INTRODUCTION

Our country is facing a number of problems on power plant. The original target of increasing the generating capacity by 30,000 MW during eight plan got reduced to 20,000 MW and fears are now being expressed about by achieving even this reduced target. This is ascribed essentially to a lack of sufficient financial resources. Privatization of generation with a view to attracting private investors, Indian & foreign, is now considered a remedy to overcome this difficulty. There has been some progress in this direction, although far from the earlier expectations. Thus, foreign investors like AES Transpower in Orissa, Enron in Maharastra, Siemens- Torrent in Gujrat and so on in the picture.

There seems to be considerable uncertainty in regard to many of these projects taking off the ground. In any case, with Rs. 4 to Rs. 4.5 crore per MW of installed capacity and at least Rs 3 crore for transmission and distribution, if not an equal amount, as it should be, and a guaranteed return of 16 per cent on equity for generation, one can see easily the trend of the cost per unit cost per unit of electricity delivered. That would easily be around Rs 3.50 per unit.

Meanwhile, the load demands are increasing fast while the additions to generating capacities are slow and relatively small and the reliabilities and quantity of power supply are deteriorating resulting in frequent interruptions and low voltages. Thus affecting industrial and agricultural production and causing inconvenience to the public in a variety of ways. Due to the demands outstripping availability, the grid systems are being operated at sub-standard frequencies resulting in serious systems disturbances and black - outs.

➢ SOLAR ENERGY IN INDIA

If the vast expanse of the Thar Desert in Northwestern India was harnessed to produce solar energy, it could light up five of Asia's most populated cities. Scientists say the endless sands of Rajasthan State could well earn the distinction of being the "biggest" solar powerhouse by 2010, producing 10,000 MW of electricity. The Rajasthan Energy Development Agency (REDA) has started the spadework on an ambitious project. "A major chunk of the desert, about 13,500 square miles, will be declared a Solar Energy Enterprise Zone like the one in Nevada (in the United States)", says director Probhat Dayal. He thinks that if the state were to install solar collectors in just one Percent of its desert, which stretches over 77,200 square miles, "we could generate 6,000 megawatts of electricity".

A city the size of Delhi with 10 Million people needs 1,800 megawatts. "This solar bowl of the desert will become the world's biggest center for Solar power generation, research and development", he declares. The earth receives some 4,000 trillion-kilowatt hours of electromagnetic Radiation from the sun- about hundred times the world's current energy consumption needs. At present, a 354 megawatt solar power project in southern California is the world's largest, providing 90 percent of global solar energy.

AN ADVANCED TECHNOLOGY FOR SOLAR

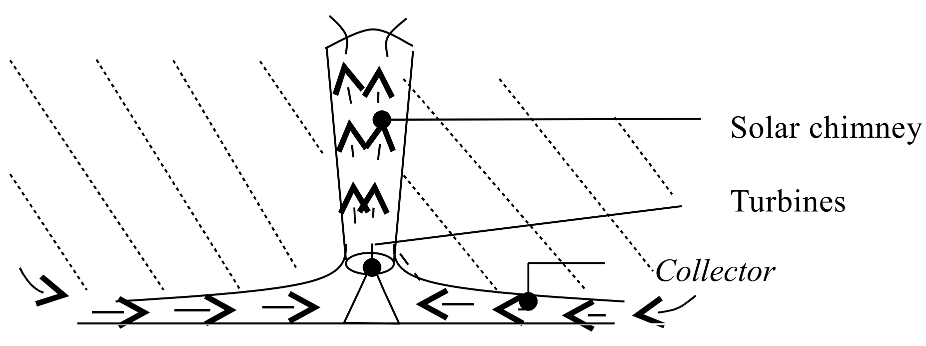
This new technology called Solar Chimney Technology; foresees to produce bulk electricity in sunny regions of the plant, by creating breeze of sufficient speed (more than 20 to 30 kph.) to run wind turbines coupled to electric generators of total o/p of 30 to 200 MW.

This Technology -

- is simple & reliable.
- does not need cooling water or produced waste heat.
- is open to environmentally neutral.
- can be install to the technologically less developed countries.

A NEW USE FOR THREE OLD TECHNOLOGIES

Man learned to make active use of solar energy at a very early stage; greenhouses helped to grow food, chimney suction ventilated & cooled building & windmills ground corn & pumped water. A Solar - Thermal Chimney simply combines them in a new way. The Solar Chimney contains three essential elements: collector, chimney, wind Turbines.



ELEMENTS OF SOLAR CHIMNEY POWER PLANT

Air is heated by solar radiation under a circular glass roof open at the periphery, this and natural ground below it form a hot air collector. In the middle of the roof is a vertical chimney with large air inlets at its base. The joint between the roof and chimney base is airtight.

As hot air is too lighter than cold air it rises up the chimney suction from the chimney then draws in more hot air from the collector and cold air comes in from the outside. Thus, solar radiation causes a constant up draught in the chimney. The energy this contains is converted into the mechanical energy by pressure stepped wind turbines at the base of chimney and into electrical energy by conventional generators.

- A single solar Chimney with a suitably large glazed roof area & high chimney can be designed to generate 100 to 200 MW. Thus even a small number of solar chimneys can replace a large nuclear power station. Solar Chimneys thus operate simply, they have a number of other advantages:
- The collector can use all solar radiation, both direct & diffused. This is crucial for tropical countries where the sky is frequently overcast. Solar Thermal power stations that can use only direct radiation are at a disadvantage there.
- The collector provides for natural energy storage at no cost. The ground under the glass roof absorbs some of the radiated energy during the day & releases it into the collector at night. Thus solar chimneys produce a significant amount of electricity at night as well.
- Solar chimneys are particularly reliable & not liable to break down, in comparison with other solar generating plants. Turbines, transmission & generator - subject to a

steady flow of air are the plant`s only moving parts. This simple & robust structure guarantees operations that need little maintenance & of course no combustible fuel.

- Unlike conventional power stations (& also other solar thermal power station types), solar chimneys do not need cooling water. This is a key advantage in many sunny countries that already have major problem with drinking water.
- The building materials needed for solar chimneys concrete, glass & steel are available everywhere in sufficient quantities.
- Solar chimneys can be built now even in less industrially developed countries. The industry already available in most countries is entirely adequate for their requirements. No investment in high-tech manufacturing plant is needed.
- Even in poor countries it is possible to build a large plant without high currency expenditure, with their own resources & work force; this creates large number of jobs & reduces electricity costs dramatically.

Solar chimneys can convert only a small proportion of the solar heat collected into electricity & thus have a "poor efficiency level". But they make up for this disadvantages economically by their cheap, robust construction, needing little maintenance. Solar chimneys need large collector areas. As economically viable use of solar electricity production plants is anyway confined to sunny areas this is not a fundamental disadvantage; as such regions usually have enormous deserts & featureless wastes. And so "land use" is not a particularly significant factor, although of course deserts are also complex biotopes that have to be protected.

MAIN ELEMENTS OF SCPP

➢ THE COLLECTOR

Hot air for the chimney is produced by greenhouse effect in a simple air collector consisting only of a glass of plastic film covering stretched horizontally 2 to 6 m above the ground. Height increases only adjacent to the chimney base, so that the air can be diverted to vertical movement without friction loss. This covering admits short wave solar radiation component and retains long-wave radiation from the heated ground. Thus, ground under the roof heats up and transfers its heat to the air flowing radially above it from the outside to the chimney, like flow heater.

A flat collector of this kind can convert up to 70 % of irradiated solar energy into heat, dependent on air throughput, annual averge 50 %. The ground under the roof also provides natural energy storage at no cost. It is fundamentally advantageous to adjust the translucency & heat insulation of the roof to the air temperature as it increases from the outside towards the tower by providing double glazing near the tower, but only there, as it is more expensive. In arid zones dust & sand inevitably collect on the glass collector roof & of course reduce its efficiency. But experience in Manzanares shows that the collector is very insensitive to dust & even rare desert rainstorms are sufficient for roof self-cleaning if it is designed (as) & stone deserts are used rather than sandy deserts. Peripheral area of the collector can be used as a greenhouse or for drying plants, at no extra cost & without significant performance loss.

A collector roof of this kind is of long span and continuous maintenance can give service up to 60 years or more. Collector efficiency is improved as rise in temp. decreases. Thus, a solar chimney collector is economic, simple in operation and has a high-energy efficiency level.

➢ THE CHIMNEY

The chimney itself is the plant's actual thermal engine. It is a pressure tube with low friction and loss (like a hydroelectric tube) because of its optimum surface-volume ratio. The up-thrust of the air heated in collector is approximately proportional to air temp. rise ΔT in collector and volume (i.e. height and diameter of the chimney). In a large solar chimneys the collector raises the temp. of air by ΔT=350C. This produces an up-draught velocity in chimney of about V=15 m/s. The efficiency of the chimney (i.e. conversion of heat into kinetic energy) is practically independent of ΔT in collector and determined by outside temp. To (lower the better) and height of chimney (higher the better).

Power = K. (Hc/To)*(Solar radiation at location)*(Area of collector)

Thus, solar chimneys can make particularly good use of the low rise in air temp. produced by heat emitted by the ground during the night and even the Meagre solar radiation of a cold winter's day!

However, compared with the collector and the turbines, the chimneys efficiency is relatively low, hence the importance of size in its efficiency curves. The chimney should be as tall as possible e.g.: at 1000 meters; tower efficiency is somewhat greater than 3%. If we compare chimney updraught with balloon buoyancy, it is clear that in terms of building costs as well it is better to build one large chimney rather than a lot of small ones; a large air balloon intended to produce the same buoyancy or lift as a lot of small ones has a much smaller surface area & is thus much cheaper. Chimney 1000 metres high can be built without difficulty.(Let it be remind that T.V. Tower in Toronto, is almost 600m height and serious plans are being made for 2000 m skyscrapers in earth-quake-ridden Japan.) But all that is needed for a solar chimney is a simple, large diameter tube, not particularly slender & subject to very few demands in comparison with inhabited buildings. There are many different ways of building this kind of chimney. They are best built freestanding in RCC. But guyed tubes, their skin made of corrugated metal sheet, cable net with cladding or membranes are also possible. All the structural approaches are familiar & tested in cooling towers. No special development is needed.

The lifespan of a RCC tower in a dry climate is at least 100 years. So called, "carbonization", by which concrete loses its ability to protect the reinforcing steel (by a gradual conversion, from the surface inwards of Ca(OH)2 in the cement into CaCO3 because of the CO2 content of the air.) cannot take place without moisture.

➢ THE TURBINES

Mechanical output in the form of rotational energy can now he derived from the vertical air-current in the chimney by turbines. Turbines in a solar chimney do not work with stepped velocity like a free-running wind energy converter, but as a cased pressure-stepped wind turbo-generator, in which, similar to a hydroelectric power station, static pressure is converted into a pipe. The energy yield of a cased pressure-stepped turbine of this kind is about eight times greater than that of the same diameter. Air speed before and after the turbine is about the same. The output achieved is proportional to the product of volume flow per time unit and the fall in pressure at the turbine. With a view to maximum energy yield the aim of the turbine regulation concept is to maximize this product under all operating conditions.

The turbine regulates air speed and air flow by means of blade tilt. If the blades are horizontal, the turbine does not turn. If the blades are vertical and allow the air to flow through undisturbed, there is no drop in pressure at the turbine and no electricity is generated. Between these two extremes there is an optimum blade setting; the output is maximized if the pressure drop at the turbine is about two thirds of the total pressure differential available. If the air stream is throttled the air takes longer to heat up. This increases the rise in temperature in the collector. This in its turn causes increase ground storage and thus enhanced night output, but also greater loss from the collector (infrared emissions and convection). Turbines are always placed at the base of the chimney. Vertical axis turbines are particularly robust and quiet in operation. The choice is between one turbine whose blades cover the whole cross-section of the chimney or six smaller turbines distributed around the circumference of the chimney wall, here the blade length of each turbine will a sixth of the chimney diameter. The diversion channel at the base of the chimney is designed for one or six turbines as appropriate. But it is also possible to arrange a lot of small turbines with horizontal axes (as used in cooling tower fans) at the periphery of the transitional area between canopy and available technology. Generator and transmission are conventional, as used in related spheres.

In a solar chimney there are no critical dynamic loads on blades, hubs and setting equipment of the kind met in free-running wind energy converters due to gustiness of the natural wind as the canopy forms an effective buffer against rapid pressure and speed changes. This makes these components structurally simple and cheap to manufacture, and they also have a long life span.

A"HYDROELECTRIC POWER STATION FOR THE DESERT"

Solar chimneys are technically very similar to hydroelectric power stations- so far the only really successful renewable energy source, the collector roof is the equivalent of the reservoir, & the chimney of the pressure pipes. Both power generation systems work with pressure-stepped turbines, & both achieve low power production costs because of their extremely long life span & low running costs. The collector roof & reservoir areas required are also comparable in size for the same electrical output. But the collector roof can be built in arid deserts & removed without any difficulty whereas useful (often even populated) land is submerged under reservoirs.

Solar chimneys work on dry air & can be operated without the corrosion & cavitation typically caused by water. They will soon be just as successful as hydroelectric power stations. Electricity yielded by a solar chimney is in proportion to the intensity of global radiation, collector area & the chimney height. Thus, there is no physical optimum. The same output can be achieved with a higher chimney & a small collector or vice-versa. Optimum dimensions can be calculated only by including specific component costs (collector, chimney, and turbines) for individual sites. And so plants of different sizes are built from site to site-but always at optimum cost, if glass is cheap & concrete dear the collector will be large with a high proportion of double glazing & a relatively low chimney, and if glass is dear there will be a smaller, largely single-glazed collector and a tall chimney.

➢ SOLAR CHIMNEY ON THE INTERNATIONAL GRID

Generally speaking solar chimneys will feed the power they produce into a grid. The alternating current generators are linked directly in the public grid by a transformer station. The thermal inertia of solar chimneys means that there are no rapid abrupt fluctuations in output of the kind produced by wind parks and photovoltaic plants (output fluctuations up to 50% of peak output within a minute causing the familiar frequency and voltage stability problems in the grid. Solar chimney output fluctuation is a maximum of 30% of the rated load within 10 to 15 minutes; this means that grid stabilization can be easily handled by the appropriate regulation stations.

In the case of island grids, without conventional power sources and no linkage with other grids, a connection of solar chimneys to pumped storage stations is ideal. These store the excess energy produced by the solar chimney by the day or year and release it when needed. Thus available energy in independent of varying amounts of sunshine by day and night, and throughout the year.

Many countries already have hydroelectric power stations, and these can also be used as pumped storage stations, if necessary their reservoirs can be covered with membranes to prevent water evaporation. The rpm of solar chimney turbines and pumps can be uncoupled from the rigid grid 50 Hz frequency by frequency converters of the kind already used by a Badenwerk hydroelectric plant in South-West Germany.

The import of solar-produced energy, from North Africa to Europe, for example, will soon be perfectly cheap and simple, as the European grid is to be extended to North Africa. Transfer costs to Europe will then be only a few cents/kWh. A large extended grid will itself also optimize energy flow between the various producers and consumers and thus need hardly any storage facilities.

If distances between solar energy stations and consumers are large, as for example from North Africa to Europe, low loss, high voltage D.C. transmission is also available. Transfer losses over a distance of 3500 km from the Sahara to central Europe will be less than 15%.

On the other hand, hydrogen technology converting solar power into hydrogen by electrolysis, transporting this and then converting it back into electricity-makes no sense, and is conceivable only for mobile use in vehicles and aircraft.

Thus, there is no technical reason why a global solar energy economy cannot be achieved. Transfer and distribution of solar energy generated in deserts no longer presents serious problems, even of an economic nature.

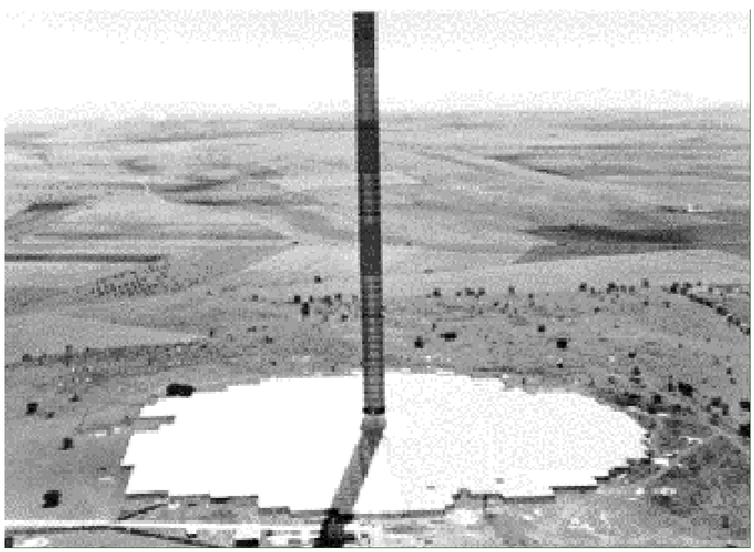
But solar energy production in central Europe or other northern countries, whatever technology is used, does not make economic sense because of low solar radiation levels and intensive land use.

THE PROTOTYPE IN MANZANARES

Objective:-

Detailed theoretical preliminary research and a wide range of wind tunnel experiments led to the establishment plant with a peak output of 50 kW on a site made available by the Spanish utility Union Electricity Fenosa in Manzanares (about 150 km south of Madrid) in 1981-82 with funds provided by the German Ministry of Research and Technology (BMFT)

The aim of this research project was to verify theoretical data established by measurement & to examine the influence of individual component on the plant's output and efficiency under realistic engineering and meteorological conditions.



To this end a chimney 195m high and 10 m in diameter was built, surrounded by a collector 240 m in diameter. The plant was equipped with extensive measurement data acquisition facilities. The performance of the plant was registered second by second by 180 sensors.

Since the type of collector roof primarily determines a solar chimney's performance costs, different building methods and materials for the collector roof were also to be tested in Manzanares. A realistic collector roof for large-scale plants has to be built 2 to 6 m above ground level. For this reason the lowest realistic height for a collector roof for large-scale technical use, 2 m, was selected for the small Manzanares Plant. (For output a roof height of only 50 cm would in fact have been ideal.) Thus only 50 KW could be achieved in Manzanares, but this realistic roof height also permitted convenience access to the turbine at the base of the chimney. This also meant that experimental planting could be carried out under the roof to investigate additional use of the collector as a greenhouse.

➢ TESTS DURING THE NINE-YEAR PROJECT

The experimental plant in Manzanares ran for about 15000 hours from 1982 onwards. The following tests were run in the course of the projects :

Different collector roof covering were tested for structural stability, durability and influence on output.

The behaviour of the plant as whole was measured second by second (ground temperature, air temperature, speed and humidity, translucency of the collector, turbine data, meteorology etc.

The ground's storage capacity was tested in terms of collector temperature and soil humidity. In order to investigate heat absorption and heat storage it was in turn left as it was, sprayed with black asphalt and covered with black plastic.

Various turbine regulation strategies were developed and tested;

Maintenance and running costs for individual components were investigated;

The thermodynamic plant simulation program developed in all details in the mean time was verified with the aid of the experimental results and accompanying wind tunnel experiments, in order to make reliable calculations for any individual site data, meteorology and plant dimensions for daily & annual energy production by large solar chimneys.

➢ THE THREE-YEAR CONTINUOUS RUNNING PHASE

In 1986 structural development works that made occasional operational interruptions necessary were completed. After that from mid 1986 to early 1989 it was possible to run the plant continuously for 32 months. Four months were set aside for special measurements & specific modifications. The plant ran continuously for 8611 hours or an average of 8.9 hours per day in this continuous operating phase, fully automatically. One person at the most was needed at the most for supervision. Thus there is no doubt that solar chimneys can be built, run in the long term & reliably maintained even in countries that are technologically less developed. Plant availability was over 95 % in this period. Sporadic storm damage to the old plastic film area of the collector was repaired without switching off the plant. The 5 % non-operational period was due to automatic plant switch-off at the weekend when the Spanish Grid occasionally failed.

THERMODYNAMICS OF SCPP

The fundamental parameters, their interrelation and their influence on performance of SCPP for steady state operation under average solar insolation are as under.

➢ ENERGY INPUT/OUTPUT FOR COLLECTOR

A solar Chimney collector converts available solar radiation, G on the collector surface, A coil into heat output. The steady state collector efficiency, n_{coil} can be expressed as ration of the heat output, heated air Q to solar insolation G times collector area, A_{coil} .

i.e. $$n_{coil} = \frac{Q}{A_{coil}\ G} \qquad \text{……………(5.1)}$$

Heat output can be expressed as product of mass how, specific heat at constant pressure and size of air temp.

$$Q = m.\ CP_a\ \Delta\ T \qquad \text{……………. (5.2)}$$

Mass flow rate m can be expressed as product of air density air velocity and frontal area of flow. At turbine

$$m = P_c\ V_c\ A_c \qquad \text{……………….(5.3)}$$

additionally heat balance for collector

$$Q = A_g\ A_{coil}\ .\ G - U\ \Delta\ T\ A_{coil} \qquad \text{……………….(5.4)}$$

Part of total energy input is used for air heating and part is lost in heat losses.

From eq. (5.1) and (5.4) the collector efficiency can also be expressed as,

$$n_{coil} = a_g - \frac{U\ \Delta\ T}{G} \qquad \text{………………(5.5)}$$

➢ UPDRAUGHT AND PRESSURE LOSSES

In this section the total draught produced by chimney and varies pressure losses are discussed,

Chimney Draught and Efficiently :-

The chimney converts the heat flow a produced by the collector into kinetic energy (convection current) and potential energy (pressure drop at turbine). Thus density difference of air caused by temp. rise in collector works as driving force. The lighter column of air in the chimney is connected to surrounding atmosphere at the base (inside the collector) and at the top of the chimney and thus acquires a lift. A pressure difference ΔP_{tot} is produced between chimney base and surroundings.

$$\Delta P_{tot} = g (P_{amb} - P_{ch}).\, dH \qquad \text{……………….(5.6)}$$

The pressure difference ΔP_{tot} can be divided into static and dynamic component.

Neglecting friction losses

$$\Delta P_{tot} = \Delta P_s - \Delta P_d \qquad \text{………………..(5.7)}$$

with the total pressure difference and the volume flow of air at $\Delta P_s = 0$ the power contained in the flow i)

$$P_{tot} = \Delta P_{tot} .V_{cmax} . A_c \qquad \text{………………..(5.8)}$$

From which efficiency of chimney can be established as

$$n_{ch} = \frac{P_{tot}}{Q} \qquad \text{…………………(5.9)}$$

Also, as total power in flow is K.E.

$$P_{tot} = \tfrac{1}{2}\, mv^2_{cmax} \qquad \text{……………… (5.10)}$$

with the simplifying premise that temperature profile run parallel inside the chimney and in open, the speed reached by free convection current can be expressed in modified Torricelli,s equation

$$V_{cmax} = 2.g.H_c \frac{\Delta T}{Ta} \qquad \text{………………(5.11)}$$

Eq (5.9) with eq (5.2) , (5.10) and (5.11) gives chimney efficiency :

$$n_{ch} = g \frac{H_c}{C_{pa}\ Ta} \qquad \text{…………………(5.12)}$$

This simplified representation explains one of basic characteristic of solar chimney which show that the chimney efficiently is fundamentally dependent only on chimney height. Thus the power contained in the how from eq (5.9) can be expressed with the aid of eq (5.2), (5.3) and (5.12).

$$P_{tot} = n_{ch}\ Q = \frac{g\ H_c}{C_p.Ta} P_{c.}\ V_{c.}\ \Delta\ T.A_c \qquad \text{…………..(5.13)}$$

With eq (5.8)

$$\Delta\ P_{tot} = P_{c.}\ g.\ H_c\ .\frac{\Delta\ T}{Ta} \qquad \text{…………..(5.13)}$$

This equation also shows the analogy with the pressure tube of hydroelectric power station at which the pressure gradient is given by

$$\Delta\ P = P_{water}\ .\ g.\ H$$

It is right to call the solar chimney the “ Hydroelectric power station of desert”.

Pressure Losses :-

Draught produced by Chimney is applied to wind turbine (reaction type) practically it not possible to utilise 100% of total draught. The various pressure losses in the plant are

1) Entry Loss :-

Head loss in keeping air velocity inlet to collector

Entry loss $= \frac{1}{2} P_{local} \cdot V^2_{entry}$

$= K \frac{1}{2} . P_c . V_c^2$ ………………..(5.15)

2) Plant Friction pressure loss :-

It includes friction loss in collector, head loss at bend when air flow diverts from collector to chimney and friction loss in chimney.

Collector friction loss $= \frac{C_f \;\; p}{2 \;\; d} V^2 . Rd$

$= \frac{K_2}{2} Pc \;\; V_c^2$ …………….(5.16)

Bend loss $= K/2 \; P_{local} . V^2_{bend}$

$= \frac{K_3}{2} Pc \;\; V_c^2$ …………….(5.17)

Friction loss at chimney $= \frac{C_f}{2} \frac{P_{local}}{D_{ch}} . V^2_{ch} . H_c$

$= K\,4/2. \; Pc \; . V_c^2$ …………….(5.18)

3) <u>Exit Loss:-</u> Pressure lost due to velocity of air at chimney exit.

$$\text{Exit loss} = ½ \; P_{local} \,.\, V^2_c$$

$$= K \; 5/2 \,.Pc \,.\, V_c^2 \qquad ……………(5.19)$$

when K_1 ,K_2 ,K_3 ,K_4 ,K_5 are constant approximately taken so to convert all losses in forms of density and velocity of air at turbine inlet condition.

Let $\quad K = K_1 + K_2 + K_3 + K_4 + K_5$

Total pressure loss = $K/2 \,.\, pc.\, V_c^2$ ……………(5.20)

Bernaluli's eq. Then

$$\Delta P_{tot} = \Delta P_s + K/2 \quad Pc \,.\, V_c^2 \qquad ……………(5.21)$$

<u>Turbine Power output :-</u>

Air velocity at inlet and outlet to turbine is same. From available pressure drop ΔP_s, across the turbine, power output by turbine is given as

$$P_{Tur} = \Delta P_s \, Vc \,.A_c \qquad ……………(5.22)$$

From eq. (5.21)

$$P_{Tur} = Vc \,.A_c \;\; (\Delta P_{tot} - K/2 \; Pc \,.\, V_c^2)……………(5.23)$$

Condition for Maximum power output from available total draught.

Differentiating eq (5.23) with respect to turbine inlet velocity Vc and testing for maximum power condition.

$$d/dVc \, (P_{Tur}) = 0$$

$$\Delta P_{tot} - K/2 \;\; Pc \,.3.\, V_c^2 = 0$$

$$V_c^2 = \frac{2 \times \Delta P_{tot}}{K.\, Pc.3} \qquad \text{put in eq (5.21)}$$

And therefore

$$\Delta P_{tot} = \Delta P_s + K/2 \,.\, Pc \times 2 \frac{\Delta P_{tot}}{K.Pc.3}$$

$$= 2/3 \,\Delta P_{tot} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(5.24)$$

i.e. 66.66% of ΔP_{tot}

Therefore a drop of 2/3 of total draught is required to be carried out across the turbine, for maximum power condition for available total updraught.

$$P_{Tur}\, max = 2/3 \,\Delta P_{tot}\, VcC \,.A_c$$

$$= 2/3.\, Pc.g.Hc\, \Delta T/Ta \,.\, Vc \,.A_c$$

$$= 2/3\, m\, g\, \frac{HcCP\, \Delta T}{CP.Ta}$$

$$= 2/3 \,.\, n_{ch}\, .Q$$

$$= 2/3 \,.\, n_{ch}\, .n_{coil}\, .A_{coil}.\, G \qquad \ldots\ldots\ldots\ldots\ldots(5.25)$$

<u>Turbine Convert Efficiency :-</u>

The turbine conversion efficiency is the ratio of power output from turbine to energy input rate.

$$n_{Tur} = \frac{P_{Tur}}{mcp.\, \Delta T}$$

$$n_{Tur} = (\, \Delta P_{tot} - K/2\, Pc \,.\, V_c^2 \,)$$

$$= \frac{Vc}{Pc.\, Ac.\, Vc.\, CP.\, \Delta T}$$

$$= \frac{Pc.g.Hc.\ \Delta T/Ta - K/2\ \ Pc\ .\ V_c^2}{Pc.C.P.\ \Delta T}$$

$$P_{Tur} = \frac{g\ Hc}{CP.Ta} - \frac{K.V_c^2}{2CP.\ \Delta T}$$

The above eq (shows material the wind turbine conversion efficiency is limited by chimney efficiency. Lower the velocity inlet to turbine improves efficiency (limiting value zero velocity theoretically) and increase in air temp rise T . improves turbine efficiency.

Plant Efficiency:- Plant efficiency is the ratio of output power total energy supplied.

$$n_{plant} = \frac{P_{Tur}}{A\ \ Coil\ .G}$$

$$= \frac{P_{Tur}}{(mcp.\Delta\ T/n_{coil})}$$

$$= n_{coil}\ .\ n_{Tur}$$

$$n_{plamt} = n_{coil} \left(n_{ch} - \frac{KVc^2}{2cp.\ \Delta\ T} \right)$$

It is required to pay equal attention on power output as well as the efficiency of the plant for maximum power pressure drop across turbine = 2/3 Δ P.

i.e. 66.66% of total updraught

for maximum plant efficiency $Vc = 0$

i.e. pressure drop across turbine = Δ P

i.e. 100% of total updraught.

Practically some minimum flow velocity is essentially required to overcome turbine friction and other plant friction. And from experimentation it found that about 80% of total updraught is to be carried out to achieve maximum efficiency of plant.

$\therefore \Delta Ps = 0.8 \Delta P$

$P_{Tur} = \Delta Ps. Vc. Ac$

$P_{Tur} = 0.8 \Delta P. Vc. Ac$

$= 0.8 \rho c\ Hc.\ \Delta T/Cp.Ta.\ Vc.Ac.$

$$= 0.8\ m\ \frac{gHc}{Cp.Tad}\ Cp.\ \Delta T$$

$= 0.8\ n_{ch}\ Q$

$= 0.8\ n_{ch}\ .n_{coil}\ .A_{coil}.\ G$

TYPICAL PLANT OPERATING PARAMETERS FOR PLANT OF RATING 5,30 AND 100 MW ARE GIVEN IN TABLE

Civil Engineering	5 MW	30 MW	100 MW
Chimney height (m)	445	750	950
Chimney radius (m)	27	42	57.5
Collector radius (m)	555	1100	1800
Collector height, external (m)	3.5	4.5	6.5
Collector height, internal (m)	11.5	15.5	20.5
Mechanical Engineering			
Type of turbine	Propeller Type		
Number of turbine	33	35	36
Distance of turbine from Chimney Centre (m)	53	84	115
Airflow rates (m/s)	8	10.4	13.8
Shaft power rating of Individual turbines (KW)	190	1071	3472
Blade tip-to-wind speed ratio	10	10	8
Rotational speed (1/min.)	153	132	105
Torque (kNm)	11.9	77.5	314.5
Operating data at rated load			
Upward air draught speed (m/s)	9.07	12.59	15.82
Total pressure difference (pa)	383.3	767.1	1100.5
Pressure drop over turbine (pa)	314.3	629.1	902.4
Friction (N)	28.6	62.9	80.6
Temperature in collector (ºC)	25.6	31.0	35.7

RESULTS

The availability of the solar chimney is reflected in the average operating hours over the years. For comparison, the measured hours of sunshine with over 150 W/m2 radiation & daylight hours from sunrise to sunset are also shown for 1987. The plant ran for a total of 3157 hours in 1987, an average of 8.8 hour per day. This includes 244 hours of night operation, proving the ground heat retention effect.

From the structural point of view it was clear that glass was preferable to plastic film for the collector. Parts of the plastic film became brittle & tore in storms even in the first year of operation; whereas the glass roof survived undamaged for the full period, despite severe storms & even hail. The glass roof also proved excellent in terms of self-cleaning by rain as well.

Examination of the turbine by the manufacturing firm after seven years` operation in 1988 showed no wear. During normal operation only visual checks & oil changes took place, this means that even the only moving parts will have a long life span.

The chimney guy rods were not protected against corrosion for this temporary use. By spring 1989 they had rusted so badly that they broke in a storm & the chimney fell down. This was predictable; but they still lasted for eight yeas rather than the essential three when they failed the necessary measurements had long been completed. As mentioned, the chimney was built in non-permanent lightweight materials simply because of the shortness of the project & the necessity of dismantling the prototype (continuous operation of a power station with an output of only 50 KW does not make economic sense.) This lightweight construction could of course not be considered for solar chimneys with realistically large dimensions & under sensible economic conditions. As a rule the chimney will be a conventional RCC tube.

Comparison of the calculated plant performance over days & years using measured meteorological data & measured plant performance agreed very well & thus confirmed the developed plant simulation program.

FABRICATION

In fabrication first of all, as per results obtained from calculations of different parameters the foundation is constructed of (dia 4 ft.). Then by folding the metallic sheet a chimney is constructed of min. height 2.5 ft. & diameter 12.5 cms.

These two parts are quite separately constructed. After this the Glass – (Blackish Green) of 3 mm is fixed on the foundation with the help of pack-ups & lamby.

The Turbine is constructed with a cartboard paper is connected inside the chimney by drilling two hole at lower side. This chimney & foundation are attached to each other by air tightning material & bits.

In this way the proper model for the solar chimney power plant is constructed.

COSTING

	MATERIAL		Rs.
1)	Collector Glass (3 mm)	=	1200
2)	Chimney Material	=	150
3)	Foundation	=	400
4)	Motor	=	40
5)	Other	=	60
6)	Matter collection	=	450
			2300/-