Green Buildings and Energy Efficiency

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atmospheric vortex engine

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The atmospheric vortex engine (AVE) uses an artificially created anchored vortex to capture the mechanical energy produced during upward heat convection. The vortex is created by admitting warm or humid air tangentially into the base of a circular wall. The heat source can be solar energy, warm seawater, warm humid air or waste industrial heat. The mechanical energy is produced in peripheral turbo-generators. The process has the potential of producing enough carbon free electricity to meet all human needs.

An atmospheric vortex engine (AVE) could look like a natural draft-cooling tower with a small controlled vortex firmly anchored at the center. The conceptual photograph of a cooling tower of Fig. 1 illustrates how a vortex engine will appear from a distance. From the inside a vortex engine will look like a large open room circular arena with a dust devil firmly anchored at its center. Fig. 2 illustrates how a natural draft-cooling tower could be modified to produce a vortex. The circular wall could have a diameter of 200 m and a height of 50 to 100 m; the vortex could have a diameter of 30 m at the base and could extend to a height of up to 15 km. An AVE could generate 200 MW of electrical power.

The heat required to sustain the vortex can be the naturally occurring heat content of ambient air or can be provided in peripheral heat exchangers; the heat source for the heater can be warm seawater or waste industrial heat. The air heaters can be wet or dry heat exchangers.

The AVE harnesses the energy responsible for hurricanes, tornadoes and waterspouts. The AVE has the same thermodynamic basis as the solar chimney except that the wall of the physical chimney is replaced by centrifugal force in a vortex and the solar collector is replaced by the earth’s surface in its unaltered state. A solar chimney consists of a tall vertical tube surrounded by a transparent solar than a physical chimney and therefore can achieve much higher heat to work conversion efficiency.

Admitting warm air tangentially at the base of a vertical axis cylindrical wall produces a convective vortex, which acts as a dynamic chimney. The vortex would be started by temporarily heating the air with fuel or steam. The pressure difference between the ambient air surrounding the station and the base of the vortex is used to drive the turbines.

Warm air enters the area within the cylindrical wall, called the arena, via tangential entry ducts. The airflow is controlled with adjustable restrictors located either upstream of the air heaters or within the tangential entry ducts. An annular roof with a central circular opening forces the air entering the arena to converge thereby forming
Atmospheric Vortex Engine

The concept was tested by AVEtec on 1 m and 4 m diameter physical models. The model vortex, which looked like a miniature dust devil, was made visible with smoke. The 4 m diameter model produced a 30 to 50 cm diameter vortex extending up to 20 m above the top of the model. Propane heaters were used to warm the air before it entered the tangential entry ducts. Figs. 4 shows photos of vortices produced with the 4 m model.

A natural draft chimney is a cylinder in radial compression, which prevents cooler ambient air from mixing with warm rising flue gas. In a vortex, the centripetal force replaces the physical chimney wall and prevents ambient air from being entrained in the rising air stream. The diameter of the vortex is self-regulating and adjusts itself until the radial pressure differential is balanced by centrifugal force of the rotating air column. The entry of air in the vortex is restricted to a thin layer next to the underlying surface wherein tangential velocity is reduced by friction.

Cooling towers are commonly used to transfer waste heat to the atmosphere. Using round numbers for illustration, a 500 MW thermal power plant typically rejects 1,000 MW of waste heat. An atmospheric vortex engine will increase the electrical output of a 500 MW plant to 700 MW by converting 20% of its 1,000 MW of waste heat to work, thereby increasing the electrical output by 40%. The AVE increases the efficiency of a thermal power by reducing the temperature of the heat sink from +30 °C at the bottom of the atmosphere to –70 °C at the tropopause. Fig. 5 shows how the AVE could increase the efficiency of any thermal power plant.

**Thermodynamics**

The work produced when a mass of air is raised isentropically from the earth’s surface to the tropopause is readily calculated with the total energy equation and is equal the reduction in the enthalpy of the air minus the increase in its potential energy. The energy produced by raising air at a pressure of 101 kPa to the 10 kPa level is close to zero when the initial temperature and humidity are 24.5 °C and 90% respectively, but increases to 4000 J/kg when the initial temperature and humidity are 24.5 °C and 100% respectively. Energy production increases with the temperature and humidity of the raised air. Humidity can readily be increased by bringing the air to equilibrium with warm water in a wet cooling tower. A mechanical energy of 4000 J/kg corresponds to a velocity of 90 m/s and to a pressure at the base of the rising air column of 96.5 kPa. Saturating the air with 30°C water would yield a specific work of 25000 J/kg corresponding to a velocity of 220 m/s.
Hurricanes depend on self-induced heat transfer from the oceans. The energy of hurricanes is mainly due to the enhanced sea to air heat transfer as a result of spraying warm water into the air. The temperature of the air at the eyewall where the air rises is typically 1.5°C lower than the eyewall surface temperature (SST). Eyewall relative humidity is typically 97%. The 24.5°C saturated air can be produced by spraying 26°C water in the air. The minimum SST required for hurricane is 26°C. Tropical sea-surface temperatures can be as high as 32°C. The temperature of power plants waste heat can be as high as 50°C.

The heat to work conversion efficiency corresponds to the efficiency of a Carnot engine where the hot source temperatures is the earth’s surface temperature and where the cold source temperature is the tropopause temperature. Approximately 35% of the heat received at the surface is converted to work during the convection process regardless of whether the heat is received as sensible or latent heat.

The temperature of saturated air decreases less rapidly with decreasing pressure than the temperature of unsaturated air because the heat of condensation warms the rising air. Heat of condensation comes into play once the condensation level has been reached which is usually at elevations of between 500 and 3,000 m. The heat source in a solar chimney, which cannot extend high enough to reach the condensation level, must be sensible heat. The heat source in a vortex engine, where the vortex can extend well past the condensation level, can be the latent heat or sensible heat. The heat source in an atmospheric vortex engine can have a lower temperature than the heat source in a conventional solar chimney because evaporation can occur at wet bulb temperature, which is lower than dry bulb temperature. Reduced pressure at the base of the vortex further enhances the heat transfer from water to air thereby increasing the enthalpy of the air and the power production.

Giving the rising air rotation about the vertical axis causes the air to spin as it rises. The resulting centrifugal force opposes the radial differential pressure. Turbulence is inhibited because when a particle of air moves inward its tangential velocity increases to conserve angular momentum, resulting in an increase in centrifugal force, which in turn pushes the air particle outward. As a result, the flow in the vortex is laminar instead of turbulent, as evidenced by the smooth thread shape often observed in waterspouts. Centrifugal force stabilizes the flow thereby reducing turbulence and friction losses. The rising air behaves like a spinning top being raised; there is little decrease in the angular momentum of the large mass of rising air in the 30 minutes or so required the air to rise from the bottom to the top of the troposphere.

Based on a specific work of 10 kJ/kg of air, a 200 MW vortex engine will have a heat input of 1,000 MW with air and water flows of 20 Mg/s, and 40 Mg/s respectively. In a vortex engine with 20 peripheral wet heat exchangers, the work and heat duty per sector will be 10 MW and 50 MW respectively. Each sector will have a single 10 MW turbine with a diameter of 5 m. Based on a precipitation rate of 12 grams of water per kilogram of air, the precipitation would be 0.24 Mg/s or 20,000 Mg/d. The precipitation produced by an AVE would be small compared to that produced in natural storms. The 20,000 Mg/d of precipitation produced by a 200 MW vortex power station will produce a rainfall of 2 mm/d when spread over an area of 10 km². The horizontal extent of the cloud cover in the downwind direction will be approximately 20 km. Airplanes could easily avoid the small highly visible vortex in a known location.

An AVE will be provided with numerous safety features to eliminate hazards. Redundant air dampers and quench systems will be provided to permit rapid shutdown. The airflow and the diameter of the vortex will be limited by the size of the tangential air entries. Natural vortices are rare in spite of the fact that natural heat sources are ubiquitous. Testing of large prototypes will be restricted to remote locations and stable atmospheric conditions until the ability to control the vortex including starting and stopping at will is demonstrated. An AVE may reduce the likelihood of natural storms by reducing the heat content of surface air in its vicinity. Entry of birds and bats could be prevented by placing screens upstream of the turbines.

The most favorable sites for the production of controlled vortices are likely to be found in maritime tropical locations like India. The water production benefits could be invaluable in dry climates. The large difference in temperature between waste heat source and ambient air in cold climates could provide favorable locations when the heat source is waste heat.

Extensive background technical information including: peer reviewed article, in depth thermodynamics analysis, drawings and videos of
models, and reference material is available on Vortex Engine web site: http://vortexengine.ca. There is a technical presentation at: http://vortexengine.ca/misc/Thermo_Pres_Short.ppt

The AVE has potential to produce large quantities of carbon free energy because the atmosphere is heated from the bottom by solar radiation and cooled from the top by infrared radiation. There is a potential of converting and capturing 10% to 35% of the heat carried upward by convection to work. Fig. 6 shows that converting 12% of the heat carried upward by convection in the atmosphere could produce 3000 times the present world electrical energy production. The energy production potential of the AVE is far greater and its cost is far less than those of more conventional solar power plants because the solar collector is the earth’s surface in its unaltered state.

Providing the energy need of a city with conventional solar power plants would require an area 50 to 500 times the area of the city and would make the area unavailable for other uses such as farming. An AVE power plant would have approximately the same footprint as a thermal power plant of equivalent capacity. Fig. 7 shows that the heat content represented by a 3°C of tropical sea temperature is 20 times the heat content of the remaining world oil resources. The AVE process provides a means of converting 30% of this heat to useful work. There is no need for collecting the solar heat; it is already stored in our oceans. Fig. 8 illustrates how the AVE replicates the waterspout process and captures the energy produced by upward airflow of humid air.

The existence of tornadoes, waterspouts, and dust-devils provides experimental proof that low intensity solar heat can produce high intensity mechanical energy. The energy produced by a tornado can be as much as produced by a large thermal power plant. The mechanical energy produced by a large hurricane can be more than the energy produced by humans in an entire year. There is plenty of stored energy already available on our planet, but we have not yet figured out how to harness it. The AVE produces a controlled river of rising air and captures the work produced by the convection process. The AVE has the potential of capturing the energy content of low temperature heat source such as warm seawater.

In addition to producing energy, the AVE process could be used to alleviate global warming, to produce precipitation, to enhance the performance of cooling towers, or to clean or elevate polluted surface air. The feasibility of the process can be demonstrated with a 50 m diameter proof of concept pilot plant. A pilot plant will not need heat exchangers; the air can be heated with steam. There is also no need for turbines or generators at the pilot plant stage. Developing the AVE will require cooperation between engineering and atmospheric science disciplines.

Developing the AVE requires the support of engineers who understand power production, who are willing to broaden their horizon and to consider new approaches, and who are capable of solving the problems that will arise during process development. The technical challenges are no more complex than with many industrial processes.

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