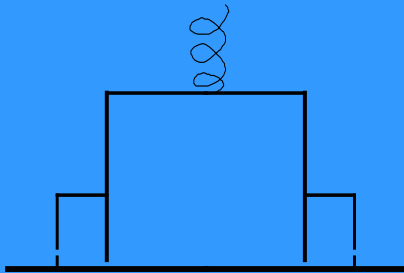
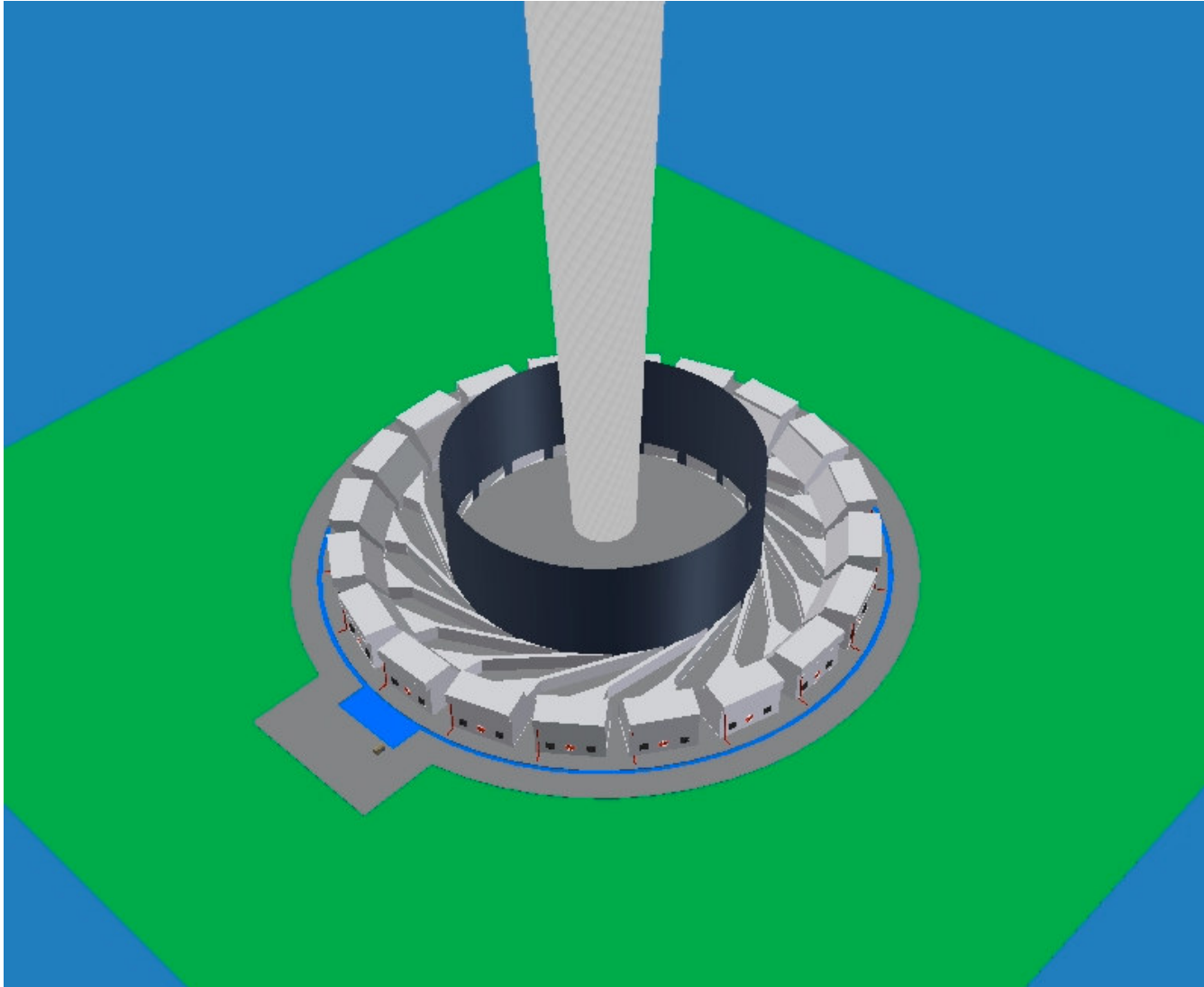




Atmospheric Vortex Engine

- Work is produced when heat is carried upward by convection in the atmosphere because more work is produced by the expansion of a warm gas than is required to compress the same gas after it has been cooled.
- The atmosphere is heated from the bottom by solar radiation and cooled from the top by short wave radiation to space.



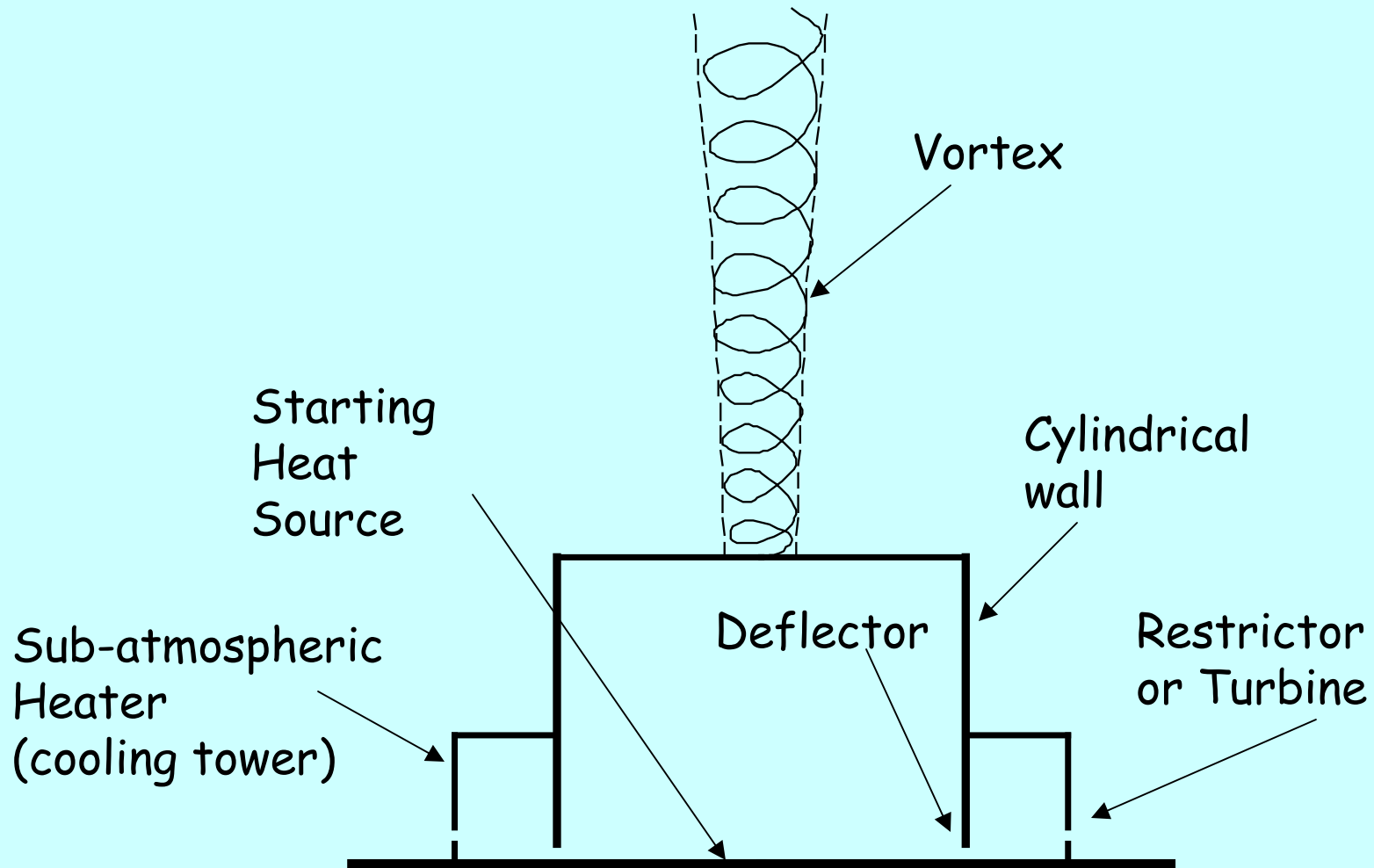


Vortex Power Station

LMM

Atmospheric Vortex Engine

2



Vortex Engine Key Components

Engine Features (1)

- The vortex is produced by admitting heated air tangentially in the base of a cylindrical wall.
- The air is heated with a low temperature heat source in a peripheral crossflow cooling tower.
- The mechanical energy is produced in a plurality of peripheral axial flow turbines.
- The vortex is started by heating the air within the station with fuel or steam.

Engine Features (2)

- The quantity of air entering the circular wall is controlled with adjustable restrictors located upstream of the deflectors.
- The vortex is stopped by restricting the flow of heated air with cyclonic rotation and if necessary opening the flow of unheated anti-cyclonic air.
- The intensity of the vortex is controlled by selectively admitting heated and unheated air through sets of deflectors with appropriate orientation.

Engine Features (3)

The heat to sustain the vortex can be:

- The natural heat content of ambient humid air,
- Heat transferred to the air in a peripheral heat exchanger.

The source of the heat can be:

- Waste industrial heat,
- Warm sea water,
- Solar heat.

There is no need to collect solar energy, existing low temperature heat sources are sufficient.

A vortex engine could eliminate the need for costly power plant heat disposal systems.

Engine Features (4)

- Work is produced when warm air is raised.
- The work produced when a kilogram of warm humid air is raised from the bottom of the atmosphere to the tropopause (12 to 18 km) can be 1000 to 5000 J/kg.
- The work produced when a kilogram of water is lowered 100 m is only 1000 J/kg.
- Warm humid air is widely available.
- Atmospheric work of convection is much greater than the kinetic energy of horizontal wind.
- With an appropriate mechanism the work of convection can be transferred down to the surface where it can be captured.

Typical Vortex Engine Size

- Circular wall diameter 50 to 200 m
- Circular wall height 30 to 80 m
- Vortex base diameter 20 to 100 m
- Vortex height 1 to 20 km
- Heat input 1000 MW. 20, 50 MW cooling bays
- Electrical output 200 MW. 20, 10 MW turbines
- Specific work 1000 to 20000 J/kg
- Air flow 20 to 100 Mg/s
- Water flow 40 to 200 Mg/s

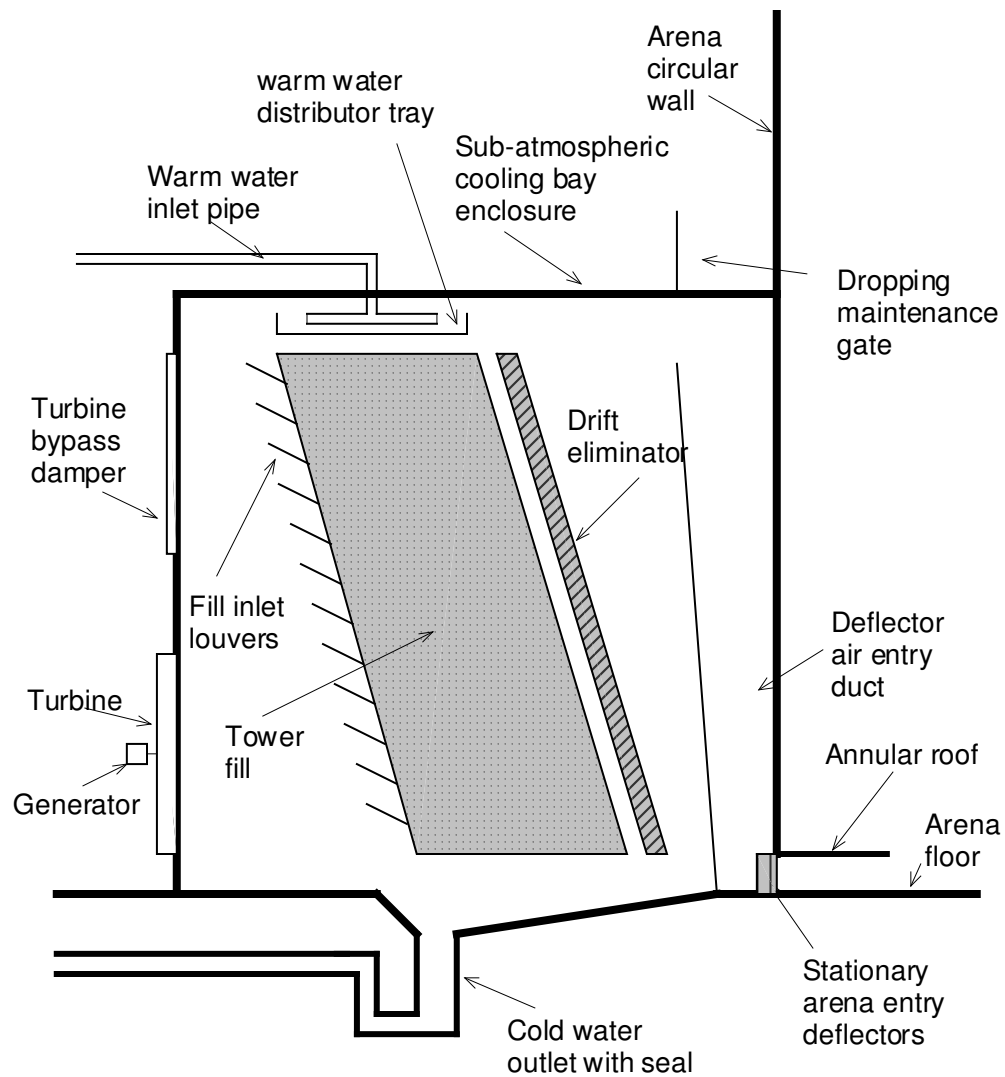
Cooling Towers



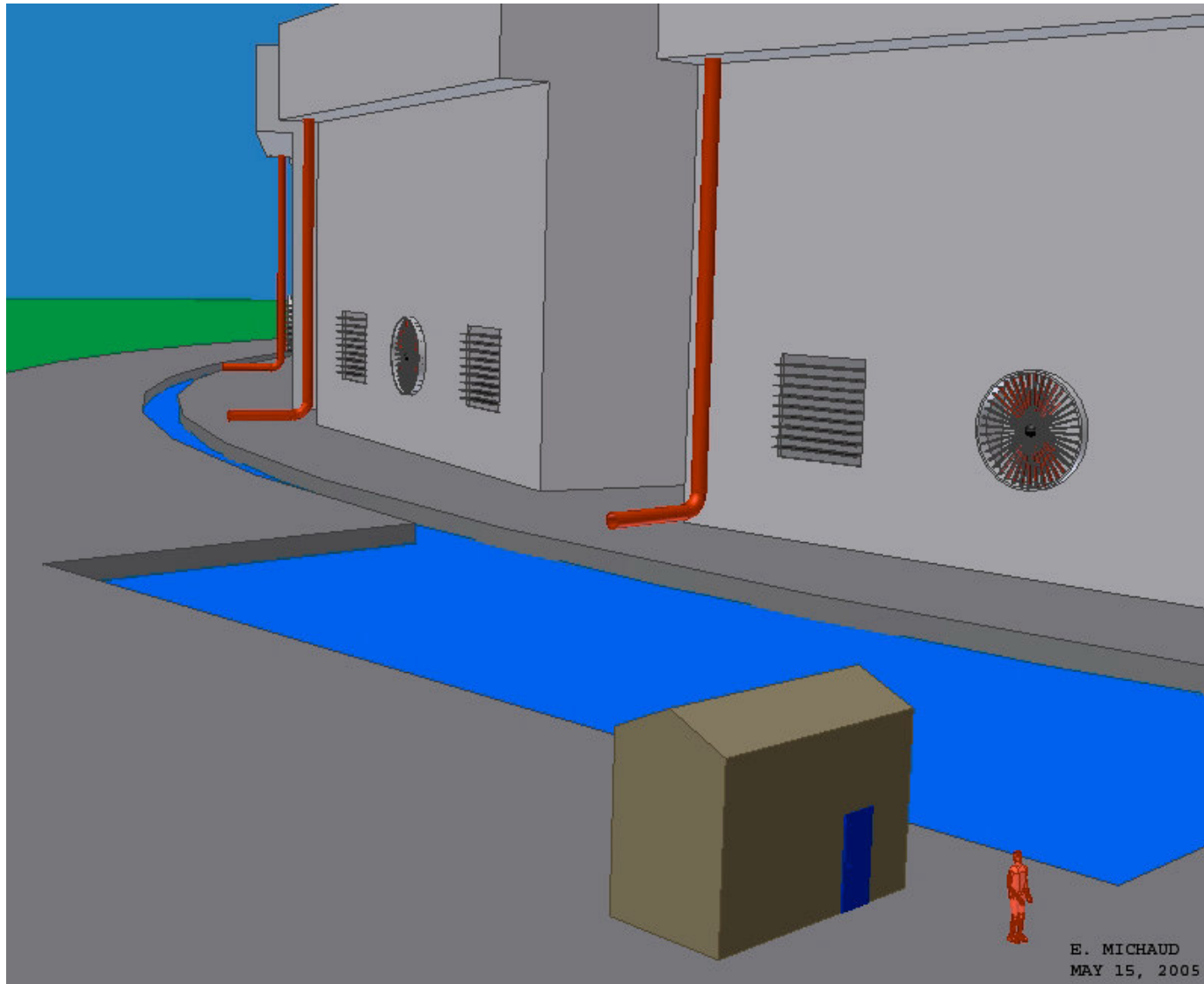
Natural Draft



Mechanical
Induced Draft



Circular Cooling Tower Cell



Turbine in Cooling Tower Air Inlet

Engine Control

- The cylindrical wall forces the air to go through the the tangential entry and prevents the wind from disturbing the vortex until it is established.
- The mass of rising air behaves like a rotating top. A massive rotating top can retain its angular momentum for the 30 minutes or so required for the air to rise to the tropopause. The station with its tangential entry is a continuous producer of rotating tops.

Chimney Principle

- A natural draft chimney is a cylinder in radial compression which prevents ambient air from mixing with rising flue gas.
- The pressure at any level is less inside the chimney than outside the chimney.
- Without the physical wall dilution by ambient air would reduce base draft.
- In a vortex, ambient air is prevented from mixing with the rising air by centrifugal force, except in the boundary layer where tangential velocity is reduced by friction.
- The existence of tornadoes proves that a vortex can have an effect similar to that of a physical chimney.

Solar Chimney



Manzanares
200 m high, 10 m diameter
Collector 0.04 sq. km
50 kw, 130 J/kg, 1 Mg/s
Spain 1982 to 1989



EnviroMission
1 km high, 130 m diameter
Collector 40 sq. km
200 MW, 800 J/kg, 300 Mg/s
Australia, 2005

Natural Vortices



Tornado



Waterspout



1.5 m diameter model



Utah Vortex Tower

LMM

Atmospheric Vortex Engine

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Utah Fire Whirl



Business Plan

Physical models under 10 m diameter: \$k 5 to \$k 500 per model

Steam assisted 10 to 30 m diameter model: \$M 0.5 to \$M 2.

Pony plant 50 m diameter vortex cooling tower: \$M 4.

Economics - Full Size Station

Station cost: \$M 30 per 100 MW

No fuel cost

No need for conventional cooling tower

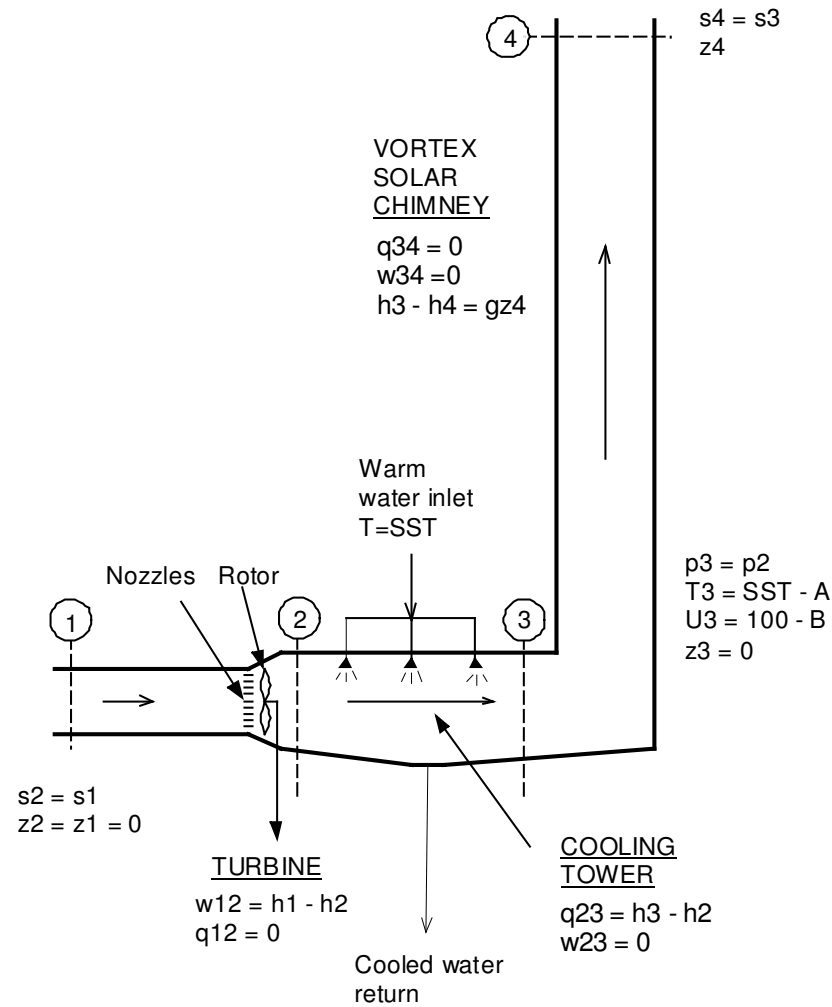
No energy to drive fans

Electricity production cost: Less than
half the cost of current sources of
electricity

Economic Incentives

- Cost of energy production lower than that of existing alternatives: no fuel requirement, no tall solar chimney, no solar collector.
- Clean renewable non-polluting energy source.
- No global warming, could become a global cooler.
- Eliminates the need for conventional cooling towers while producing power at reduced cost.
- Could produce rain as valuable byproduct.
- The mechanical energy produced and dissipated in the atmosphere is 10000 times more than the electrical energy produced by humans.
- Converting 20% of the waste heat from a thermal power plant to work would increase power output by 40%. 500 MW -> 700 MW.

Thermodynamic Ideal Cycle Equivalent

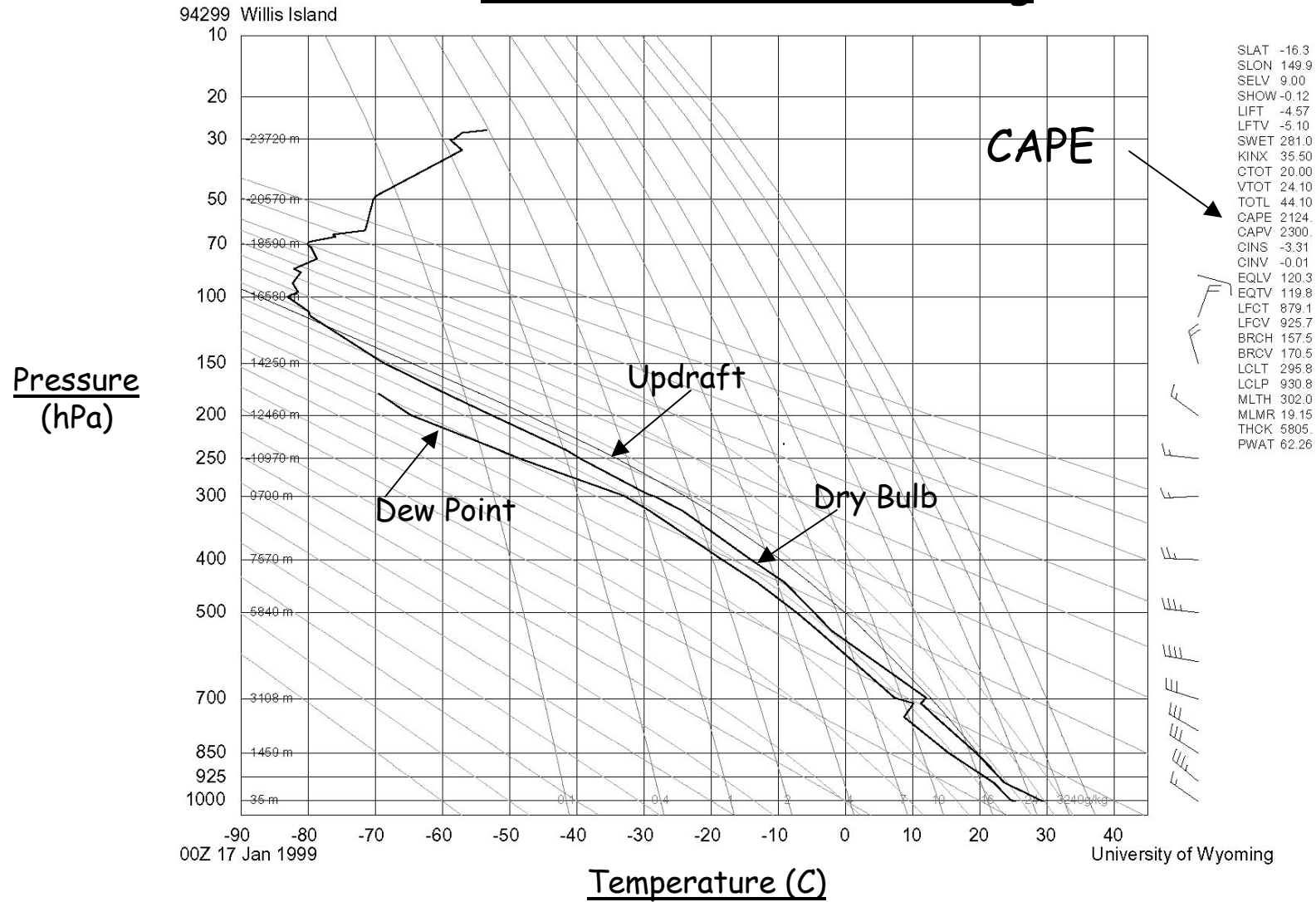


Typical Energy Calculations

Vortex solar chimney energy calculations for a range of temperature and humidity approach to sea surface temperature (SST). Ambient surface air conditions: $P_1 = 100.3$ kPa, $T_1 = 29.4$ °C, $U_1 = 77.5\%$, $r_1 = r_2 = 20.50$ g kg⁻¹, $s_1 = s_2 = 287.0$ J kg⁻¹ K⁻¹, $h_1 = 81920$ J kg⁻¹. Heights based on 17 January 1999, 0000Z Willis Island sounding. Approach based on SST = 30.4 °C.

<u>Properties</u>	<u>Case 0</u> <u>$q_{23} = 0$</u>	<u>Case 1</u> <u>$A=3, B=10$</u>	<u>Case 2</u> <u>$A=1, B=10$</u>	<u>Case 3</u> <u>$A=1, B=5$</u>	<u>Case 4</u> <u>$A=0, B=0$</u>
$P_2 = P_3$ (kPa)	95.80	91.38	83.42	81.02	74.62
$P_1 - P_2$ (kPa)	4.50	8.92	16.88	19.28	25.68
T_2 (°C)	25.47	23.10	19.99	18.99	16.14
U_2 (%)	94	103	115	119	131
h_2 (J kg ⁻¹)	77820	73670	65720	63200	56150
$T_3 = \text{SST} - A$ (°C)	25.47	27.4	29.4	29.4	30.4
$U_3 = 100 - B$ (%)	94	90	90	95	100
$r_3 = r_4$ (g kg ⁻¹)	20.50	23.25	28.87	31.43	38.35
h_3 (J kg ⁻¹)	77820	86840	103320	109840	128590
$s_3 = s_4$ (J K ⁻¹ kg ⁻¹)	287.0	331.3	413.5	444.1	531.1
P_4 (kPa)	10	10.0	7.0	7.0	5.0
T_4 (°C)	-77.39	-68.01	-69.91	-63.21	-62.77
z_4 (m)	16570	16570	18580	18580	20560
h_4 (J kg ⁻¹)	-87890	-79330	-84020	-77970	-80630
$h_4 + gz_4(1 + r_4)$	77820	86840	103320	109840	128590
$q_{23} = h_3 - h_2$ (J kg ⁻¹)	0	13170	37590	46650	72440
$w_{12} = h_1 - h_2$ (J kg ⁻¹)	4090	8250	16190	18720	25770
v_x (m s ⁻¹)	90	128	180	193	227
$\Delta w_{12}/\Delta T_3$	n/a	4050	base	n/a	n/a
$\Delta w_{12}/\Delta U_3$	n/a	n/a	base	512	n/a
$\Delta w_{12}/\Delta r_3$	n/a	n/a	base	1000	n/a
$\Delta w_{12}/\Delta q_{23}$	n/a	32.8%	base	28.1%	28.2%

Raw Willis Island Sounding



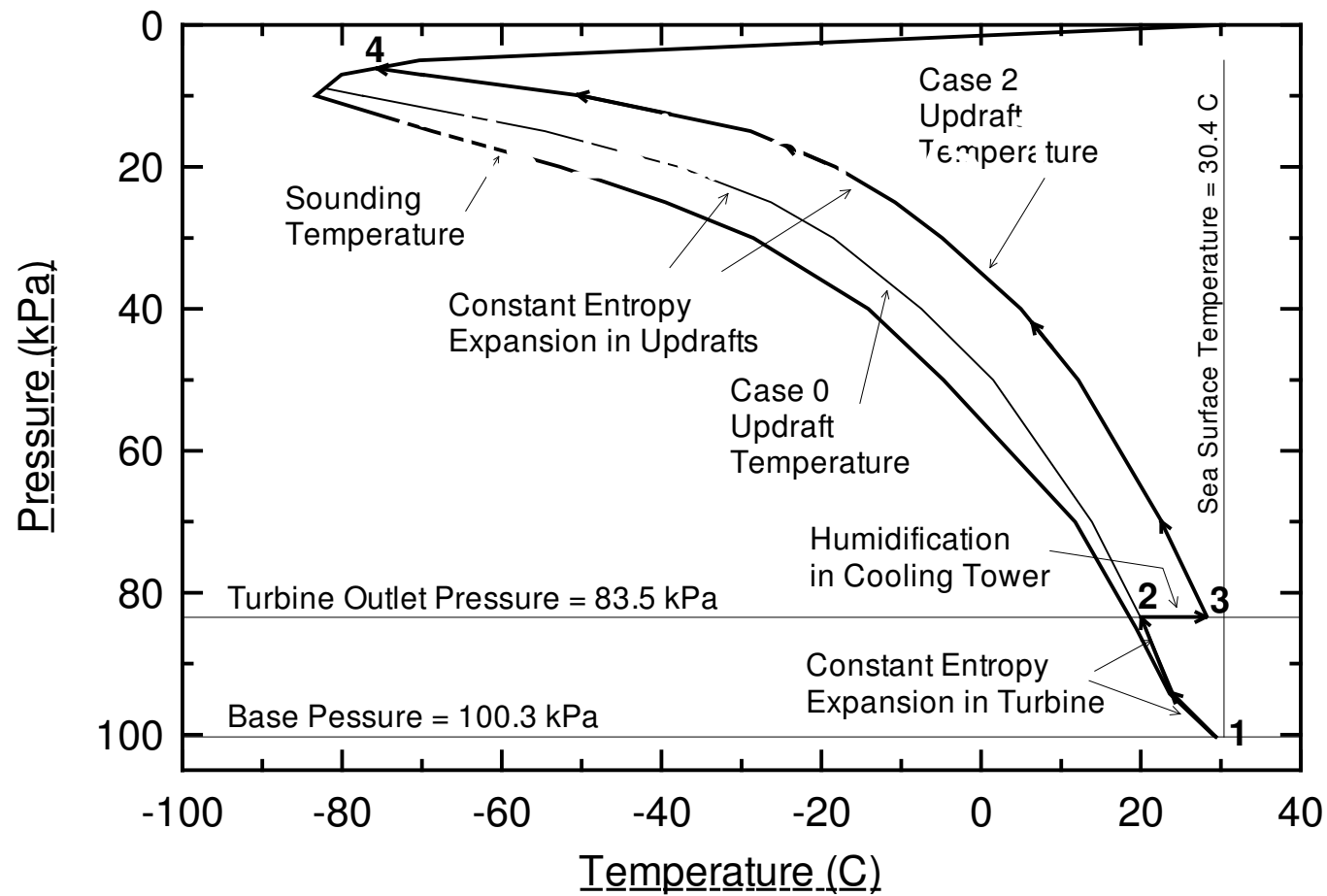
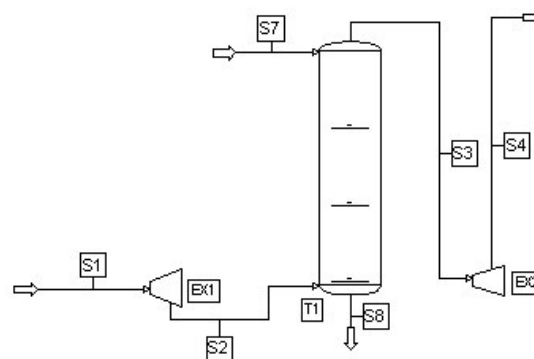


Fig. 3 Willis Island sounding and updraft temperatures



CALCULATOR

$$WK_NET = EX2_WK - M3 \cdot g \cdot z$$

CONTROLLER

Vary P2 until $WK_NET = 0$

Stream Name		S1	S2	S3	S4	S7	S8
Phase		Vapor	Mixed	Vapor	Mixed	Liquid	Liquid
Pressure	KPA	100.30	75.47	75.47	5.00	100.00	75.47
Temperature	C	30.00	16.66	31.14	-62.63	33.00	24.68
Total Sp. Enthalpy	KJ/KG	47.528	23.218	95.437	-106.050	122.777	85.842
Total Sp. Entropy	KJ/KG-C	6.507	6.507	6.718	6.718	5.106	4.984
Total Mass Rate	KG/SEC	1020.500	1020.500	1039.928	1039.928	2000.000	1980.572
Total Enthalpy	M*WATT	48.502	23.694	99.247	-110.284	245.555	170.015

Calculator Name		CA1
EX1 WORK (MW)		24.81
EX2 WORK (MW)		209.53
Heat Duty (MW)		75.54
Height (m)		20560

Pro II Simulation

Simulation Highlights

<u>Water Temperature (C)</u>	<u>Power (MW)</u>
25	0
26	30
33	250
40	400

Note: based on an air flow of 10 tonnes/s (12 times Manzanares flow)

- Large change in elevation are required to achieve significant efficiency.
 - Manzanares 200 m 0.6%
 - SolarMission 1000 m 3%
 - Vortex Engine 18000 m 25%

Turbines

- The turbine differential pressure can be 1 to 30 kPa.
- The turbine could be an axial expander where the kinetic energy is produced in fixed nozzles and captured by rotating blades - similar to the expander stage of a gas turbine .
- The work is proportional to turbine differential pressure:
5000 J/kg -> 100 m/s -> 5 kPa
20000 J/kg -> 200 m/s -> 20 kPa

Pressure Effect on Heat Transfer

- Reduced pressure in the cooling tower enhances heat transfer because the affinity of air for water increases as pressure decreases.
- For a given air temperature, the quantity of water that air can hold increase as pressure decreases.
- For a given mixing ratio, wet bulb temperature decreases with decreasing pressure.
- Reducing pressure by 20 kPa can reduce both wet bulb temperature and cooled water temperature by 10 C, resulting in higher thermal power plant efficiency.

Calculation Summary (1)

- The Convective Energy (CE) of tropical oceanic sounding is typically between 1000 and 2000 J/kg.
- The CE of continental air can exceed 5000 J/kg during periods of high insolation, and can be negative during periods of low insolation.
- Adding heat to air, whether sensible or latent, increases CE by 20 to 30% of the added heat.
- Saturating air with 40 C waste heat can increase CE to 40000 J/kg.

Calculation Summary (2)

- The upward convective heat flux at the bottom of the atmosphere averages 150 W/m^2 .
- The troposphere receives heat at an average temperature of $+20 \text{ C}$ (293 K) and gives up heat at an average temperature of -20 C (253 K).
- The heat to work conversion efficiency is approximately 15%. ($40/290$).
- Therefore the work produced and dissipated in the atmosphere is 20 to 30 W/m^2 .
- Heat cannot be carried upward by convection without the the work of expansion exceeding the work of compression.
- The work is produced during upward heat convection process and not necessarily when the heat is received or given up.

Other Vortex Engine Uses

- Production of precipitation
- Production of clouds
- Reduction of local surface temperature
- Global cooler
- Removing polluted surface air
- Reduction of cooling water outlet temperature



Dust Devil