

Wire Development Workshop

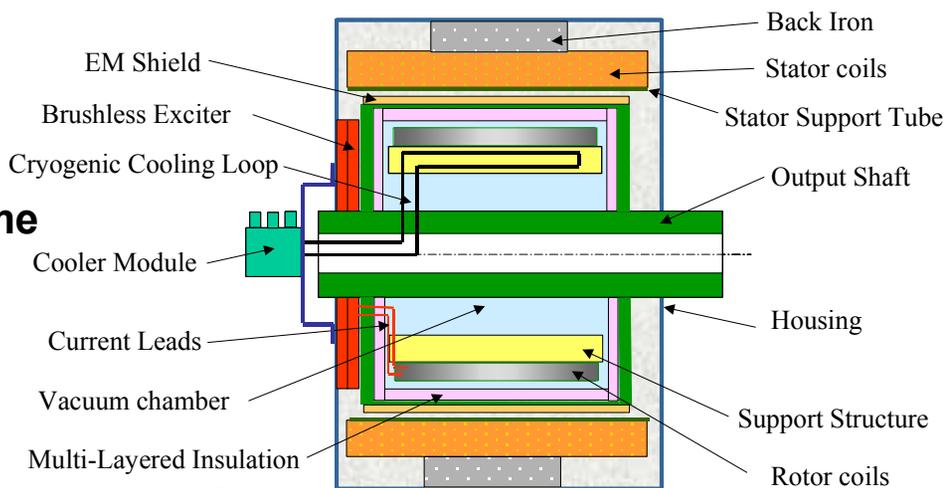
HTS Motor Technology & YBCO Specification

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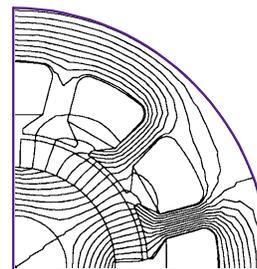
1	HTS Machine Experience
2	HTS Ship Propulsion
3	5 MW Motor
4	YBCO Specification
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Electric Machine Design: HTS Machine Topology

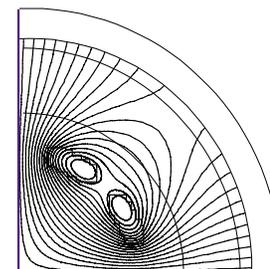
- Multi phase synchronous air core machine
- HTS in DC rotor field only
- Rotor is vacuum insulated
- Refrigeration in the stationary reference frame
- Copper “Litz” armature (>room temp)
- Low reactance due to large effective air-gap
- Effectively zero rotor I^2R high efficiency
- Removal of iron teeth removes another major source of loss
- Lack of iron teeth removes a major source of structure borne noise
- Uses any drive suitable for a synchronous machine



*PM &
Conventional*



*Air
Core
HTS*



AMSC 5,000 HP 1800 rpm: Previous HTS Motor Development Activities



The AMSC-Reliance Electric Phase I development of a 200 HP motor successfully concluded in 1996



The AMSC-Rockwell 1,000 HP motor (Phase II) satisfactorily tested in Summer 2000 and has since exceeded performance expectations



Siemens Large Drive Division in cooperation with Siemens R&D center at Erlangen recently tested a 380 kW HTS-motor, funded by the German Ministry for Education and Research (BMBF).

AMSC 5,000 HP 1800 rpm: AMSC 5000 hp Motor Parameters & Test Results

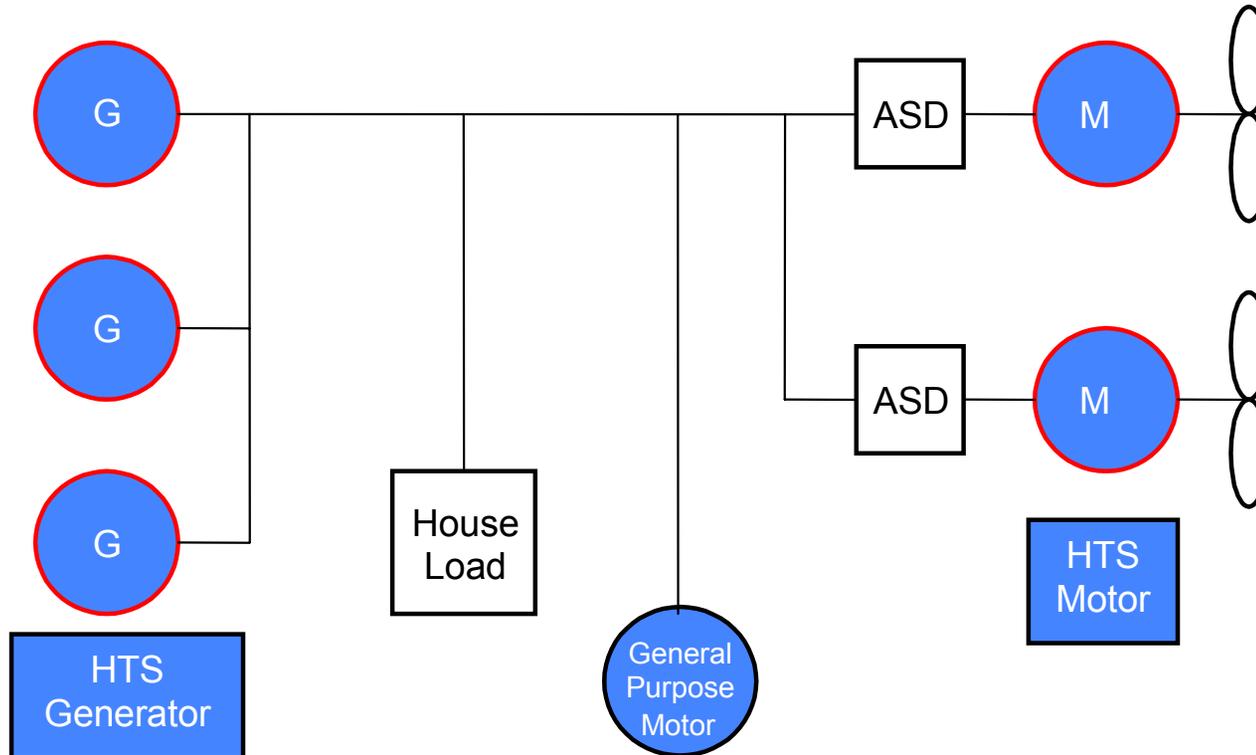
- Factory and load testing complete per IEEE 115
- The motor is 97.7% efficiency
- 1/3 reduction in volume compared to the industry standard
- 40% reduction in losses compared to the industry standard



List of parameters	List of parameters
Motor output	Motor output 5000 hp (nominal, tested to 7,000 HP transient, and 5900 HP maximum steady state)
Speed	1800 rpm
Pole number	4
Line voltage	6.6 kV
Full load efficiency	97.7 %
Operating power factor - leading	0.99
Straight length of machine	23.2 inches
HTS field inductance	8.8 Henry
HTS field current	156 Amps
Stator resistance	0.10 Ohm
Stator current	333 Amps
Load angle at full load	-17.069 deg
D-axis synchronous reactance	0.32 pu
Q-axis synchronous reactance	0.32 pu
D-axis transient reactance	0.27 pu
D-axis subtransient reactance	0.173 pu
Q-axis subtransient reactance	0.173 pu
Stator short circuit time constant	0.031 sec

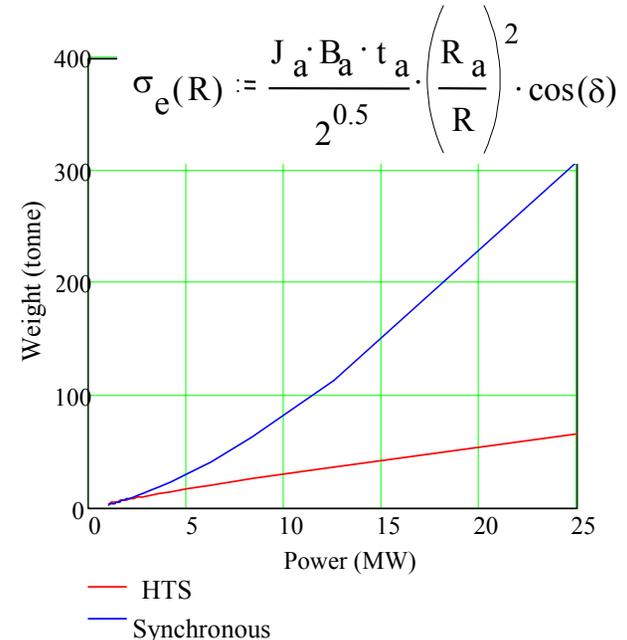
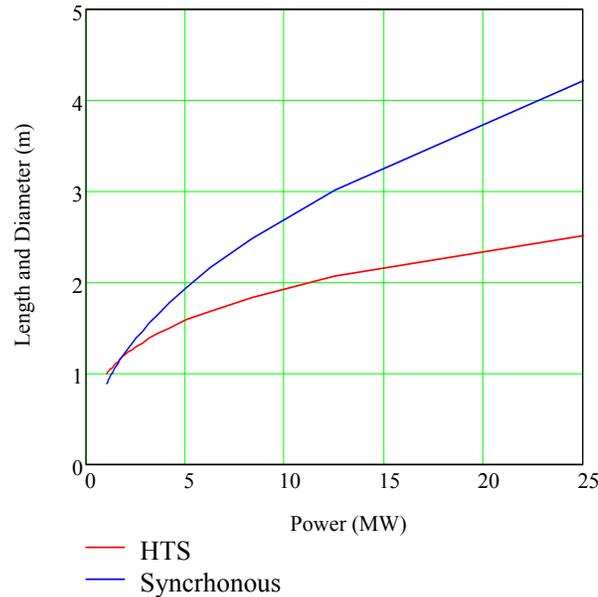
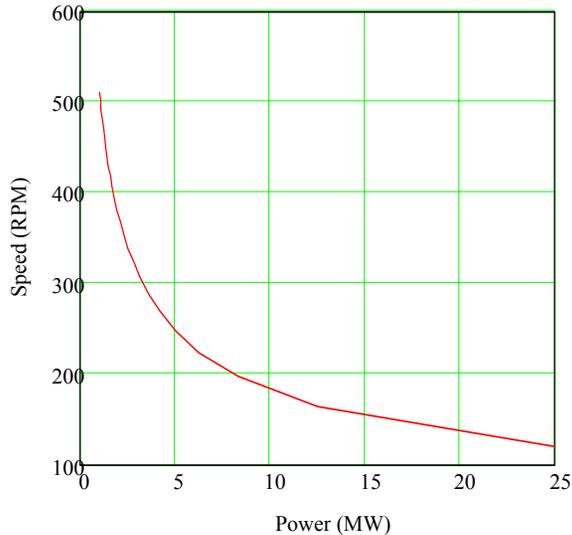
Achieved Successful Demonstration of a Powerful HTS Motor

Ship Propulsion: Electrical System Components

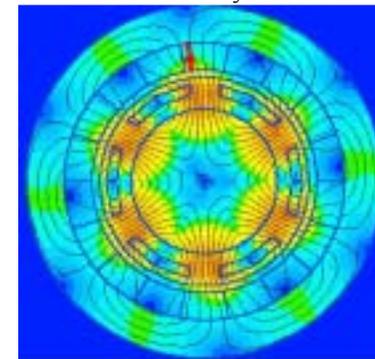


The Ship Electrical System Could Employ HTS Generators, Propulsion Motors And General Purpose Motors

Ship Propulsion Sizing: Approximate HTS Machine Scaling Advantage for Ship Drives

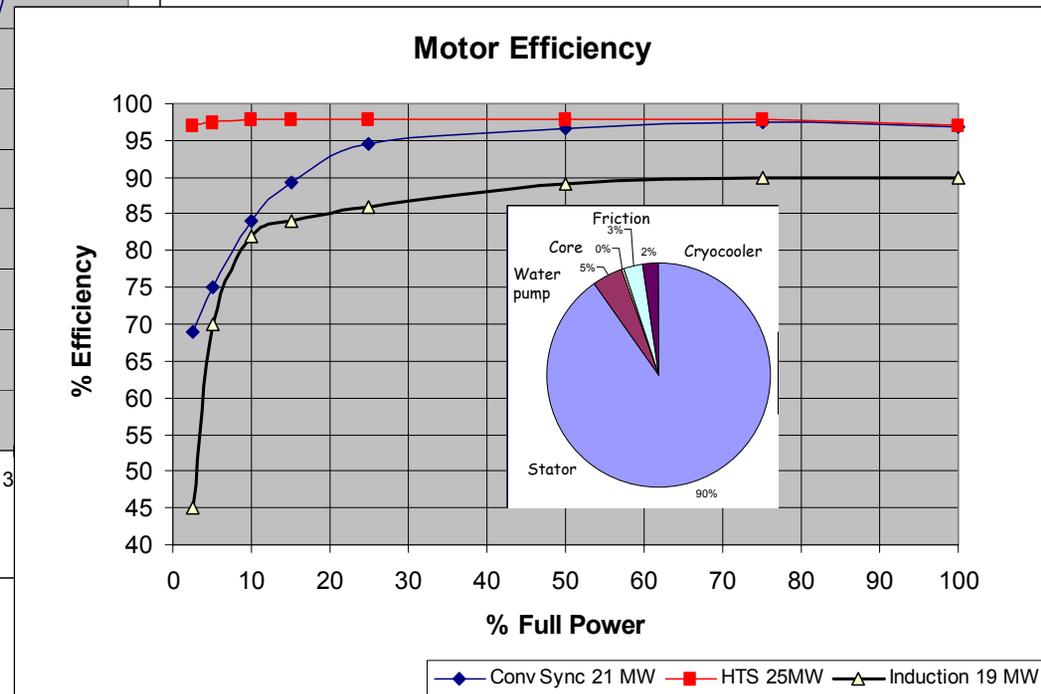
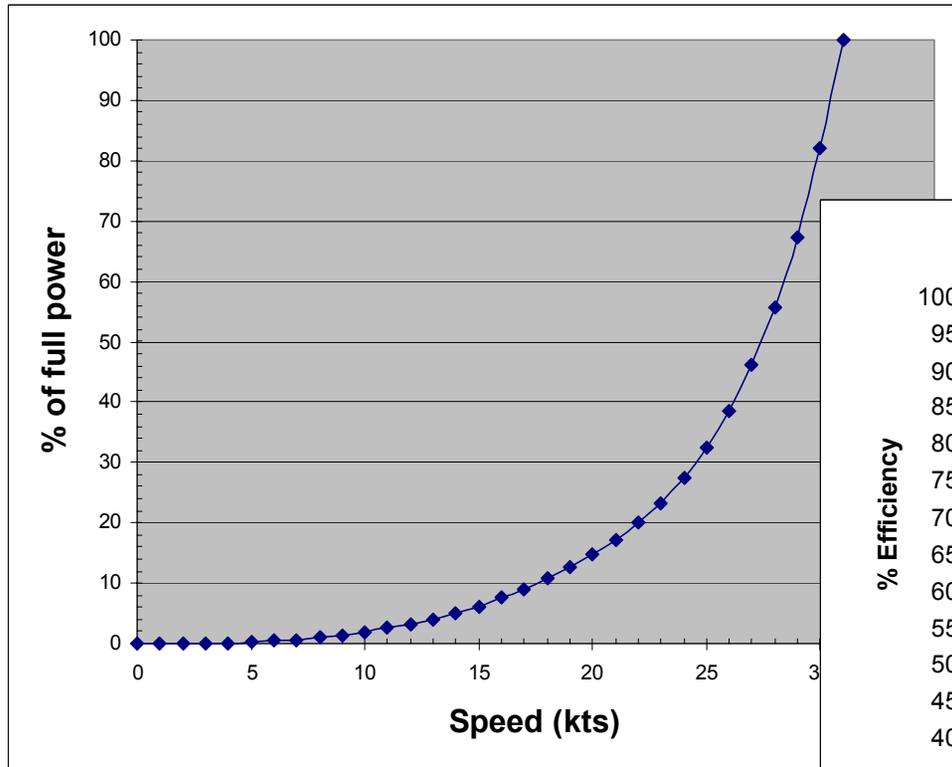


- HTS machine torque scales as the 5th power of dimension
- Most conventional machines scale as the cube of dimension
- The true advantage of HTS machines is realized in high torque applications
- A number of machines have been studied and the above scaling provides an approximate indication of the advantage
- High gap shear stress between 20 and 70 psi



Ship Propulsion Sizing

Key HTS Issues: Full and Part Load Efficiency



The Efficiency Advantage at Full Speed is Significant and at Part Load is even Larger.

5 MW: Status

- **Key achievements of 2000***
 - Completed 25 MW, 120 RPM motor conceptual design
 - Defined specifications for a sub-scale 5 MW motor for component development
 - Identified critical components for development
 - Performed some component development work
- **Key achievements of 2001***
 - Designed 5 MW sub-scale motor
 - Started manufacturing 5 MW polesets
- **Key activities in 2002****
 - Manufacturing 5 MW sub-scale
- **Key activities in 2003****
 - Complete motor assembly
 - Factory testing



* Funded by the Office of Naval Research

** Funded in part by the Office of Naval Research

5 MW: Component Validation - Rotor Testing

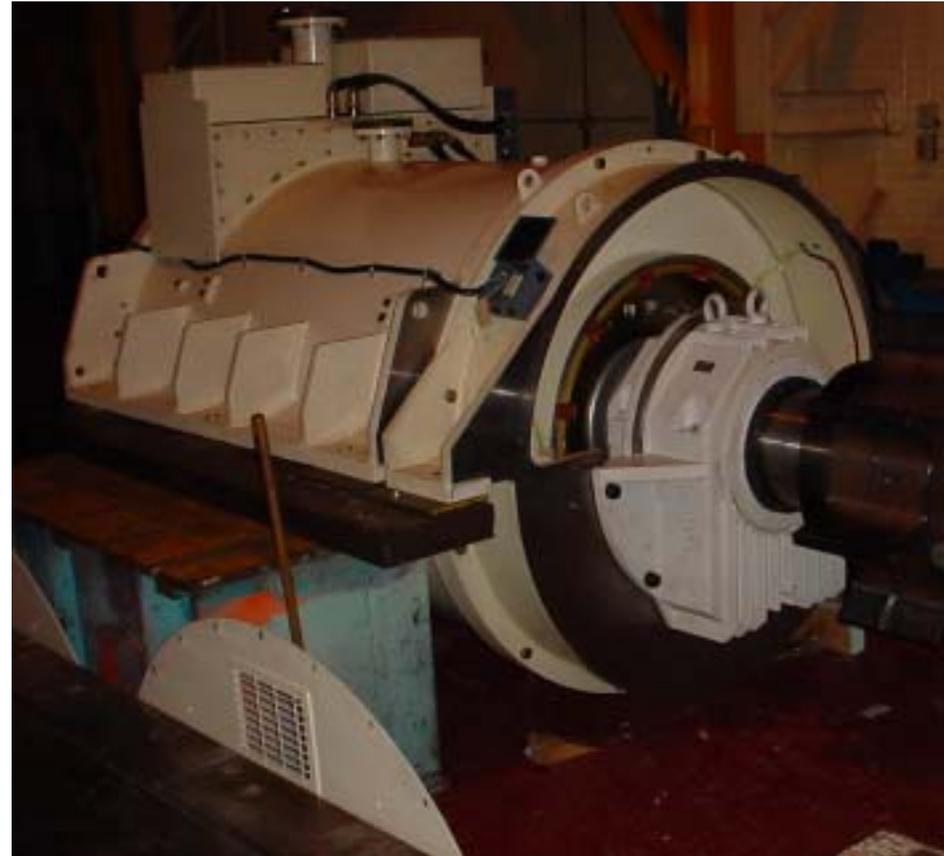
The rotor and associated hardware has been tested including:

- Excitation/Telemetry – full current
- Refrigeration – operating temperature in full and degraded modes
- Field winding – full design current



Assembled 5 MW Motor

- Motor Assembly completed
- No load testing begins in early February



YBCO Specification for Motors

Requirement	Value
Mechanical	3 ksi cyclic fatigue normal to broad face.
	>-0.2 % & >+0.3 % strain in the wire direction.
Bend	>3 inch diameter, prefer neutral axis

YBCO Specification for Motors

Requirement	Value
Operating Temperature	>35 K
Current	100 to 200 A @ T,B
Width	<5 mm
Limiting flux density	1 to 3 T
Field Dependence	45 deg limits
Current Density	$J_e \sim 20000 \text{ A/cm}^2$

YBCO Specification for Motors

Requirement	Value
Stability	Local defects generate < 0.25 W
DC dissipation	0.5 W/km
AC loss	on some transients.
Fault/Recovery	2 times operating current @ 160 ms

Summary: We are Focused on Key Electric Machine Markets

- Ship propulsion is our primary focus because of HTS machine scaling advantages relative to other technologies.
- Naval and marine motors are our first target.
- Naval and marine generators are the next logical target.
- Today's technologies will meet the selected market needs.
- YBCO developments will extend the market for this technology.

We are Positioned to Capitalize on Wire and Refrigeration Enabling Technologies Available Today and Tomorrow