel at the end of the transit, which can save the ship over $165,000. Conversely, a full plant alignment instead of split plant would cost the ship an additional 52,000 gallons of fuel at a value of over $198,000 to complete the same transit. This table alone provides a very powerful tool to display how much fuel and money can be saved simply by selecting the most efficient plant alignment and transit speed.

Savings / Expenditures Comparison

NEED HELP?

Select Configuration: Split Plant 1A/2B

Plant Configuration	Speed	GPH Saved / Expended	GPNM Saved / Expended	Transit Gallons Saved / Expended	Transit Savings / Expended
Trail Shaft 1A Optimal Speed	15.5	39.6	17.4	43,417	$165,417
Trail Shaft 1A	12.0	151.4	12.9	32,234	$122,810
Split Plant 1A/2B	12.0	0.0	0.0	0	$0
Full Power	12.0	210.4	20.8	52,053	$198,323

Figure B-9. OSTP Tab – Savings/Expenditures Screenshot.

B.2.5.8.4 <u>OSTP Tab – Proposed Transit Replenishment Requirements</u>. The final portion of the OSTP tab is the Proposed Transit Replenishment Requirements. Using the inputs provided by the user at the beginning of OSTP, this portion of the program provides the user with a proposed schedule for when underway replenishments will be required during the transit. Starting with the amount of fuel onboard, the tool calculates how long it takes until the fuel onboard reaches the minimum fuel threshold. At this point, the program indicates that the ship should be replenished, and calculates the amount of fuel the ship needs in order to fill the tanks to the maximum fuel threshold. If more than one replenishment is required during the transit, the tool will list each replenishment along with an approximate number of days and hours into the transit when the replenishment will need to occur. Finally, the tool will also calculate how much fuel should be remaining onboard at the end of the transit provided that the ship followed the proposed transit replenishment schedule. Figure B-10 shows the results for the example used throughout this Appendix. From the tool, it can be determined that for the same 2,500-nautical mile transit, operating in trail shaft at 15.2 knots, the ship can expect to need an underway replenishment on day six of the transit, approximately 139 hours into the transit. On that day, the ship should replenish with 127,450 gallons of fuel. At the end of the transit, the ship will have just over 408,000 gallons of fuel onboard, or 90 percent of the full load capacity. If the ship were to conduct the transit in a full power mode, it would require replenishment on day five and would complete the transit with only 69 percent of the full load capacity. This feature can be extremely useful to a ship when planning a transit and determining when and where they may need to meet with an oiler to conduct a replenishment-at-sea exercise. It is important to note that there are a lot of factors that will affect the fuel consumption during a transit, and the values provided in the OSTP tool are approximate. Changes in weather, electric load, speed changes, etc., can all increase or decrease the fuel consumption, which can then decrease or increase the time between replenishments, respectively. Lastly, the button "Update Replenishment Requirements" must be pushed every time a transit input is changed to ensure the replenishment requirements reflect the proposed transit. A message below the button will remind the user whether the results shown reflect the proposed transit, or whether the user needs to click the button to update the results.

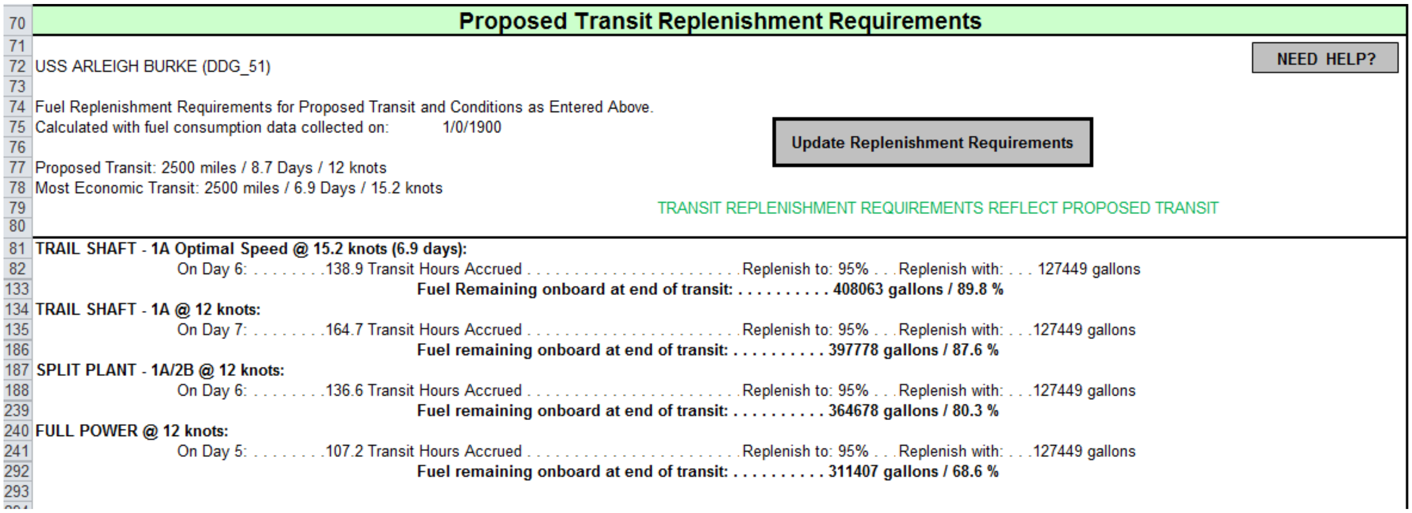


Figure B-10. OSTP Tab – Proposed Transit Replenishment Requirements Screenshot.

B.3 NAVSEA REQUEST FOR SECAT DATA.

In an effort to further expand the usefulness of this tool, NAVSEA requests that any ship that utilizes the SECAT Tool to develop fuel curves send their results to the NAVSEA iENCON Program Manager. This will give NAVSEA the opportunity to compile the data and redistribute to the entire Fleet via frequent updates to the SECAT Tool. This would give the opportunity for ships within a class to share fuel curves and transit results in order to provide more ships the resources necessary to make energy conscious decisions.

APPENDIX C
PLANT ALIGNMENT BOARDS AND NOMOGRAMS

C.1 PURPOSE.

This Appendix includes Plant Alignment Status Boards and Fuel Rate Nomograms for the ship classes listed in table C-1. Ship classes not listed means that the data is not available at this time (i.e., LCS 1, LCS 2, LHD 8, LPD 17, and MCM 1).

Table C-1. Available Data.

Class	Nomogram	Plant Alignment Status Board
CG 47	X	X
DDG 51	X	X
LCC 19	X	
LHA 6	X	
LHD 1	X	X
LSD 41	X	X
LSD 49	X	
PC 1	X	

C.2 USE OF STATUS BOARDS AND NOMOGRAMS.

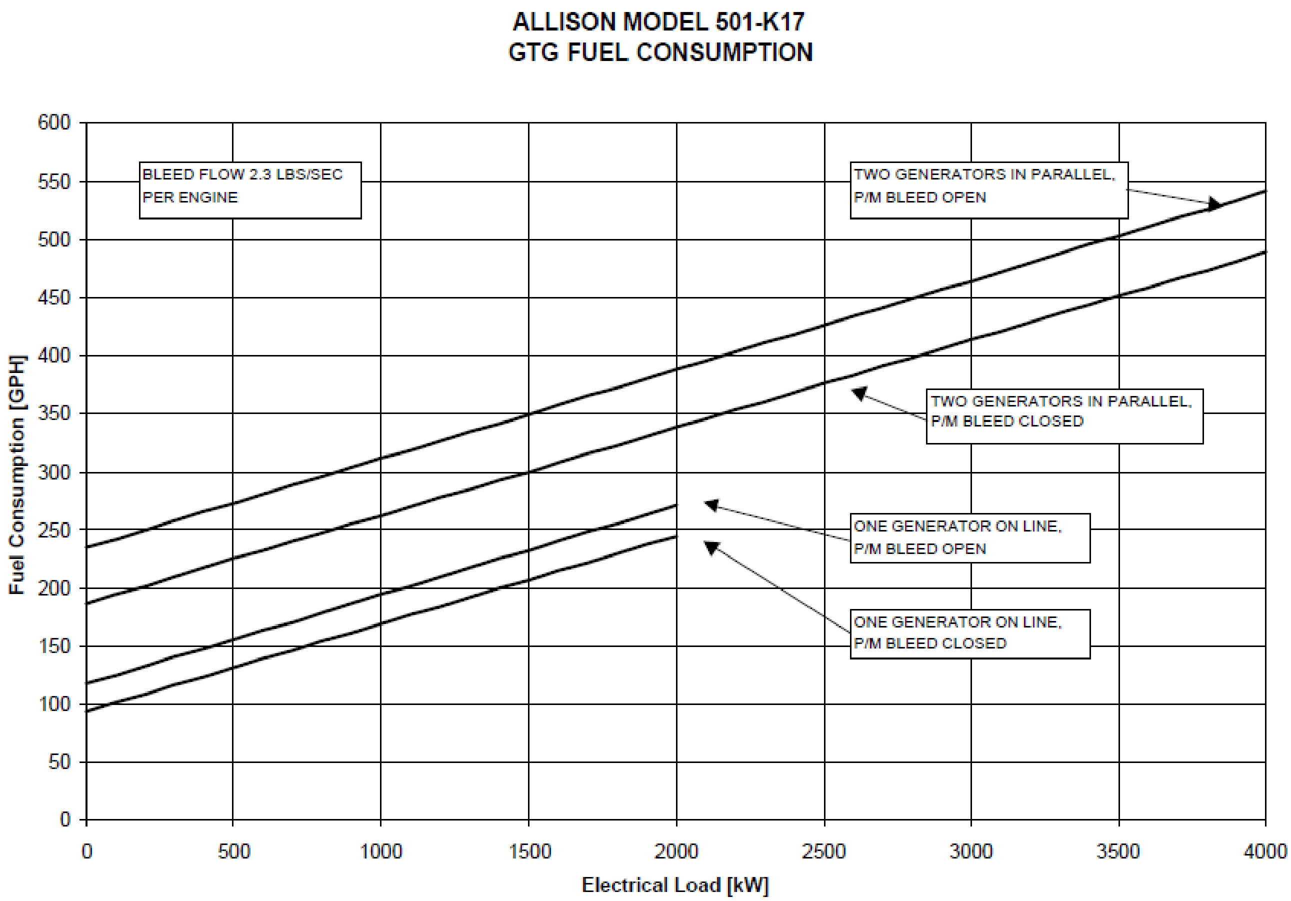
These status boards and nomograms can be used to verify plant alignment and determine fuel consumption as described in Appendix B. Economical alignment recommendations are listed in the far right columns of the Plant Alignment Status Boards. Operation with the recommended economical number of components will result in the greatest fuel savings.

C.3 NEW SHIP CLASSES.

In addition to these Plant Alignment Status Boards and Fuel Rate Nomograms, iENCON also has ship class fuel curves available by request for most ship classes. Trial data has not been made available to the iENCON program to develop fuel consumption curves for the LHD 8 or MCM 1 classes at the time of release of this revision of the Guide.

Equipment	Operating	Economic Alignment	
		Trail Shaft	Full Power
GAS TURBINE - MAIN PROPULSION	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	FOUR
GAS TURBINE - GENERATOR	☐ 1 ☐ 2 ☐ 3	ASRQ	TWO
FIRE PUMP	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	ASRQ	ASRQ
LUBE OIL PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	TWO
F.O. SERVICE PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	TWO
CRP PUMP	☐ 1 ☐ 2	TWO	0
SALT WATER SERVICE PUMP	☐ 1 ☐ 2 ☐ 3	TWO	TWO
AIR CONDITIONING UNIT	☐ 1 ☐ 2 ☐ 3	ASRQ	ASRQ
REFRIGERATION UNIT	☐ 1 ☐ 2	ONE	ONE
LP AIR COMPRESSOR	☐ 1 ☐ 2	ASRQ	ASRQ
HP AIR COMPRESSOR	☐ 1 ☐ 2	ASRQ	ASRQ
DISTILLING PLANT	☐ 1 ☐ 2	ASRQ	ASRQ
STEERING GEAR	☐ 1A ☐ 1B ☐ 2A ☐ 2B	TWO	TWO

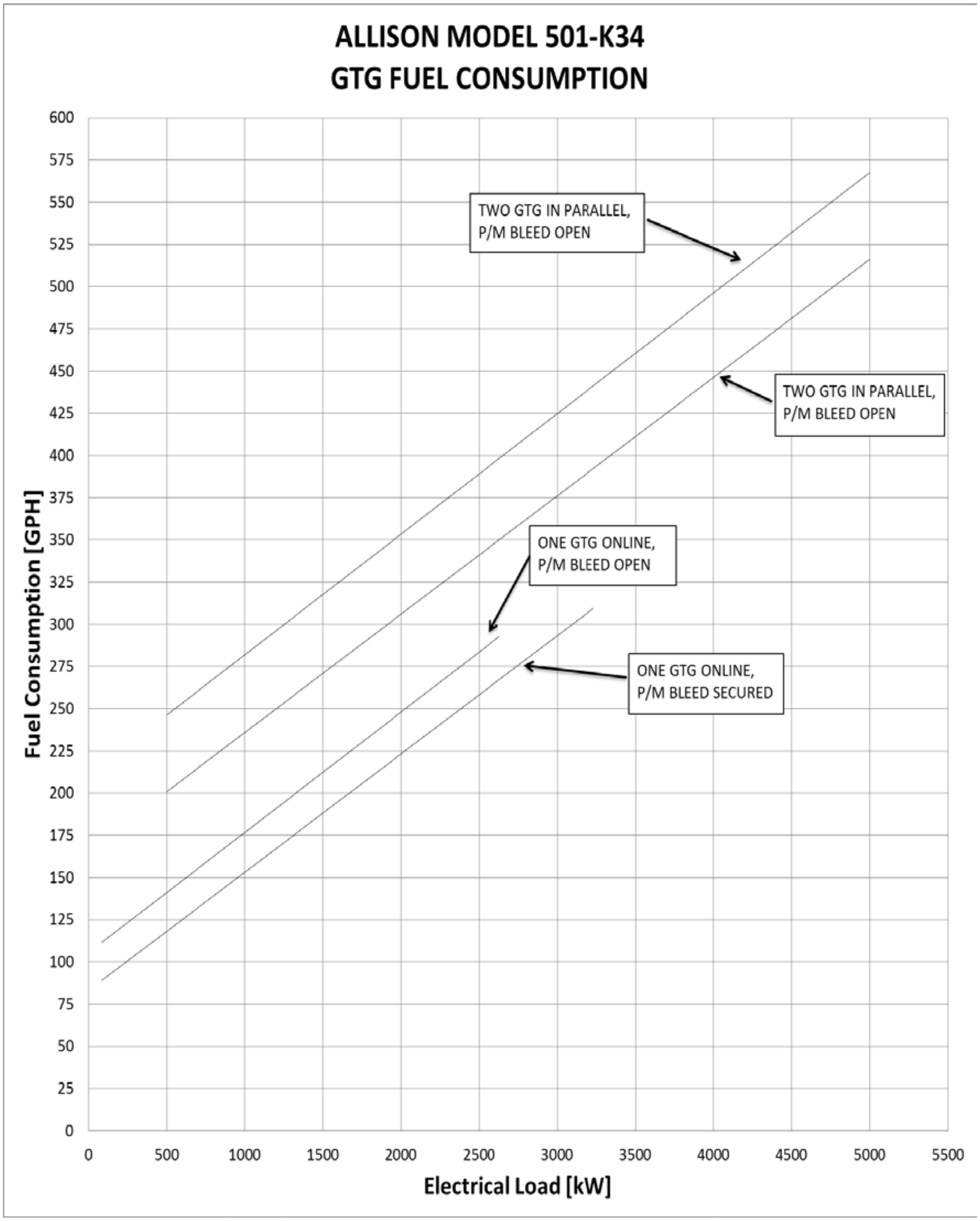
Plant Alignment Status Board 1. CG 47 Class.



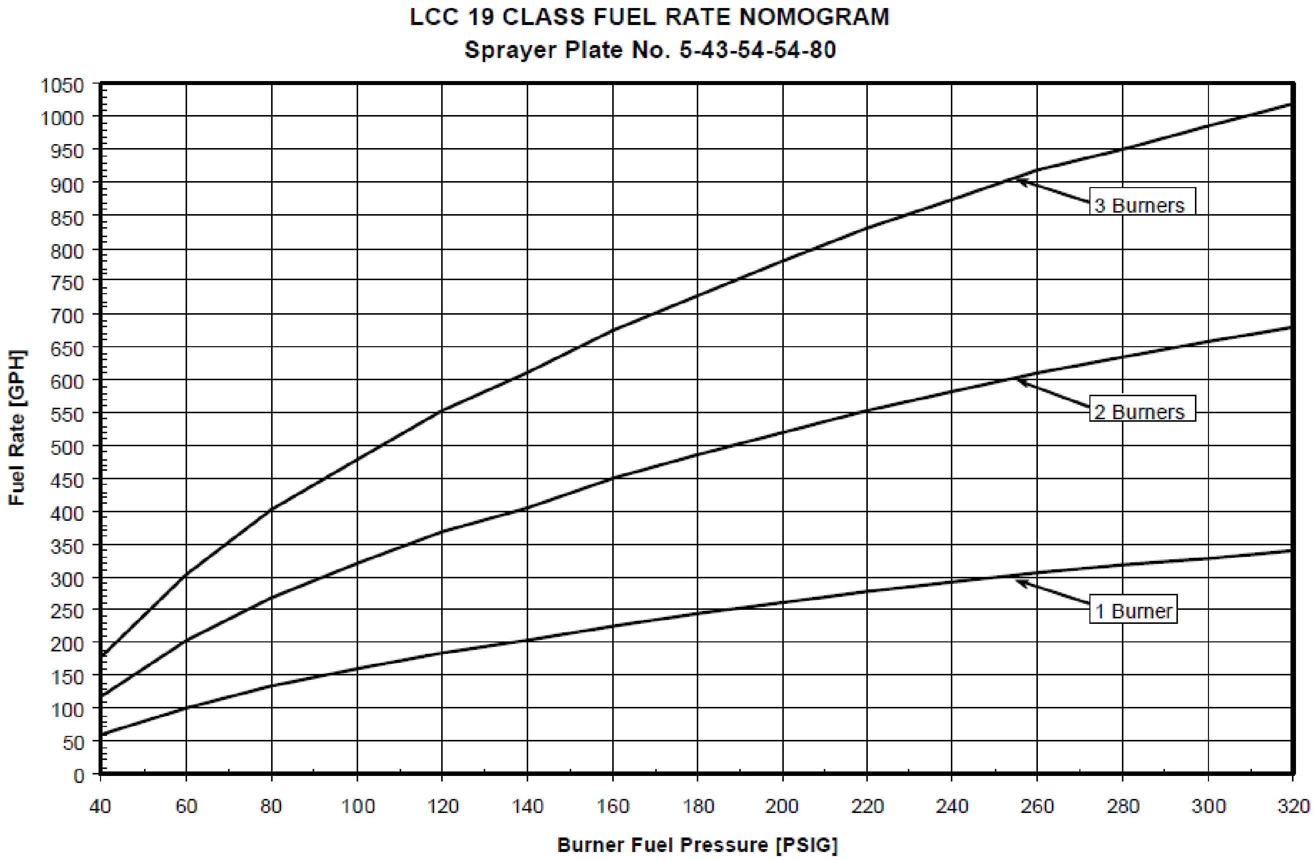
Fuel Rate Nomogram 1. CG 47 Class.

Equipment	Operating	Economic Alignment	
		Trail Shaft	Full Power
GAS TURBINE - MAIN PROPULSION	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	FOUR
GAS TURBINE - GENERATOR	☐ 1 ☐ 2 ☐ 3	ASRQ	TWO
FIRE PUMP	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	ASRQ	ASRQ
LUBE OIL PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	TWO
F.O. SERVICE PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	TWO
CRP PUMP	☐ 1 ☐ 2	TWO	0
SALT WATER SERVICE PUMP	☐ 1 ☐ 2 ☐ 3	TWO	TWO
AIR CONDITIONING UNIT	☐ 1 ☐ 2 ☐ 3	ASRQ	ASRQ
REFRIGERATION UNIT	☐ 1 ☐ 2	ONE	ONE
LP AIR COMPRESSOR	☐ 1 ☐ 2	ASRQ	ASRQ
HP AIR COMPRESSOR	☐ 1 ☐ 2	ASRQ	ASRQ
DISTILLING PLANT	☐ 1 ☐ 2	ASRQ	ASRQ
STEERING GEAR	☐ 1A ☐ 1B ☐ 2A ☐ 2B	TWO	TWO

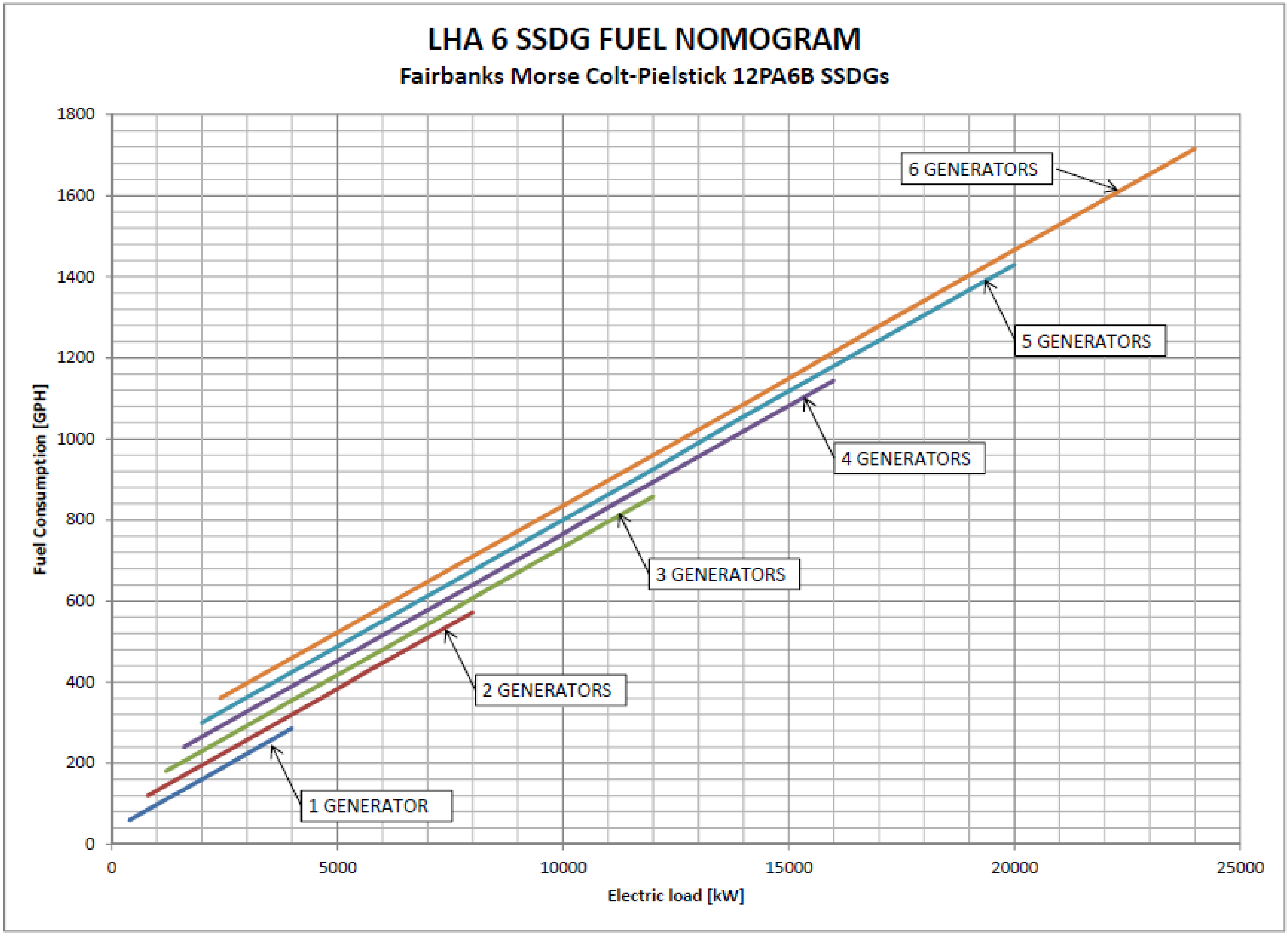
Plant Alignment Status Board 2. DDG 51 Class.



Fuel Rate Nomogram 2. DDG 51 Class (FLT I, II, and IIA).



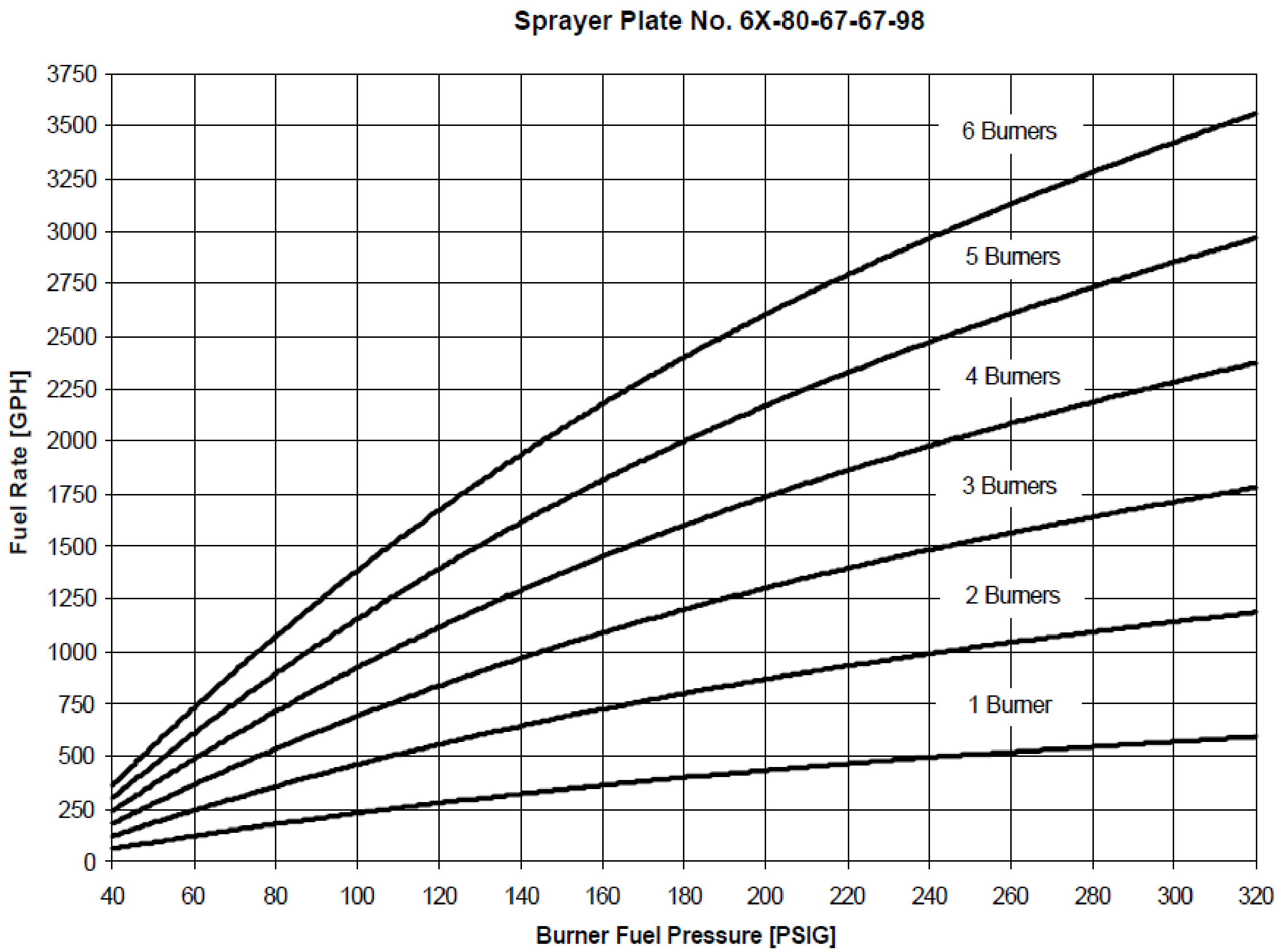
Fuel Rate Nomogram 3. LCC 19 Class.



Fuel Rate Nomogram 4. LHA 6 Class.

Equipment	Operating	Economic Alignment		
		Port	One Boiler	Two Boiler
BOILER	☐ 1 ☐ 2	ONE	ONE	TWO
MAIN FD BLOWER	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	ONE	TWO
PORT	☐ 1 ☐ 2	ONE	0	0
OPERATING MAIN FEED PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	ONE	TWO
IDLING MAIN FEED PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	0	0
FEED BOOSTER PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	ONE	TWO
F.O. SERVICE PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE	ONE	TWO
STEAM FIRE PUMP	☐ 5 ☐ 6 ☐ 7 ☐ 8	0	0	0
ELECT. FIRE PUMP	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 9 ☐ 10 ☐ 11 ☐ 12	ASRQ	ASRQ	ASRQ
MAIN CIRC. PUMP	☐ 1 ☐ 2	0	0	0
MAIN COND. PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	TWO	TWO
MAIN AIR EJECTOR	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	TWO	TWO
L.O. SERVICE PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	TWO	TWO
FWDCT PUMP	☐ 1 ☐ 2	ONE	TWO	TWO
OPERATING SSTG	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	ASRQ	TWO	TWO
IDLING SSTG	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	0	0	0
A/C COMPRESSORS	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6	ASRQ	ASRQ	ASRQ
DISTILLING PLANT	☐ 1 ☐ 2	ASRQ	ASRQ	ASRQ
AUX. EXH. DUMP	☐ MAIN ☐ AUX	AUX	MAIN	MAIN
AUGMENT VALVE	(FWD) ☐ OPEN (AFT) ☐ OPEN	CLOSED	CLOSED	CLOSED

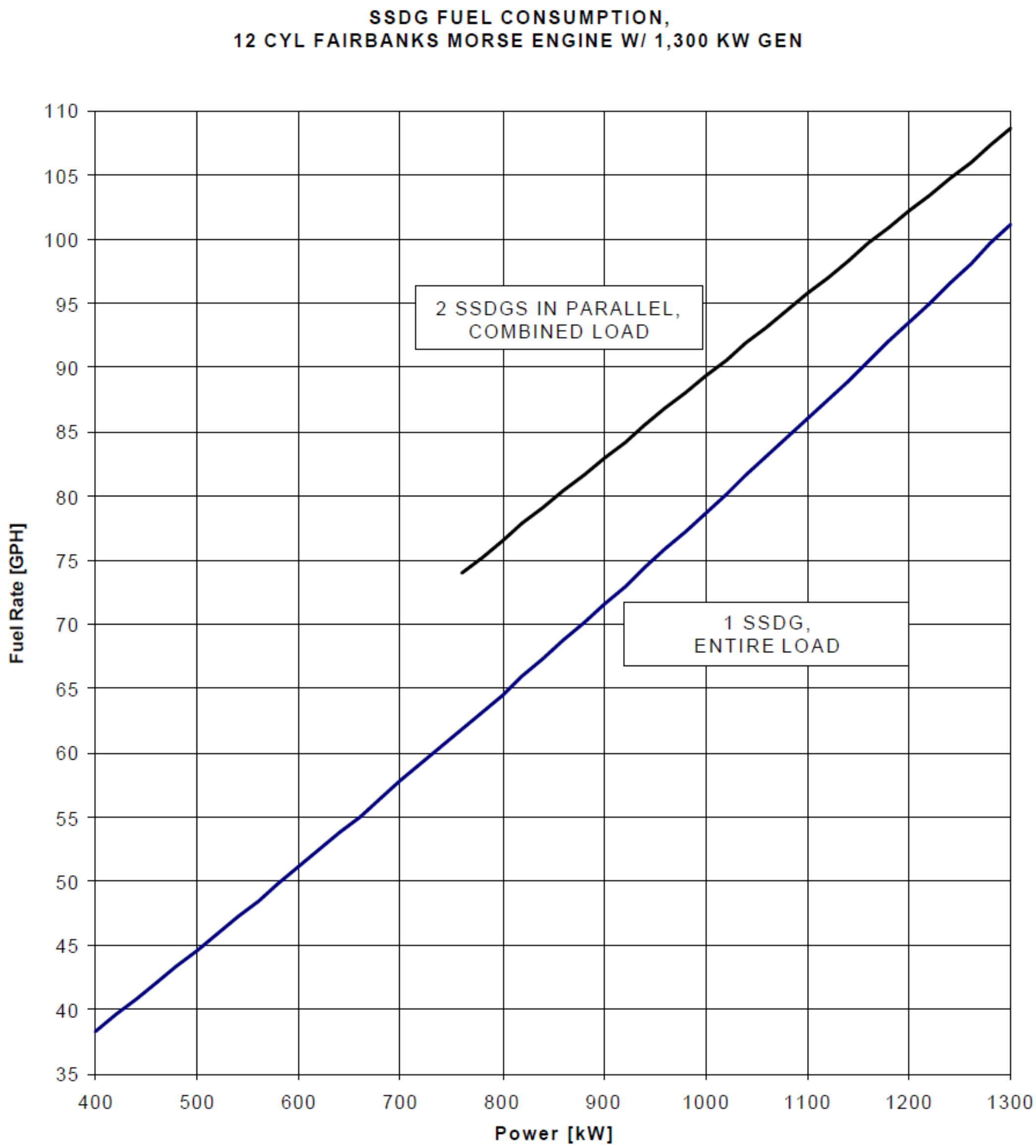
Plant Alignment Status Board 3. LHD 1 Class.



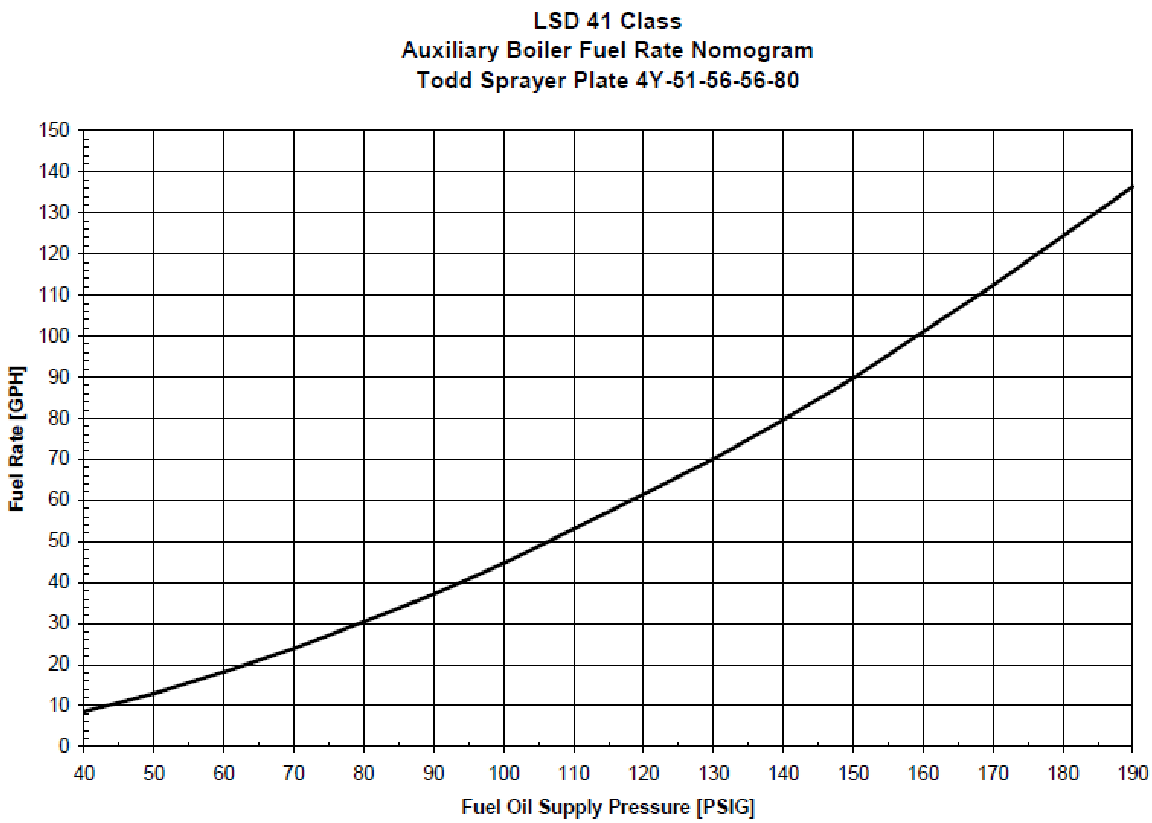
Fuel Rate Nomogram 5. LHD 1 Class.

Equipment	Operating	Economic Alignment	
		Trail / Split	Full Power
MAIN PROPULSION ENGINES	☐ 1A ☐ 1B ☐ 2A ☐ 2B	ONE/TWO	FOUR
SSDG	☐ 1 ☐ 2 ☐ 3	ASRQ	TWO
AUXILIARY BOILER	☐ 1 ☐ 2	ASRQ	ONE
FIRE PUMP	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5	ASRQ	ASRQ
FUEL OIL SERVICE PUMP	☐ 1 ☐ 2	0	0
LUBE OIL SERVICE PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	0
RALO PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	0
RED. GEAR L.O. PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	0
JACKET WATER PUMP	☐ 1A ☐ 1B ☐ 2A ☐ 2B	0	0
SALT WATER COOLING PUMP	☐ 1 ☐ 2 ☐ 3 ☐ 4	ONE/TWO	TWO
FUEL OIL PURIFIER	☐ 1 ☐ 2	ASRQ	ASRQ
LUBE OIL PURIFIER	☐ 1 ☐ 2	TWO	TWO
CPP STANDBY PUMP	☐ 1 ☐ 2	TWO	0
AIR CONDITIONING UNIT	☐ 1 ☐ 2 ☐ 3 ☐ 4	ASRQ	ASRQ
REFRIGERATION UNIT	☐ 1 ☐ 2	ONE	ONE
LP AIR COMPRESSOR	☐ 1 ☐ 2 ☐ 3	ASRQ	ASRQ
HP AIR COMPRESSOR	☐ 1 ☐ 2	ASRQ	ASRQ
DISTILLING PLANT	☐ 1 ☐ 2	ASRQ	TWO
STEERING GEAR	☐ 1A ☐ 1B ☐ 2A ☐ 2B	TWO	TWO

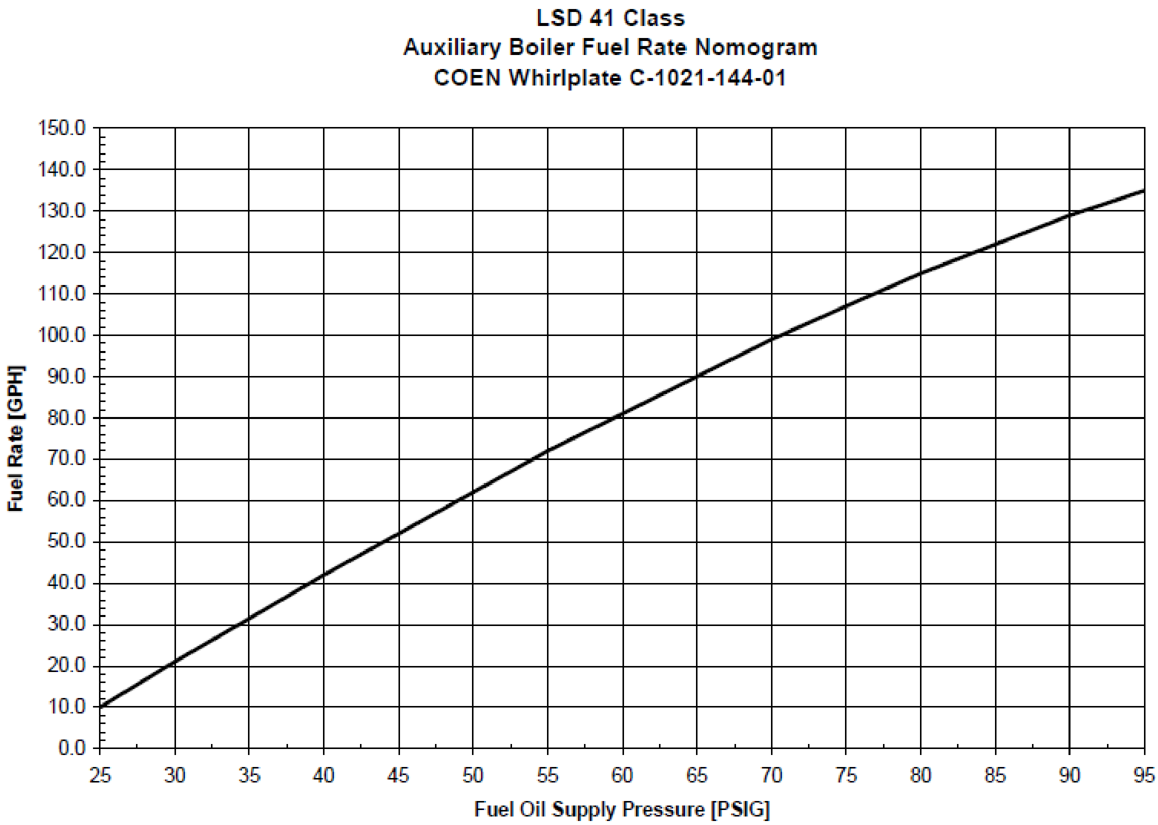
Plant Alignment Status Board 4. LSD 41 Class.



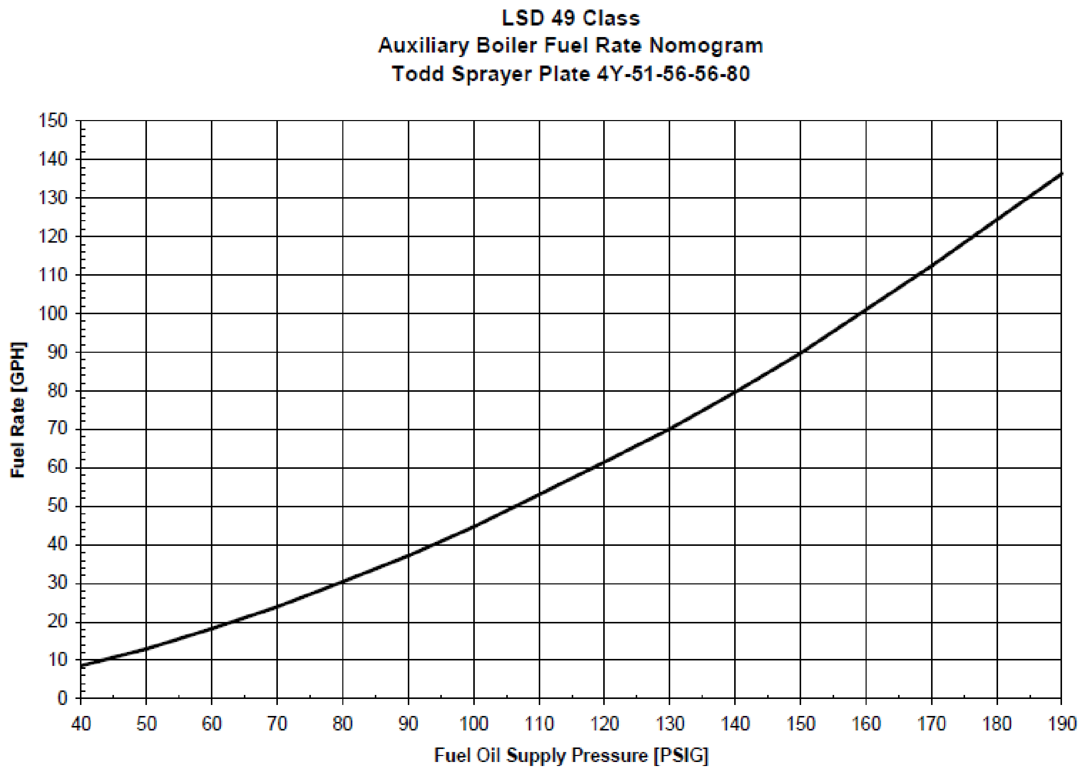
Fuel Rate Nomogram 6. LSD 41 Class SSDG.



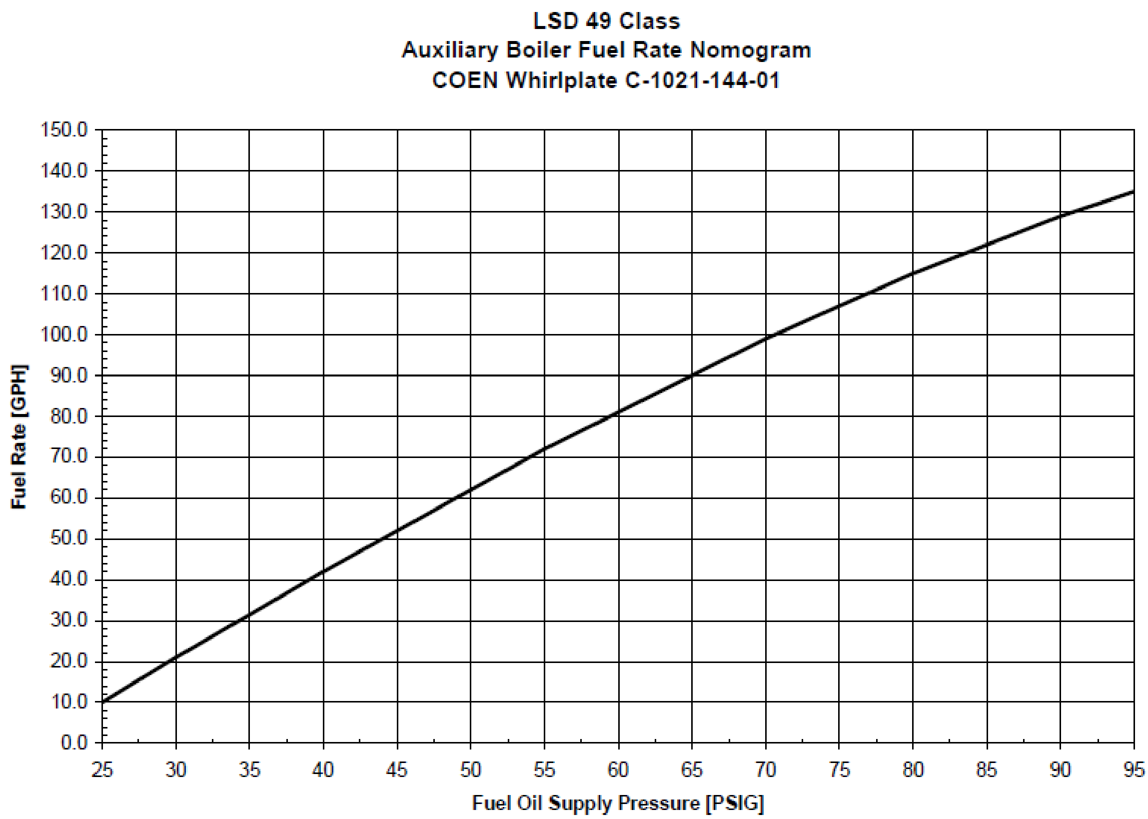
Fuel Rate Nomogram 7. LSD 41 Class Aux Boiler–Todd.



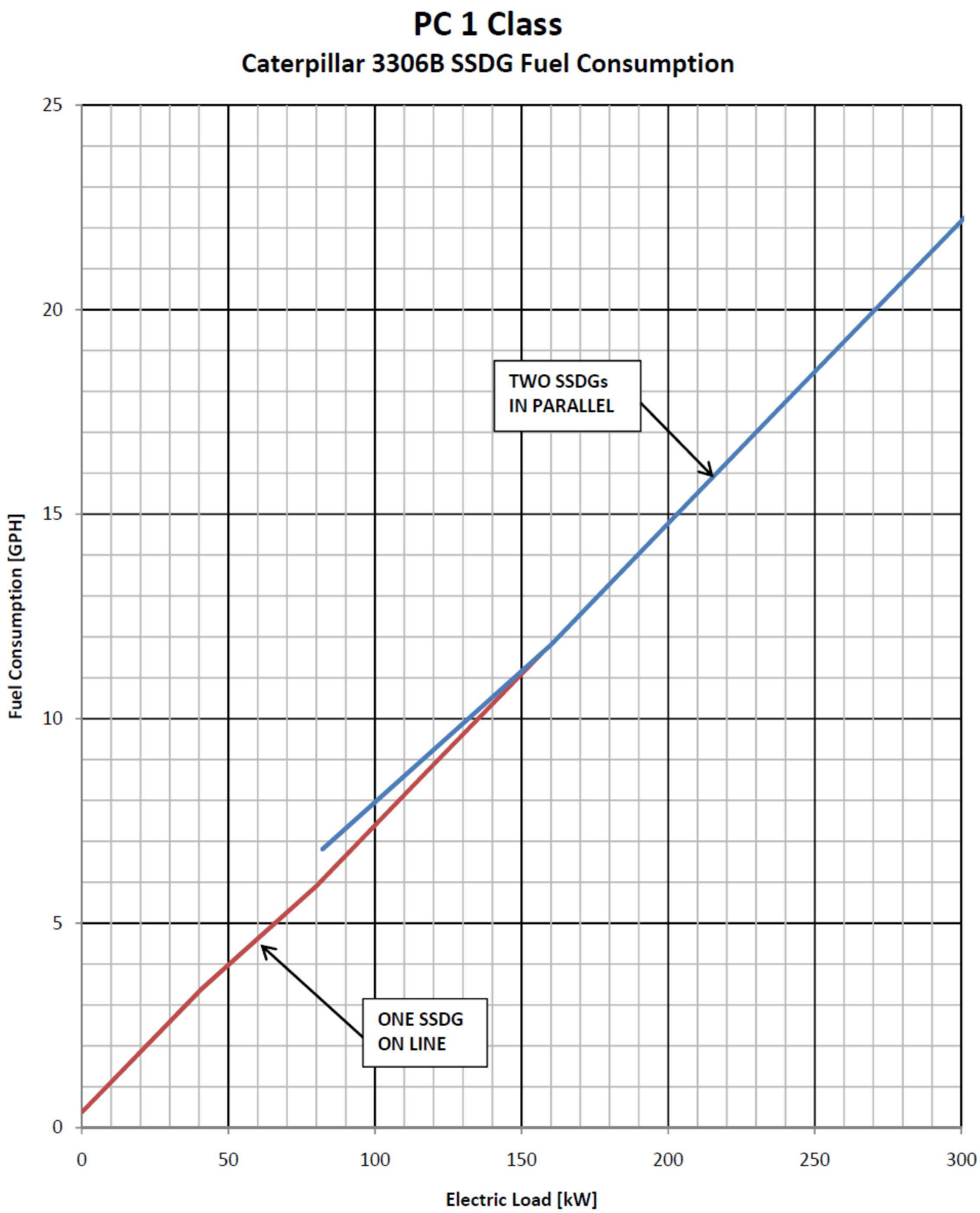
Fuel Rate Nomogram 8. LSD 41 Class Aux Boiler–COEN.



Fuel Rate Nomogram 9. LSD 49 Class Aux Boiler–Todd.



Fuel Rate Nomogram 10. LSD 49 Class Aux Boiler–COEN.



Fuel Rate Nomogram 11. PC 1 Class.

APPENDIX D
BOSC TOOL

D.1 BOSC TOOL OVERVIEW.

NAVSEA developed the Battlegroup Optimum Speed Calculator (BOSC) Tool to assist U.S. Navy ships and battlegroup transit planners in selecting the most efficient transit speed for any steady-state transit consisting of more than one fossil-fueled ship. When mission and schedule allow for some flexibility, this tool will determine the most fuel-efficient transit speed and plant alignments for a group of up to ten ships. The tool will compare the total fuel burned at the planned SOA vs. the battlegroup optimum transit speed for a transit. The most recent complete tool and instructions are provided on the iENCON website (www.i-encon.com) and can also be requested from NAVSEA. This tool is applicable for all steam turbine, gas turbine, and diesel engine powered ships, except newer ship classes where class fuel data is not available.

D.2 BOSC TOOL USER GUIDE.

This Appendix provides a step-by-step user guide for the BOSC Tool, along with screenshots to help familiarize the user with the tool. The BOSC Tool was created to be extremely user friendly and require minimal inputs to calculate a solution.

D.2.1 Computer Requirements to Run Tool. The BOSC Tool was developed using Microsoft Excel; it should be compatible with any government laptop onboard a ship or pier-side as long as Microsoft Excel is installed. An internet connection is not required to run the tool.

D.2.2 Using the Tool. The BOSC Tool includes three tabs: Instructions, BOSC, and Alignment Legend. The Instructions tab is self-explanatory and will therefore not be repeated here. The BOSC tab contains all inputs and outputs to the program. It is here that users select a group of ships from a list of current fossil-fuel burning ships, provide transit input including distance and time, and finally, the current cost of fuel. With this minimal input, BOSC will provide graphic and tabulated data for the entire battlegroup including fuel consumption at each speed, individual ship plant alignments, and fuel consumption and cost comparison of the planned transit versus the optimum transit. Lastly, the Alignment Legend tab provides a key for defining the abbreviated alignments for each ship class in the Alignment Legend table (see D.2.2.4).

D.2.2.1 User Inputs – Ship Selection. All required user input cells are colored peach. The first required user input under the BOSC tab is to select up to ten ships from the list of ships. Once a ship is selected, the cells in blue will automatically update to display the ship class and maximum transit speed (Note: This is not the maximum ship speed; it is only the maximum speed shown in corresponding NAVSEA iENCON class fuel consumption curves.). The BOSC Tool will also display the Coat of Arms for each ship selected. Figure D-1 shows a screenshot of the input portion of the BOSC Tool where the user selects the ships. For the example used throughout this appendix, the assumed battlegroup consists of two cruisers, two destroyers, and one amphibious assault ship.

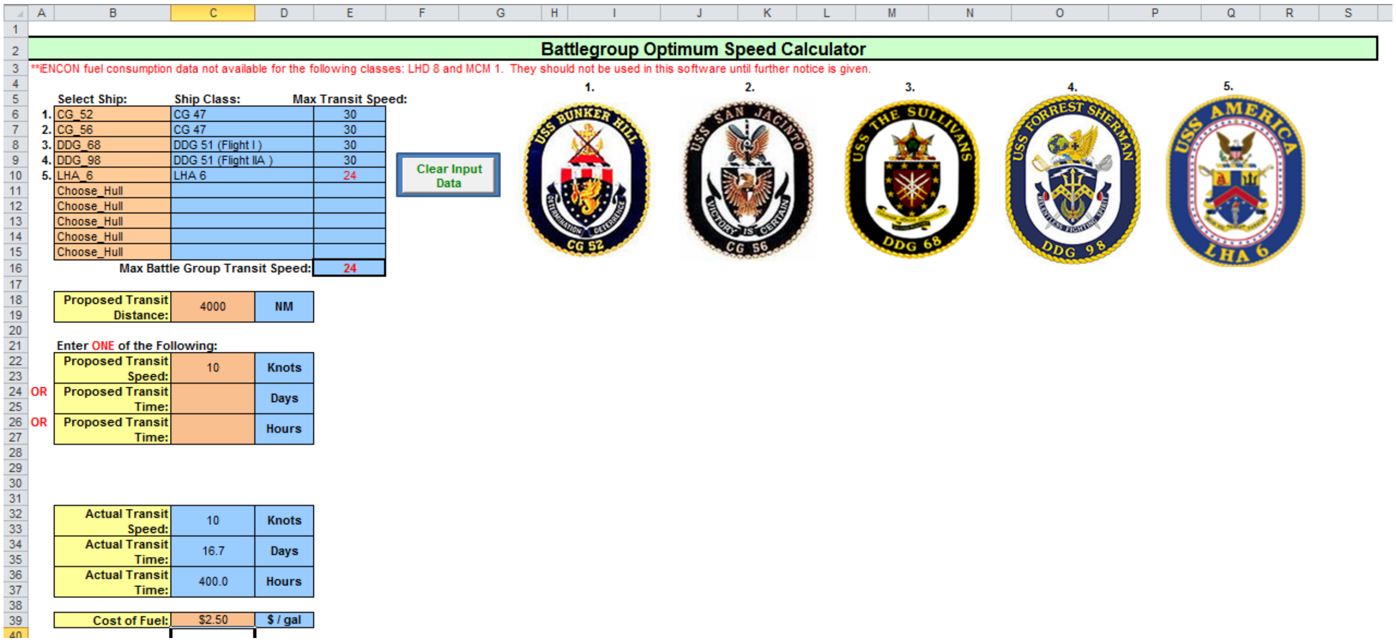


Figure D-1. BOSC Input Screen.

D.2.2.2 User Inputs – Transit Selection. Next, the user must input the transit data. A proposed transit distance is required. Additionally, the user must input either a transit speed, or transit time (in either days or hours). It is important that the user only input one value (either speed or time) for the program to function properly. The input screenshot in figure D-1 above also depicts the transit selection input.

D.2.2.3 User Inputs – Fuel Cost. Lastly, the user should input the current fuel cost per gallon for the BOSC Tool to properly calculate monetary fuel savings. The input screenshot in figure D-1 above also depicts the fuel cost input.

D.2.2.4 Outputs – Battlegroup Composite Fuel Data. After selecting the ships which compose the battlegroup, inputting transit distance and time or speed and the cost of fuel, the BOSC Tool will display a variety of outputs. The first output is two data tables under the “Battlegroup Composite Fuel Data” section. The table to the left displays the total battlegroup fuel consumption for each speed between 5 knots and the maximum battlegroup speed. The maximum battlegroup speed is the lowest maximum speed of each individual ship in the battlegroup, shown in the table where the ships were selected in D.2.2.1. The table to the right displays the plant alignment for each ship at each battlegroup speed. See figure D-2 for the Battlegroup Composite Fuel Data display for the example battlegroup used in this appendix.

Battlegroup Composite Fuel Data

TOTAL FUEL CONSUMPTION DATA					
SPEED	GEN GPH	ME GPH	BLR GPH	TOT GPH	GPNM
5	2109	1113	0	3222	644.3
6	2109	1207	0	3316	552.6
7	2109	1328	0	3437	491.0
8	2109	1488	0	3597	449.7
9	2109	1688	0	3797	421.9
10	2109	1929	0	4038	403.8
11	2109	2215	0	4324	393.1
12	2109	2532	0	4641	386.7
13	2109	2876	0	4985	383.5
14	2109	3670	0	5779	412.8
15	2109	4125	0	6234	415.6
16	2109	4633	0	6742	421.4
17	2109	5231	0	7340	431.8
18	2109	5886	0	7995	444.2
19	2109	6678	0	8787	462.5
20	2109	7485	0	9594	479.7
21	2109	8992	0	11101	528.6
22	2109	10005	0	12114	550.6
23	2109	11047	0	13156	572.0
24	2109	13115	0	15224	634.3

ALIGNMENT LEGEND (MOST EFFICIENT)					
SPEED	CG_52	CG_56	DDG_68	DDG_98	LHA_6
5	TS	TS	TS	TS	APM
6	TS	TS	TS	TS	APM
7	TS	TS	TS	TS	APM
8	TS	TS	TS	TS	APM
9	TS	TS	TS	TS	APM
10	TS	TS	TS	TS	APM
11	TS	TS	TS	TS	APM
12	TS	TS	TS	TS	APM
13	TS	TS	TS	TS	APM
14	TS	TS	TS	TS	TS
15	TS	TS	TS	TS	TS
16	TS	TS	TS	TS	TS
17	TS	TS	TS	TS	TS
18	TS	TS	TS	TS	TS
19	TS	TS	TS	TS	FP
20	TS	TS	TS	TS	FP
21	SP	SP	TS	SP	FP
22	SP	SP	SP	SP	FP
23	SP	SP	SP	SP	FP
24	FP	FP	SP	SP	FP
SEE TAB "ALIGNMENT LEGEND" FOR DEFINITIONS					

Figure D-2. BOSC Battlegroup Composite Fuel Data Screenshot.

D.2.2.5 Outputs – Battlegroup Composite Fuel Curves. The next section, "Battlegroup Composite Fuel Curves", displays the combined GPH vs. knots and GPNM vs. knots fuel curves for the entire battlegroup. Each plot displays the proposed transit speed with an orange diamond and the BOSC-calculated optimum transit speed with a green box. Additionally, each chart contains an "Update Axis Scales" button, which will automatically reset the axis settings for easy viewing. The user must ensure macros are enabled for this button to function properly. See figure D-3 for the Battlegroup Composite Fuel Curves display for the example battlegroup used in this appendix.

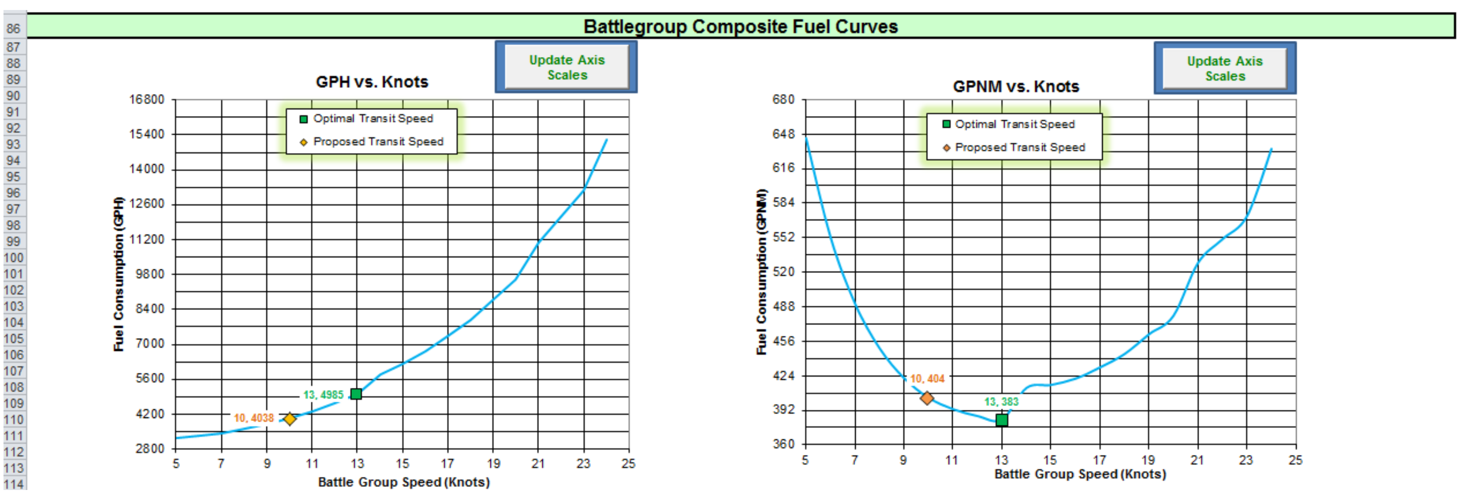


Figure D-3. BOSC Battlegroup Composite Fuel Curves Screenshot.

D.2.2.6 Outputs – Battlegroup Transit Fuel Consumption Results. The last section, "Battlegroup Transit Fuel Consumption Results", displays several comparative data tables of the proposed transit versus the optimum transit. The tables to the left display the results for the proposed transit, including transit speed, distance, and time, as well as the total battlegroup fuel consumption (GPH and GPNM), transit gallons, and projected fuel cost broken down by ship. The tables to the right display the same information for the calculated optimum transit speed. Finally, the two green columns to the far right display the difference in total gallons and fuel cost between the optimum speed and proposed speed by ship. In some cases, an individual ship may burn more fuel at the optimum battlegroup transit speed; however, the battlegroup as a whole still saves fuel. The total fuel saved in gallons and cost is displayed, as well as the percent reduction in fuel used at the optimum battlegroup transit speed. Lastly, the program will provide a recommendation to maintain speed, speed up, or slow down to save more fuel (in the case of this example, the recommendation is to increase transit speed). This recommendation should only be followed if the mission allows for a change in the proposed transit speed. See figure D-4 for a display of the Battlegroup Transit Fuel Consumption Results for the example battlegroup used in this appendix.

Battlegroup Transit Fuel Consumption Results

Proposed Transit Speed:	10	(Knots)
Proposed Transit Distance:	4000	(NM)
Proposed Transit Time:	16.7	Days
Proposed Transit Time:	400	Hours

Optimum Transit Speed:	13	(Knots)
Proposed Transit Distance:	4000	(NM)
Optimum Transit Time:	12.8	Days
Optimum Transit Time:	308	Hours

(Added Time) / Reduced Time to Complete Transit	
3.8	Days
92	Hours

PROPOSED TRANSIT

	Ship	Alignment	GPH	GPNM	Transit Gallons	Projected Fuel Cost
1.	CG_52	TS	827	83	330,658	$826,644
2.	CG_56	TS	827	83	330,658	$826,644
3.	DDG_68	TS	737	74	294,800	$737,000
4.	DDG_98	TS	729	73	291,782	$729,456
5.	LHA_6	APM	918	92	367,124	$917,811
		Totals:	4038	404	1,615,022	$4,037,555

OPTIMUM TRANSIT

	Ship	Alignment	GPH	GPNM	Transit Gallons	Projected Fuel Cost	Gallons (Above)/Below Proposed Transit	Cost (Above)/Below Proposed Transit
1.	CG_52	TS	1004	77.2	308,784	$771,960	21,874	$54,684
2.	CG_56	TS	1004	77.2	308,784	$771,960	21,874	$54,684
3.	DDG_68	TS	930	71.5	286,154	$715,385	8,646	$21,615
4.	DDG_98	TS	879	67.6	270,480	$676,200	21,302	$53,256
5.	LHA_6	APM	1169	89.9	359,765	$899,413	7,359	$18,397
		Totals:	4985	383	1,533,967	$3,834,918	81,055	$202,637

% Reduction:	5.0%

YOUR BATTLEGROUP TRANSIT SPEED IS BELOW YOUR OPTIMUM TRANSIT SPEED.
INCREASING SPEED CAN ACTUALLY REDUCE FUEL CONSUMPTION AND SHORTEN TRANSIT TIME!

Figure D-4. BOSC Battlegroup Transit Fuel Consumption Results Screenshot.

APPENDIX E
LIST OF ACRONYMS

E.1 LIST OF ACRONYMS.

ACRONYM	TITLE
A/C	Air Condition
ACTS	Aegis Combat Training Systems
BHP	Brake Horse Power
BID	Blow-In Doors
BMEP	Brake Mean Effective Pressure
BOSC	Battlegroup Optimum Transit Calculator
BTU	British Thermal Unit
CNO	Chief of Naval Operations
CNSL	Commander, Naval Surface Forces, Atlantic
CNSP	Commander, Naval Surface Forces, Pacific
CO	Commanding Officer
DFM	Diesel Fuel Marine
DFT	Deaerating Feed Tank
DITS	Division-In-The-Spotlight
EABC	Electronic Automated Boiler Control
ECB	Energy Conservation Board
ECM	Energy Conservation Measure
ENCON	Energy Conservation Guide
EOOW	Engineering Officer of the Watch
EOP	Engineering Operational Procedures
EOSS	Engineering Operational Sequencing System
EPEC	Environmental Protection and Energy Conservation
FEM	Fleet Energy Manager
FITREP	Fitness Report
FOD	Foreign Object Damage
FOM	Fuel Oil Meter
GAL	Gallons
GGF	Great Green Fleet

GPD	Gallons per Day
GPH	Gallons per Hour
GPNM	Gallons per Nautical Mile
GTE	Gas Turbine Engine
GTG	Gas Turbine Generator
GTM	Gas Turbine Main
HPAC	High Pressure Air Compressor
HR	Hours
ICAS	Integrated Condition Assessment System
iENCON	Incentivized Energy Conservation
LB	Pound
MACHALT	Machinery Alteration
NAVSEA	Naval Sea Systems Command
NEURS	Navy Energy Usage Reporting System
NM	Nautical Miles
NSTM	Naval Ships' Technical Manual
NUW	Not-Underway
OBT	Onboard Trainer
OLV	Online Verification
OPNAV	Office of the Chief of Naval Operations
OPTAR	Operational Target
OSTP	Optimum Ship Transit Program
OTSR	Optimum Track Ship Routing
PIM	Planned Intended Movement
POD	Plan of the Day
RAS	Replenishment at SEA
RIMPAC	Rim of the Pacific
RMD	Restricted Maneuvering Doctrine
SECAT	Ship Energy Conservation Assist Training
SECNAV	Secretary of the Navy
SEM	Shipboard Energy Manager
SGA	Stack Gas Analyzer
SOA	Speed of Advance
SSDG	Ship Service Diesel Generators

SSGTG	Ship Service Gas Turbine Generator
SSTG	Ship Service Turbine Generators
TESS	Tactical Environmental Support System
TFE	Task Force Energy
TYCOM	Type Commander
UNREP	Underway Replenishments

Ref: NAVSEAINST 4160.3 NAVSEA S0005-AA-GYD-030/TMMP

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