The Power Tower

by Scott S. Pickard*

An aeroelectric system cools air in a large concrete chimney-like structure which produces a down draft that drives turbines and turns generators to produce electricity. While giving a general introduction to the entire system and its development, this article focuses on the design and construction of the concrete chimney, which presents the greatest single challenge towards the realization of aeroelectric solar power.

Keywords: chimneys; concrete construction; corrosion resistance; dynamic loads; earthquake resistant structures; marine atmospheres; **precast concrete;** protective coatings; weatherproofing; wind pressure; structural design.

The concept of aeroelectric solar power proposes to build an electrical power generation system that extracts solar energy from the atmosphere. The system consists of an 8000 ft (2438 m) chimney-like structure into which atomized water is sprayed at the top (Fig. 1). The evaporation of the spray causes the air to cool and the cooled air sinks down the chimney. This flow of air turns wind turbines that are coupled to electrical generators. The amount of power produced depends on current atmospheric conditions (temperature and humidity) and the volume of water supplied to the system. The power can be regulated to correspond to the needs of a regional power network.

Although the idea for aeroelectric power was formulated during a 1965 Lockheed study of desalination, the major development has been carried out by Agbabian Associates of El Segundo, California. Prior to joining that firm in 1978, the inventor, Dr. Phillip R. Carlson, carried out a four-year independent investigation. Since then, he and other staff members, under the direction of Dr. M. S. Agbabian, have been attempting to develop the concept into constructible and economically viable designs. As a result of this work, other industrial organizations have been added to provide expertise in all critical areas. The industrial team now includes:

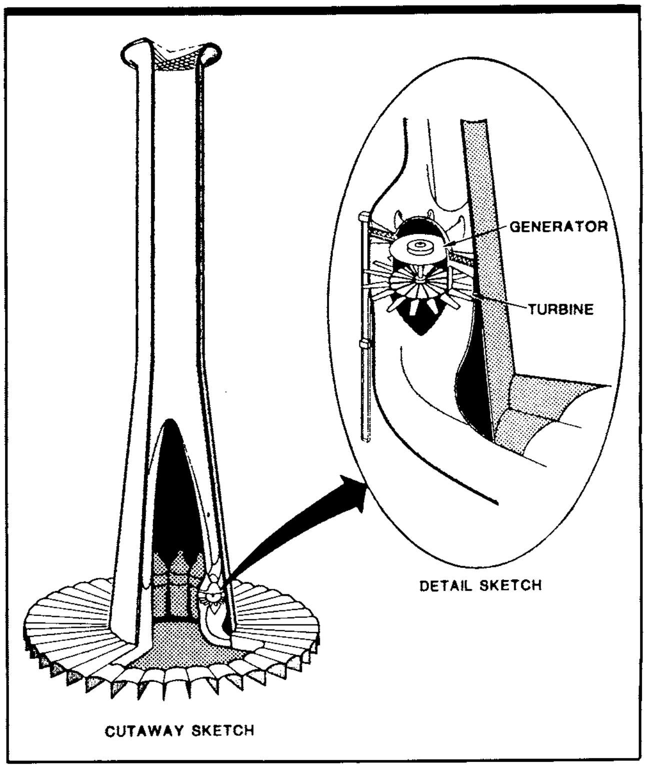

Fig. 1 — The aeroelectric power plant consists of a tall chimney-like structure into which atomized water is sprayed at the top. Cool air descends and turns turbines that are connected to electrical generators.

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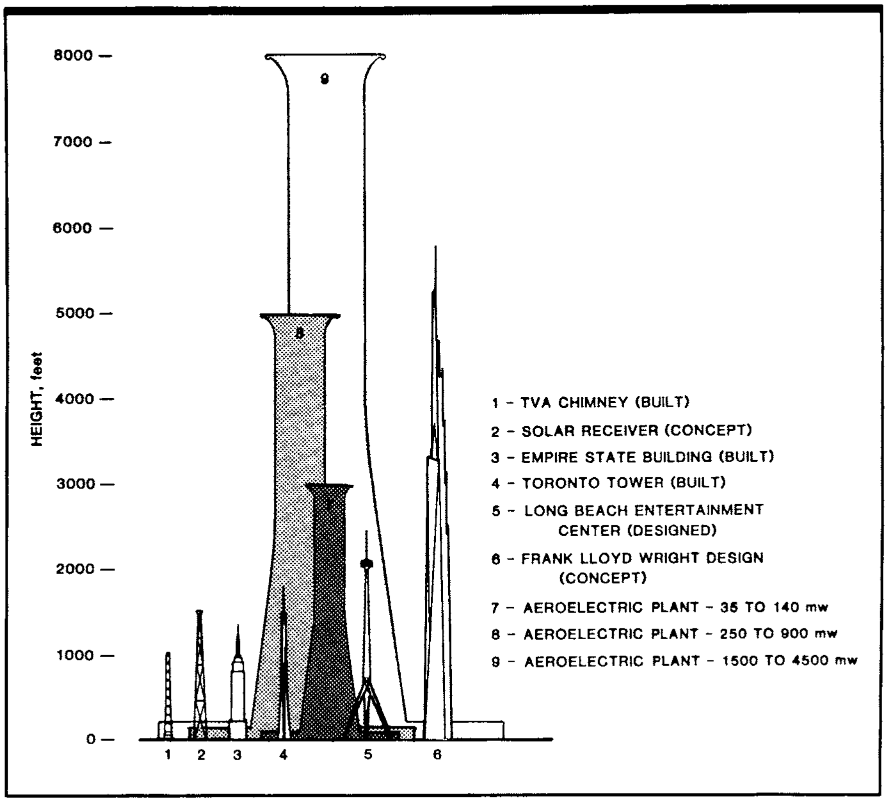

Fig. 2 — In terms of sheer size, the aeroelectric plant rivals any structure conceived by man.

1. Agbabian Assoc., El Segundo, Calif. — Systems engineering, structural design.
2. Morrison-Knudsen, Boise, Idaho — Chimney and aqueduct construction.
3. Siemens-Allis, Atlanta, Georgia — Electrical power output.
4. Allis-Chalmers, Milwaukee, Wisconsin — Pumping.
5. The Budd Company, Ft. Washington, Pennsylvania — Wind turbine design.

It is estimated that an aeroelectric power plant can produce electricity on a scale with hydroelectric power. And while depletable fuels will become more and more expensive, the fuel for aeroelectric power is water and remains unlimited and virtually unaffected by economic inflation.

Commercialization of the concept requires the production of subsystems that rely on technologies already well established. It is proposed that the system be largely assembled with either existing hardware or modifications to that hardware.

But in terms of sheer size, the aeroelectric plant rivals any structure conceived by man (Fig. 2). The immense size of the concrete chimney challenges the imagination, and its construction presents the greatest single challenge towards the realization of aeroelectric solar power.

A preliminary design concept

The basic configuration of the chimney (as proposed at this point in the concept's development) is a vertical cylinder stiffened for buckling by external horizontal rings with vertical ribs providing longitudinal support for the cylinder wall. This concept is analogous to the thin-shell monocoque construction used in the aerospace industry for airplanes and space vehicles. It is proposed to construct the chimney with prestressed precast concrete modules.

The chimney must withstand the steady loads due to gravity and the dynamic loads due to wind and earthquake. It must also withstand the effects of weather for the 100-year planned life of the structure. Stress computations have been carried out for a baseline system utilizing an 8000 ft (2438 m) chimney.

The diffuser structure is a relatively low and large-diameter roof supported by radial vertical walls spaced at 6 deg intervals around the chimney (Fig. 1). The roof consists of individual vaults resting on the walls. The inner circle of the roof and the walls terminates and is built in at the chimney. The outer circle of the diffuser is open to permit the spent air to exhaust directly to the atmosphere. The size of the diffuser is small in comparison to the chimney, but the diffuser by conventional standards is large with a height of approximately 270 ft (82 m) and a width of 210 ft (64 m) at each opening.

Tapered barrel vaults are very strong in resisting gravity loads and vertical earthquake shaking. The vaulted roof design is a compromise meant to resist combined horizontal and vertical shaking as well as dead weight loads.

Construction of the chimney

Precast concrete module construction, at this time, appears to be the best construction approach (Fig. 3).

An assembled module would consist of three parts: the chimney wall, a horizontal x-element, and a vertical x-element. Modules for the top portion of the structure would weigh approximately 25 tons. Near the bottom, their weight would be 6 times this figure. Approximately 40,000 modules would be required for the entire chimney.

Vertical (gravitational) loads would be carried by inner and outer concrete beams. The beams would be continuous from top to bottom.

Horizontal (ovaling) loads due to wind would be carried by horizontal circumferential concrete beams. These beams would be post-tensioned by wire cables running through them. These cables would be continuous around the entire chimney. The wire would exert sufficient compressive forces so that under the maximum ovaling load no beam would experience tension.

Shear loads would be carried by diagonal concrete struts between the inner and outer vertical beams. Similar struts extend between the inner and outer horizontal beams.

Since the network of beams and struts does not provide stability against torsion, torsional stiffness would be provided by the chimney wall, which is attached to the inner vertical and horizontal beams.

A repetitive procedure could assemble this system of beams into modules, which in turn would combine to form the overall structure.

One concept for a crane to lift and place the precast modules involves support at 4 points on a rail that is attached to the inner surface of the chimney (Fig. 4). The hoisting cable would be wound on a drum at the base of the chimney. The drum and power unit would be on a mobile platform that could position itself directly below the crane.

The two outer arms of the crane would be attached at the top by telescoping devices that permit the crane to tip forward until it is approximately over the desired position. Wind forces on the module would be so great that powered winches would be necessary to handle the cables to orient and position the section.

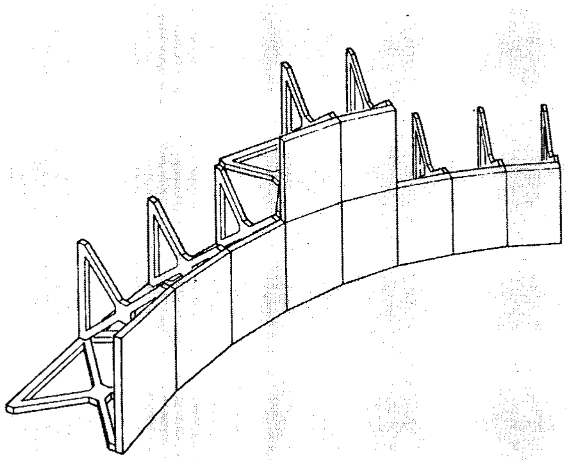

Fig. 3 — Precast concrete lattice modules.

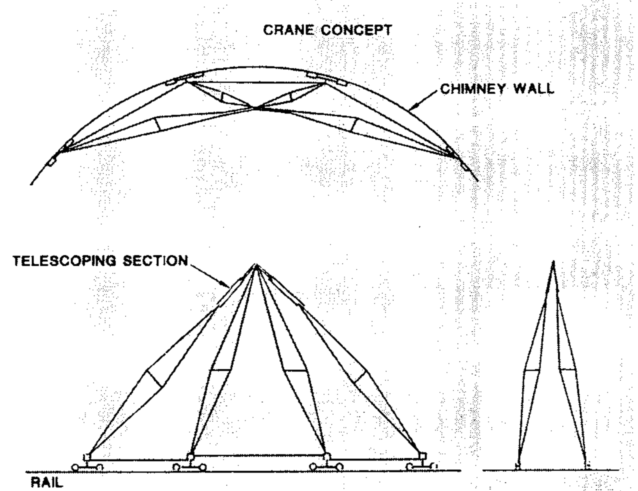

Fig. 4 — Crane mounted on chimney inner wall.

Seawater corrosion

The inner wall of the chimney would be wet continuously with seawater droplets emerging from the atomizer. These droplets increase in salt concentration as the air moves downward, so that near the bottom and in the diffuser area the salt concentration could be as much as 10 times that of ocean water. To prevent chloride corrosion of the reinforcing steel, and corrosion of the concrete from other constituents of the seawater, it is planned to coat the inner surface of the chimney and diffuser with an organic elastomeric coating.

Prospects for development

The development team's objective is to make aeroelectric solar power a reality and be a contributing source of energy for the country.

Preceding a full-scale plant would be a demonstration system that justifies further development efforts. The demonstration plant must show that investment cost per kilowatt and a total cost per kilowatt hour for full-scale systems are competitive. Environmental acceptability must be scrutinized since this factor has restricted the development of electrical power plants of all types. □

Information and figures for this article were substantially taken from "Aeroelectric Solar Power," Agbabian Associates, El Segundo, CA, June, 1980, Revision 1, July 3, 1980.