characteristically high starting torque accompanied by its low overall aerodynamic efficiency. Perhaps its most important future use will be in conjunction with a Darrieus rotor to supply the necessary starting torque.

The Darrieus rotor looks somewhat like an "eggbeater" (Fig. 5). The blades are high-performance symmetric airfoils formed into a gentle curve called a "troposkien." This shape is selected to minimize the bending stresses in the blades. There are usually two or three blades in a turbine, and as shown in Fig. 2, the turbines operate efficiently at high speed.

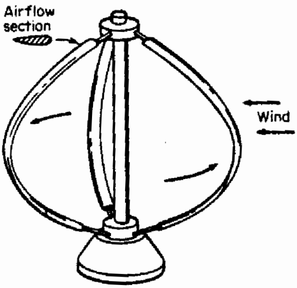

Fig. 5 Darrieus rotor.

The third important cross-wind-axis turbine, the cyclogiro wind turbine (Fig. 6), is similar to the Darrieus rotor but with two important differences. First, the airfoils are straight, and second, the orientation (pitch) of the blades is continuously changed during rotation to maximize wind force. The peak power coefficients predicted for these turbines are greater than for any turbine (Fig. 2). Notice that the cyclogiro-turbine performance curve slightly exceeds the theoretical maximum for wind-axis turbines because the cyclogiro turbine decelerates a larger portion of the wind than does a wind-axis turbine of the same projected area of rotor disk.

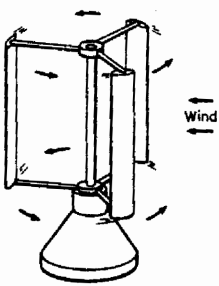

Fig. 6 Cyclogiro rotor.

A major advantage of the Darrieus rotor—insensitivity to wind direction—is not a property of the cyclogiro turbine. For maximum efficiency the cam mechanism which controls local blade pitch must be continuously oriented into the wind. Care must be taken not to overemphasize the aerodynamic efficiency of wind-turbine configurations. The most important criterion in evaluating WECSs is the power produced on a per-unit-cost basis. The relationships between the turbine configurations discussed here and their potential production costs are not well known at this time. However, this information will be forthcoming.

Wind-augmentor systems are also being studied in conjunction with wind turbines. Two of the most important are the diffuser-augmentation and the vortex-augmentation systems. The cost effectiveness of these systems is not known at this time.

Use of Wind-Energy Conversion System Historically, wind-energy conversion systems were first used for milling grain and for pumping water. These tasks were ideally suited for wind-power sources, since the intermittent nature of the wind did not adversely affect the operation. Because water pumping is such an ideal load match for a wind-power system, there will no doubt be a resurgence and an expansion of irrigation and stock-watering usage powered by WECS.

The largest impact of wind power on the energy picture in the developed countries of the world is expected to be in the generation of electric power. This will probably involve pumping power directly into the power grid. Some applications may tie in with energy-storage systems involving compressed air, storage batteries, heated or pumped water, production of hydrogen, etc.

The generation of electricity will probably be accomplished by one of two systems: (1) synchronous ac generators, which require the wind turbine to operate at constant r/min; (2) variable r/min constant-frequency systems, which may be alternators rectified to dc (and then perhaps inverted to ac) or field-modulated generator systems.

Power in the Wind There are three major considerations

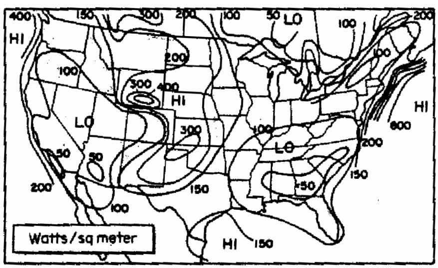

Fig. 7 Annual average available wind power in the United States.

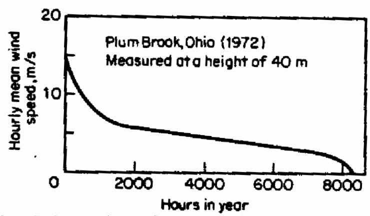

Fig. 8 Wind variability at Plum Brook, OH (1972).