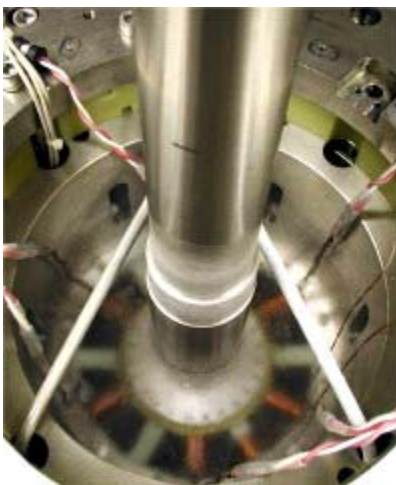


# Cryogenic Electric Motor Tested

Technology for pollution-free "electric flight" is being evaluated in a number of NASA Glenn Research Center programs. One approach is to drive propulsive fans or propellers with electric motors powered by fuel cells running on hydrogen. For large transport aircraft, conventional electric motors are far too heavy to be feasible. However, since hydrogen fuel would almost surely be carried as liquid, a propulsive electric motor could be cooled to near liquid hydrogen temperature (-423 °F) by using the fuel for cooling before it goes to the fuel cells. Motor windings could be either superconducting or high-purity normal copper or aluminum. The electrical resistance of pure metals can drop to 1/100th or less of their room-temperature resistance at liquid hydrogen temperature. In either case, super or normal, much higher current density is possible in motor windings. This leads to more compact motors that are projected to produce 20 hp/lb or more in large sizes, in comparison to on the order of 2 hp/lb for large conventional motors. High power density is the major goal. To support cryogenic motor development, we have designed and built in-house a small motor (7-in. outside diameter) for operation in liquid nitrogen.



*Switched reluctance motor submerged in liquid nitrogen (with 6 of 12 motor coils and a sensor coil installed).*

The motor is of the switched reluctance type. It can run both at room temperature and in liquid nitrogen. In early testing, we operated it in liquid nitrogen to 11,000 rpm and at room temperature to 16,000 rpm. The motor produced 10.6-kW (14.2-hp) power and 21 N·m (15.5 ft·lb) torque with all of its 12 coils installed. Operating with only its own inertia as a load, the motor can accelerate from a 500 rpm idle to 8000 rpm in 0.23 sec. It is shown in the photograph submerged in liquid nitrogen. The haziness is due partly to the liquid nitrogen that covers the motor and partly to moisture from the room condensing in the cold nitrogen gas over the motor. Frost is also visible on some of the parts.

The maximum current density we have used is 30 A/mm<sup>2</sup>, which is not sustainable at room temperature in a steady state. (Maximum room-temperature current density in steady state would be about 11 A/mm<sup>2</sup>). However, in liquid nitrogen we have shown that

maximum coil current densities of about 100 A/mm<sup>2</sup> (at the 50-percent duty cycle for coils in the motor) are possible in a steady state for coils that are specially configured for good heat transfer.

Upgrading the power conditioning will extend the high torque produced at low rpm to higher rpm. This will markedly increase the power production (and hence the specific power). The present limits of 160 V and 30 A per phase will be increased to 300 V and 100 A per phase in the first upgrade stage. A factor of 4 or more increase in power (from 14 kW) is predicted in the upgraded configuration.

The motor serves two purposes. It is a test bed for special motor winding configurations, and it will validate structural, electromagnetic, and heat transfer analysis and design procedures that can subsequently be applied to liquid-hydrogen-cooled motors.

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