Ship Requirements

Shipboard Power System Fundamentals

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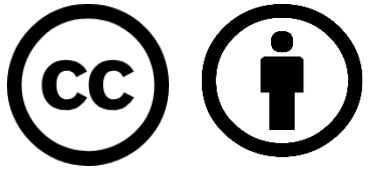
Dr. Norbert Doerry



Essential Questions

What are the key requirements that drive size, weight and cost of ship power and propulsion systems?	Understand
How do the key requirements impact power and propulsion system designs?	Understand
How are the key requirements established?	Understand
What is the impact of when the key requirements are established on the power and propulsion system design?	Understand

Key requirements

- Flexibility
  - Ability to adapt a ship's systems to evolve over the ship's life to achieve new objectives
- Sustained / Service speed
  - Naval ships: sustained speed is the speed that must be attained (or surpassed) when the propulsion system is operating at 80% of its rated power with the ship having a clean, full load displacement, and in calm water.
  - Commercial ships: The power needed to propel the ship at the service speed with a full load displacement, clean bottom and calm water is calculated. To this power is added sea margin (for conditions other than calm water) and engine margin to determine the minimum propulsion power required.
  - Sustained speed and service speed are often nearly the same.
- Endurance
  - Determines the minimum required capacity of the fuel tanks
  - Often defined as how far a ship should be capable of traveling at an endurance speed using all of the ship's burnable fuel.
  - Commercial ships often use the service speed as the endurance speed
- 'Compromised Mobility' speed
  - Allowable degradation in the ship's achievable speed following damage.
- Survivability
  - Expected residual mobility capability a ship should have or be able to restore following exposure to a threat.

Key requirements (continued)

- Low Observable Mode
  - Limitations on acoustic, thermal, and electromagnetic signatures.
- Operating and Support costs
  - Expectations with respect to costs associated with fuel, manpower, and maintenance.
- Emissions
  - MARPOL limits sulfur oxide and nitrogen oxide emissions as well as establishes mandatory measures to reduce greenhouse gas emissions.
- Special Loads
  - Some loads have characteristics such as pulsed current waveforms, high power requirements, and dynamically challenging; accommodating these loads can have significant impact on power system design.

Key requirement impact on power and propulsion system design

- Flexibility
  - Naval ships: Service Life Allowances
  - Commercial ships: Usually not provided significant flexibility
  - Modularity and other flexibility features apply in specific situations
- Sustained / Service speed
  - Shaft power roughly proportional to speed cubed.
  - Propellers generally limited to 50 MW, usually kept to below 35 MW per shaft
  - Operational profile drives propulsion type.
    - Ships operating often near their sustained / service speed typically mechanical drive
- Endurance
  - Typically use efficient diesel engines to optimize for the endurance condition
  - Additional light weight / power dense gas turbines considered to achieve sustained/service speed
- ‘Compromised Mobility’ speed
  - Naval Ships: If low enough, can be satisfied with forward drop propulsor
  - Naval Ships: Alternately, with the assumption that one shaft will survive, the use of twin shafts.
  - Commercial Ships: Derived result from redundancy requirements
- Survivability
  - Naval ships: separation of generator sets and zonal survivability for larger ships.
  - Commercial ships: certain ship types required by SOLAS to have “Safe Return to Port” provisions.

Key requirement impact on power and propulsion system design (continued)

- Low Observable Mode
  - Energy storage enables operating at low speed without prime movers online.
- Operating and Support costs
  - Minimize number and type of prime movers
  - Prime movers able to operate efficiently at power levels consistent with speed-time profile and ship service loads at the associated operating condition
  - Consider single shaft, contra-rotating propellers, azimuthing propulsors
- Emissions
  - MARPOL emission requirements are driving the commercial industry to alternate fuels: Liquified Natural Gas, Ammonia, and purely electrical storage.
  - Depending of fuel used and prime mover, may require an Exhaust Gas Cleaning System (EGCS)
- Special Loads
  - Specialized high power loads that are not operated when the ship is at its maximum speed may lead to the use of integrated power systems or hybrid electric drive.

Establishing key requirements

- Key ship-level requirements typically determined during ship concept design.
- Products of concept design
  - Set of operational requirements
  - Cost estimates for procuring and sustaining a ship that achieves the set of operational requirements
  - An assessment of the utility of a ship that meets the set of operational requirements.
- One or more ship concept designs created to develop the products
  - The ship concept designs are an intermediate product, not a final product
- Concept designs may analyze multiple sets of operational requirements.
  - Each set of requirements is often called a “Capability Concept”
  - Multiple ship concepts may be developed for each capability concept to develop representative cost estimates.

Impact of key requirements timing on power and propulsion system design

- Not all requirements are finalized at the beginning of Preliminary Design.
- Approaches to account for uncertain or changing requirements
  - Design Robustness
    - Additional capability is provided in the design to account for full range of uncertainty in the requirements.
    - Design margin (during design process)
    - Service Life Allowance (while in service)
  - Design Flexibility
    - Space, Weight, and Services allocations, or
    - Easy substitution of equipment with equipment having a higher rating.