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Calculating Surface Ship Energy Usage, Energy Cost, and Fully Burdened Cost of Energy

ABSTRACT

On June 20, 2011, the Assistant Secretary of the Navy for Research, Development and Acquisition, ASN(RDA), issued a memo stating, "The Fully Burdened Cost of Energy (FBCE) must be calculated using operational scenarios or use conditions specified in the program's AoA[1] guidance. System Commands (SYSCOMS) will develop a uniform method for calculating FBCE to support their respective acquisition programs." In response to this memo, the Naval Sea Systems Command (NAVSEA) initiated a project to develop a Design Data Sheet (DDS) to document the "uniform method". Following extensive review within the technical community, on August 7, 2012, NAVSEA issued DDS 200-2, *Calculation of Surface Ship Annual Energy Usage, Annual Energy Cost, and Fully Burdened Cost of Energy*.

KEYWORDS

Fully burdened cost of energy calculation
Ship energy usage

Introduction

On June 20, 2011, the Assistant Secretary of the Navy for Research, Development and Acquisition, ASN(RDA), issued a memo stating, "The Fully Burdened Cost of Energy (FBCE) must be calculated using operational scenarios or use conditions specified in the program's AoA[1] guidance. System Commands (SYSCOMS) will develop a uniform method for calculating FBCE to support their respective acquisition programs." In response to this memo, the Naval Sea Systems Command (NAVSEA) initiated a project to develop a Design Data Sheet (DDS) to document the "uniform method". Following extensive review within the technical community, on August 7, 2012, NAVSEA issued DDS 200-2, *Calculation of Surface Ship Annual Energy Usage, Annual Energy Cost, and Fully Burdened Cost of Energy*.

The end product of DDS 200-2 is an estimate of the amount of fuel consumed by a surface ship in each year of its service life (as well as the sum over the service life), and an estimate of the cost of that fuel. DDS 200-2 breaks the calculations into four tasks: Operational Profile Development, Annual Energy Usage Calculation, Fully Burdened Cost of Energy Calculation, and Annual Energy Cost Calculation. The inter-relationship of these tasks is shown in Figure 1. A worked example of the process is provided as an appendix to DDS 200-2.

The Operational Profile Development methods are based on the methods used for a 2007 Navy report to Congress, *Alternative Propulsion Methods for Surface Combatants and Amphibious Warfare Ships*. The Fully Burdened Cost of Energy Calculation method is based on an internal SEA 05C document.

1 Analysis of Alternatives.

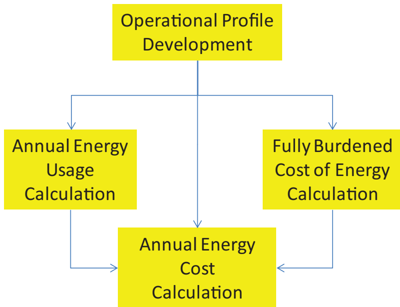

FIGURE 1. Task relationships.

Operational Profile Development

On a surface ship, fuel is consumed for propulsion, electric power generation, and the ship's vehicles. The amount of fuel consumed at any given time is governed by what the ship is tasked with doing. For the purposes of energy usage calculations, the lowest level of ship tasking is described by "ship states". Examples of ship states include:

- Inport – shore
- Inport – anchor
- Underway – peacetime cruising
- Underway – wartime cruising
- Underway – Anti-Submarine Warfare (ASW) operations (mission)
- Underway – Anti-Air Warfare (AAW) operations (mission)
- Underway – Anti-Surface Warfare (ASuW) operations (mission)
- Underway – Surveillance operations (mission)
- Underway – Theater Ballistic Missile Defense (TBMD) station (mission)

The definitions of the ship states must align with the way in which electric loads are estimated. The process for conducting an Electric Power Load Analysis (EPLA) is defined in DDS 310-1. Additionally, a speed-percent time profile must also be developed for each ship state. Three methods are identified for creating speed-percent time profiles:

- construct Design Reference Missions (DRM) to gain insight to develop a profile from scratch
- use measured data from a ship with a similar mission
- use data from the provided appendices (based on data from FY 1998-2002)

The next, higher-level description of ship operations is the "Operational Mode". Operational modes describe, in a general manner, how a ship is employed over a period of time, typically at least one month. Examples of operational modes include:

- presence and training at home
- presence overseas
- TBMD operations
- lesser contingency operations
- Major Combat Operations (MCO)
- maintenance and modernization

The operational modes and ship states are linked by a ship state participation table. For each operational mode, a percent time is assigned to each ship state.

Using the operational modes, one or more ship deployment and employment profiles are developed. For each year in the ship's projected service life, an estimate is made for the number of hours spent in each of the operational modes. For many studies, three profiles are usually sufficient to bound a ship's energy usage:

- Low–peacetime operations with no MCOs and a limited number of lesser contingency operations
- Medium–add a single MCO to the Low profile
- High–add two MCOs to the Low profile.

Annual Energy Usage Calculation

The annual energy usage calculations produce an estimate for the amount of energy used in each year of the ship's projected service life for each ship deployment and employment profile. This information is tabulated in an annual energy usage table. The annual energy usage is decomposed into up to three parts:

- fuel (kg) consumed by the ship
- shore power (kW-h) used by the ship (if required)
- fuel (kg) consumed by embarked vehicles (if required)

For the fuel consumed by the ship, a ship state fuel rate (kg/h) is calculated for each ship state. The average ship fuel rate calculations use the 24-hour electric loads, as computed using DDS 310-1, and the speed-percent time profiles associated with the ship state. The calculation method for the calculated ship state fuel rate is the same as the method used in DDS 200-1 for the operational presence burnable fuel load. The calculated ship state fuel rate corresponds to the DDS 200-1 calculated operational presence fuel rate, multiplied by the plant deterioration allowance.

The ship state participation table is used to develop calculated operational mode fuel rates (kg/h) for each operational mode. The ship deployment and employment profiles are used to estimate the amount of fuel (kg) consumed in each year of the ship's projected service life.

Shore power is estimated using the EPLA. The ship state participation table and the ship deployment and employment profiles are applied to the shore power calculation to estimate the amount of shore power electrical energy consumed (kW-h).

Fuel consumed by embarked vehicles is estimated by modeling their concept of operations to project the fuel rate (kg/h) for each ship state. The ship state participation table and the ship deployment and employment profiles are applied to this fuel rate to estimate the amount of fuel (kg) consumed in each year of the ship's projected service life.

Fully Burdened Cost of Energy Calculation

The Fully Burdened Cost of Energy calculations produce a table of the projected fully burdened cost of fuel ($/kg) and the fully burdened cost of electricity ($/kW-h) for each operational mode for each year in the ship deployment and employment profiles. Since considerable uncertainty exists in projecting future fuel costs, these costs should be presented as either ranges or random variables.

The fully burdened cost of fuel consists of the DLA Energy standard price for fuel and the fuel burden. The DLA Energy standard price is the anticipated cost of providing fuel to defense customers, and is more than the commodity price of fuel. The fuel burden accounts for additional costs to the Navy that includes storage and handling costs, the depreciation, operation, and support costs of fuel delivery ships, and environmental costs. Methods for approximating each element of the fully burdened cost of fuel are provided in the design data sheet.

The fully burdened cost of shore power can be approximated using data from the Defense Utility Energy Reporting System (DUERS), and the Energy Information Administration (EIA) Annual Energy Outlook (AEO).

Annual Energy Cost Calculation

The annual cost of energy is calculated by applying the fully burdened cost of fuel and the fully burdened cost of shore power to the annual energy usage tables. Since the fully burdened cost of fuel and the annual energy usage tables may include ranges or random variables, the annual cost of energy may also be represented as a range or a random variable.

Some studies may require variations in calculation methods. For example, a study may require propulsion and ship service fuel costs to be categorized separately. In other studies, the energy costs of an entire ship class may be of interest.

Future Work

While DDS 200-2 is significant because it is the first time a standardized process has been established to calculate annual energy usage, energy cost, and the fully burdened cost of energy, additional work is needed to fully implement the process.

First, standardized design tools are needed to implement the process. Currently, spreadsheets are custom-crafted for each application of the process. While this method works, it does require a significant amount of effort to implement the process each time. Additionally, validating spreadsheets can be difficult and calculation errors may be introduced, but not readily noticed. The Center for Innovation in Ship Design (CISD) has recently created a Speed-Time Profile Tool using Visual Basic for Applications (VBA) within the Microsoft Excel environment. This tool implements the process for developing speed time profiles as defined in DDS 200-2, and is being evaluated for adoption within the Navy's ship design community.

Additionally, updated speed-percent time profiles that reflect more recent fleet data is needed. DDS 200-2 is currently approved for public release, enabling the methods to be easily shared with academia and industry. To prevent the necessity of restricting distribution of this DDS, a series of supplements that is restricted to U.S. Government personnel and contractors is currently under development. The supplements in this series reflect more recent data, as well as data for more ships in the current fleet.

Conclusion

DDS 200-2 provides a process for estimating annual energy usage and the fully burdened cost of energy of surface ships. This process fulfills the direction of ASN(RDA) to use a uniform method for conducting the calculations. Over time, as the Navy seeks to minimize total ownership cost, it will likely influence the optimization of power and propulsion systems, mission load efficiencies, the hydrodynamic shape of hulls and appendages, and concepts of operation.

Copies of Design Data Sheets are available from Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard D.C. 20376-5160, or by email at CommandStandards@navy.mil with the subject line "DDS request". Additionally, DDS 200-2 is available from the Defense Technical Information Center (DTIC) on its website (http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA565827)

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