PASSIVE COOLING OF BUILDINGS

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PASSIVE COOLING

• WHY TO PASSIVE COOLING

-The world trade in A/C equipment has been tripled during the last decade.

-Annual purchases of A/C in Europe has been increased tremedeously, (800 Per Cent In Greece)

-The use of A/C creates important problems of peak electricity load , (23 % in USA)

-The use CFC's creates environmental problems

-The use of A/C creates indoor air quality problems

PASSIVE COOLING

- FRAMEWORK FOR CONSIDERING PASSIVE COOLING

1. PROTECTION FROM HEAT GAINS :
Landscaping, Building form, Layout and External Finishings, Solar Control, Thermal Insulation, Control of Internal Gains

2. MODULATION OF HEAT GAINS : Use of the thermal capacity of the building.

3. HEAT DISSIPATION : Rejection of the excess heat to an environmental heat sink, (Evaporative, Convective, Ground)

PASSIVE COOLING

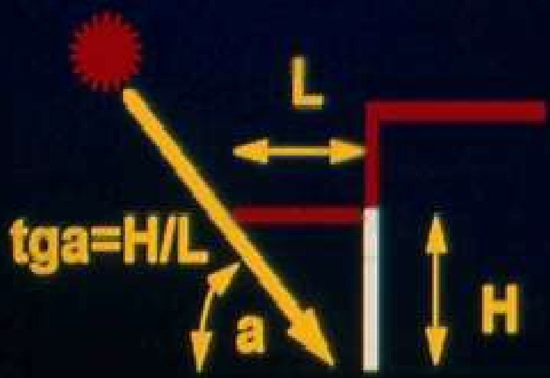
• SOLAR CONTROL - 1

Efficient solar control of external transparent and opaque elements of the building's envelope decreases the heat flow to the building.

Shading can be achieved using trees and natural vegetation, neighbouring buildings, and fixed or mobile shading elements attached on the building's envelope.

PASSIVE COOLING

• SOLAR CONTROL - 2



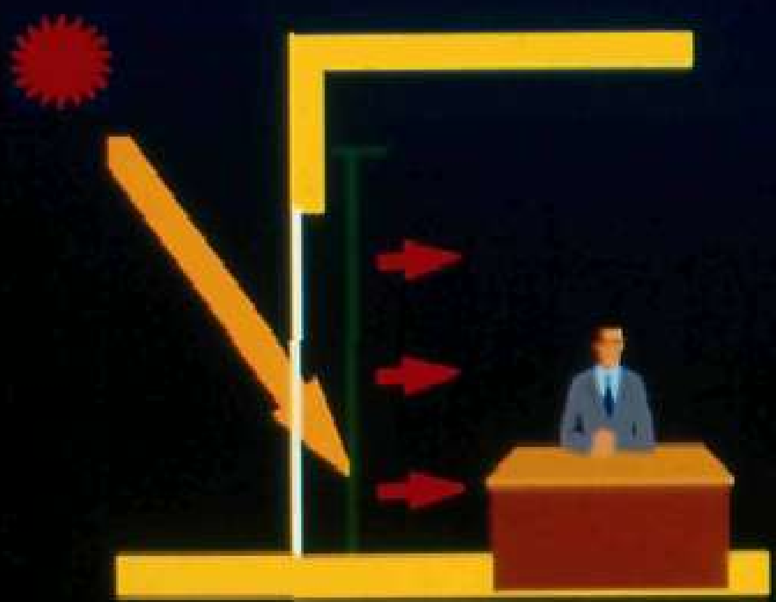
Fixed or movable external shading devices like overhangs, offer efficient solar control to direct solar radiation.

However, the effect of diffuse and ground reflected radiation should be taken into account.

Design of the external shading devices should be based on the optimisation of the heating, cooling and lighting performance of the building

PASSIVE COOLING

• SOLAR CONTROL - 3



Internal shading devices are less efficient than the external because solar radiation enters partly to the building.

Internal shading devices should permit natural ventilation and transmission of daylight.

A combination of external and internal shading devices can offer efficient solar control.

PASSIVE COOLING

• MICROCLIMATE - 1

Modifications of microclimate around buildings can help to improve indoor comfort conditions and to reduce cooling loads, while also providing protected spaces for outdoor use.

•Appropriate siting of a building can provide natural solar protection and help to take advantage of local winds

PASSIVE COOLING

• MICROCLIMATE-2

•Vegetation provides natural protection from the sun and evaporative cooling.

•An average tree evaporates 1460 kg of water per sunny day which is the equivalent of 870 MJ cooling capacity,

•Evapotranspiration from one tree can save 1-2.4 MJ of electricity in A/C per year.

•Latent heat transfer from wet grass can result in temperature 6-8 C cooler than exposed soil and one acre of grass can trasfer more than 50 GJ per day

PASSIVE COOLING

• MICROCLIMATE-3

Other landscape techniques include the use of pools or ponds, fountains or sprays cascades or falls, drip or mist irrigation and surface or subsurface irrigated areas such as rock and pebbles.

- Under mean conditions of wind speed, dry and wet bulb temperatures, the energy released by a square meter of open water surface is close to 200 Joules.

NATURAL VENTILATION

• WIND PRESSURE

$$P_w = 0.5\ C_p u^2$$

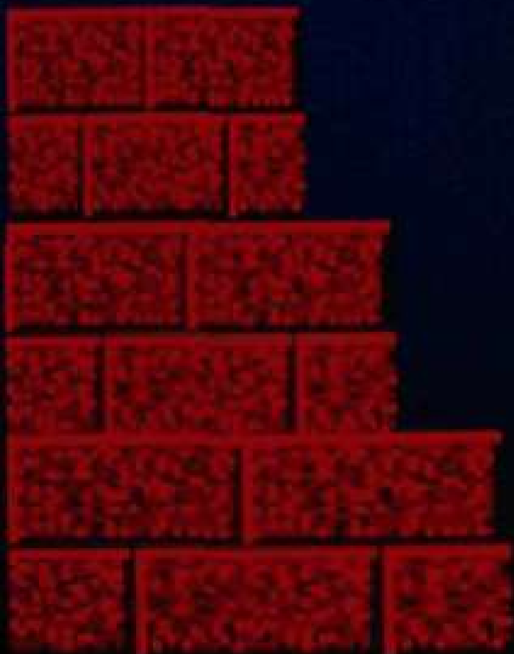
C_p = Pressure Coefficient

C_p is determined by :

- The Building Geometry
- The Wind Velocity
- The location of the building relative to other buildings and the topography of the terrain

PASSIVE COOLING

• THERMAL MASS - 1



The term Thermal mass describes the ability of ordinary building materials to store heat. In general, the heavier the material the more heat it will store. In summer the thermal mass soaks up the excess heat that enters through the building fabric reducing thus the peak indoor temperatures.

During the night, the heat is slowly released to passing cool breezes that are moving through the building.

PASSIVE COOLING

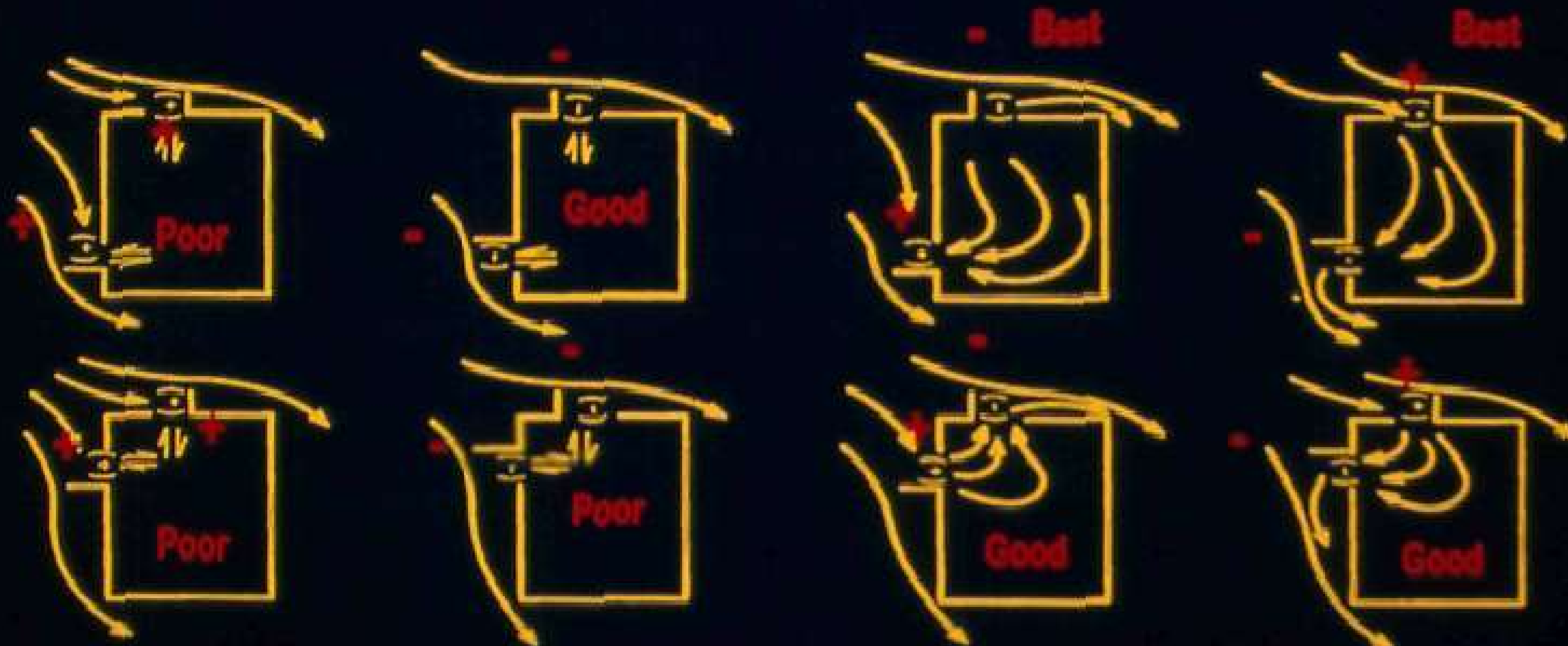
• THERMAL MASS - 2

The optimum design of thermal mass should be considered in conjuction with the heating and cooling performance of the building.

The occupation schedule of the building, the use or not of heating and cooling systems as well as the control of the climatic devices are the parameters influencing and determining the optimum level and placing of the thermal mass.

NATURAL VENTILATION

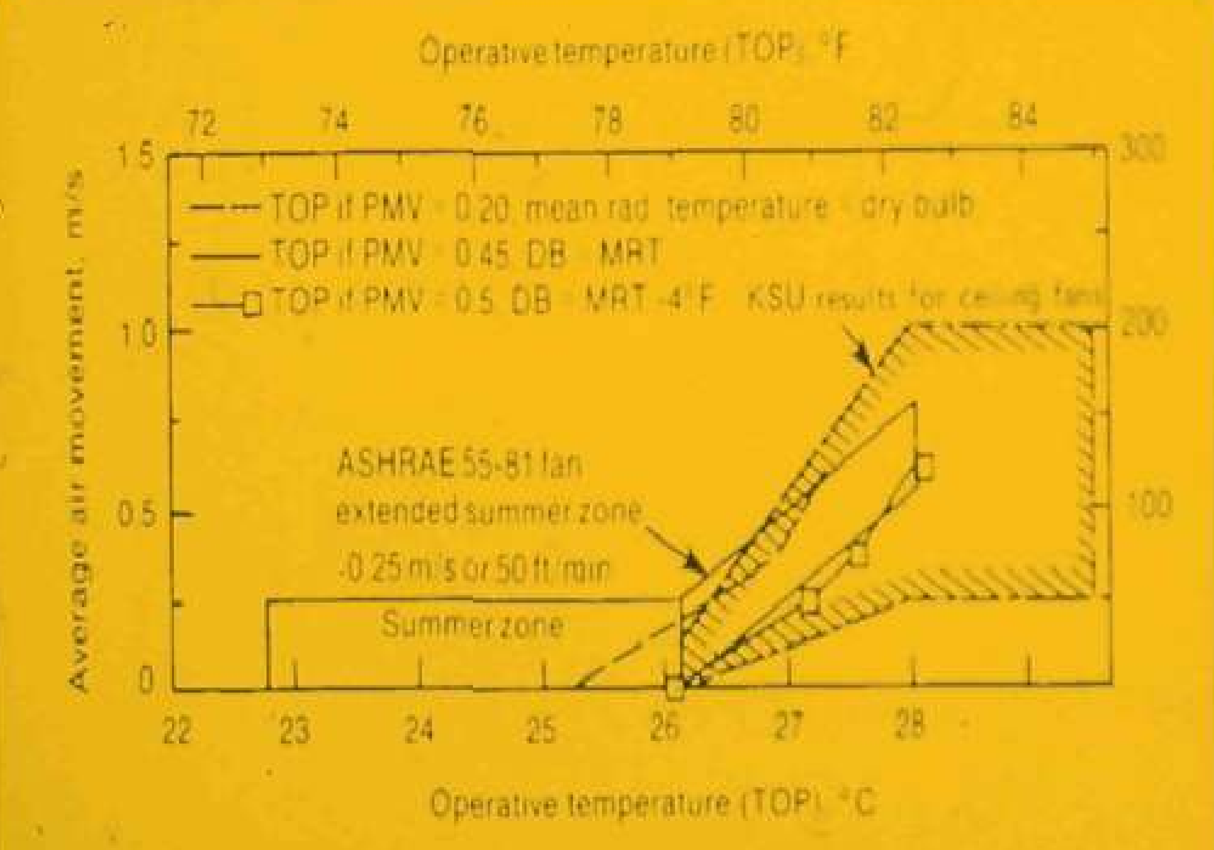
•VENTILATION AUGMENTATION BY WING WALLS-4



Apertures on Adjacent Wall : Expected Ventilation Results for several wing wall configurations

NATURAL VENTILATION

• CEILING FANS

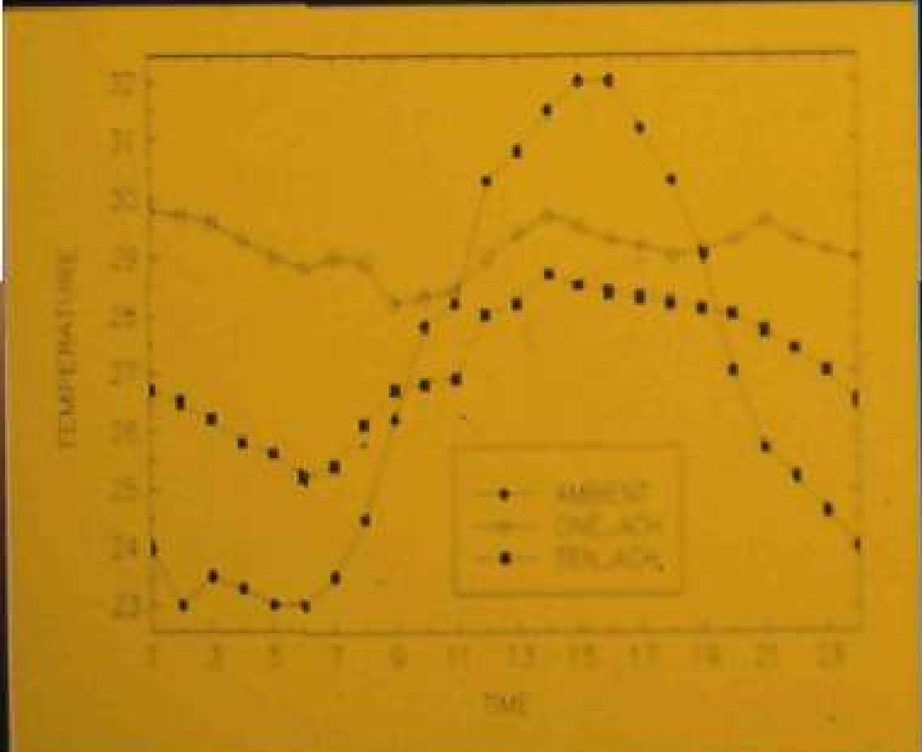


Experiments show that air motion induced by ceiling fans can increase the preferred temperature to 29 C at 50 % relative humidity.

NATURAL VENTILATION

• NIGHT VENTILATION

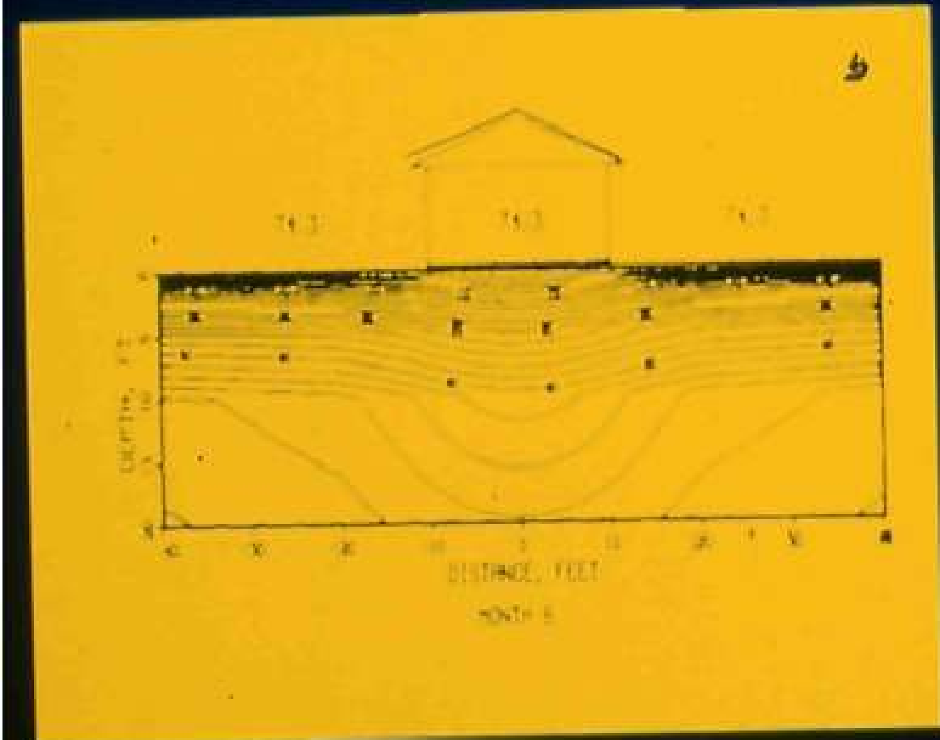
Daily Variation of a typical Building in Greece with 1 and 10 ACH



Ambient temperature during night is low. Circulation of the outdoor air inside the building cools the building's mass and decreases the peak indoor temperatures during the day period. Experiments show that it is possible to decrease the maximum daily temperature of the building by 1 to 2 C.

GROUND COOLING

• DEFINITIONS



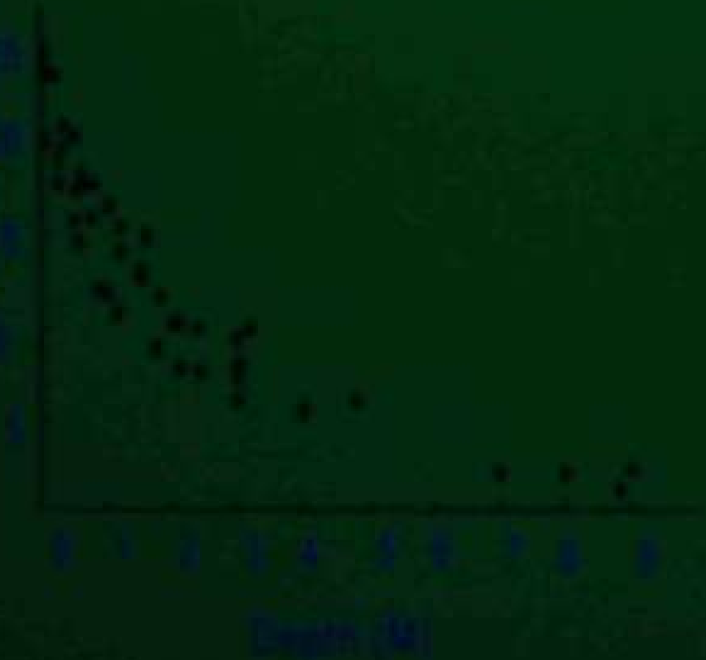
During the summer the soil temperature at certain depth is considerably lower than the ambient temperature. Therefore, ground offers an important source for the dissipation of the buildings excess heat. There are two strategies for the use of the ground :

1. Direct Earth Contact Cooling
2. Buried Pipes.

GROUND COOLING

• THE GROUND TEMPERATURE

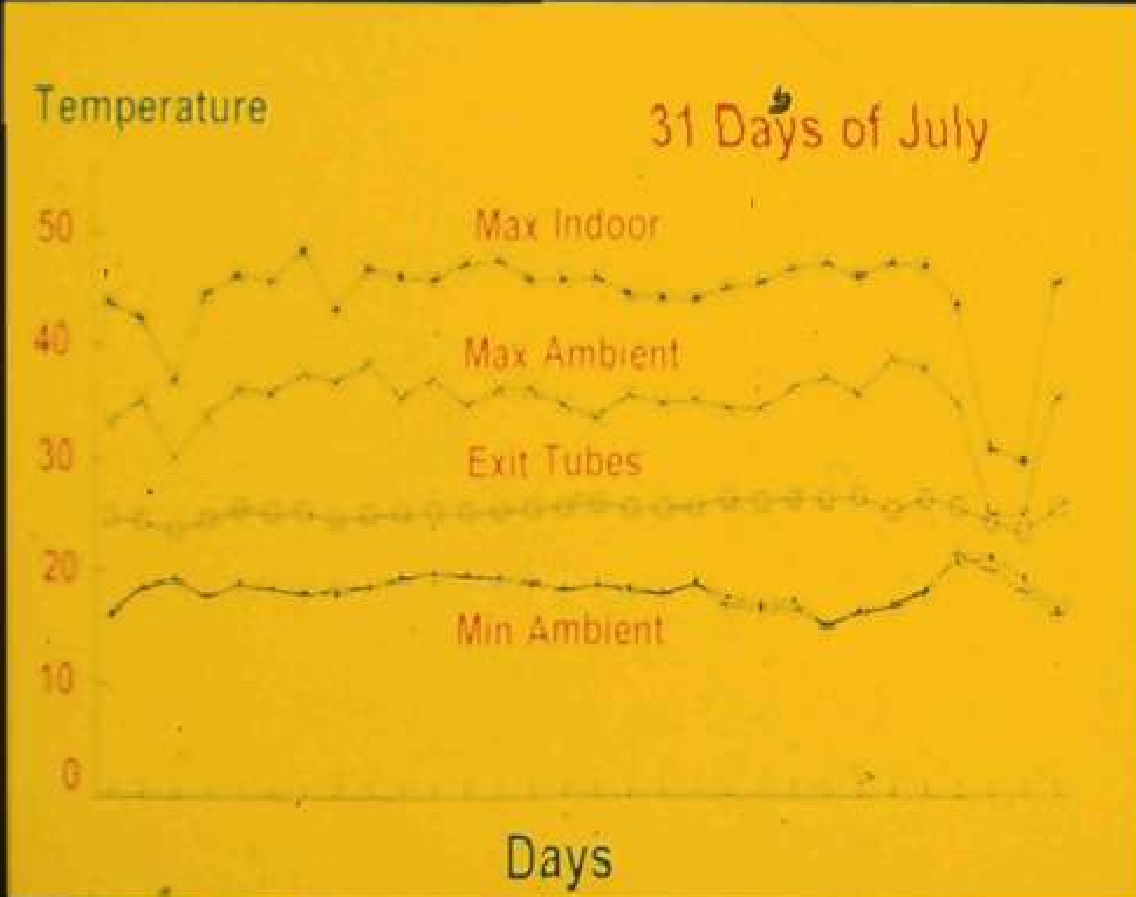
$$T_{z,t}=T_m-A_s \exp[-z(\pi/365\alpha)^{0.5}] \cos[2\pi/365[t-t_o-z/2(365/\pi\alpha)^{0.5}]]$$



Assuming a homogeneous soil of constant thermal diffusivity, á, the ground temperature at any depth z and time t is given by the above expression where Tm and As are the mean annual and the amplitute of the ground temperature

GROUND COOLING

• PERFORMANCE OF BURIED PIPES

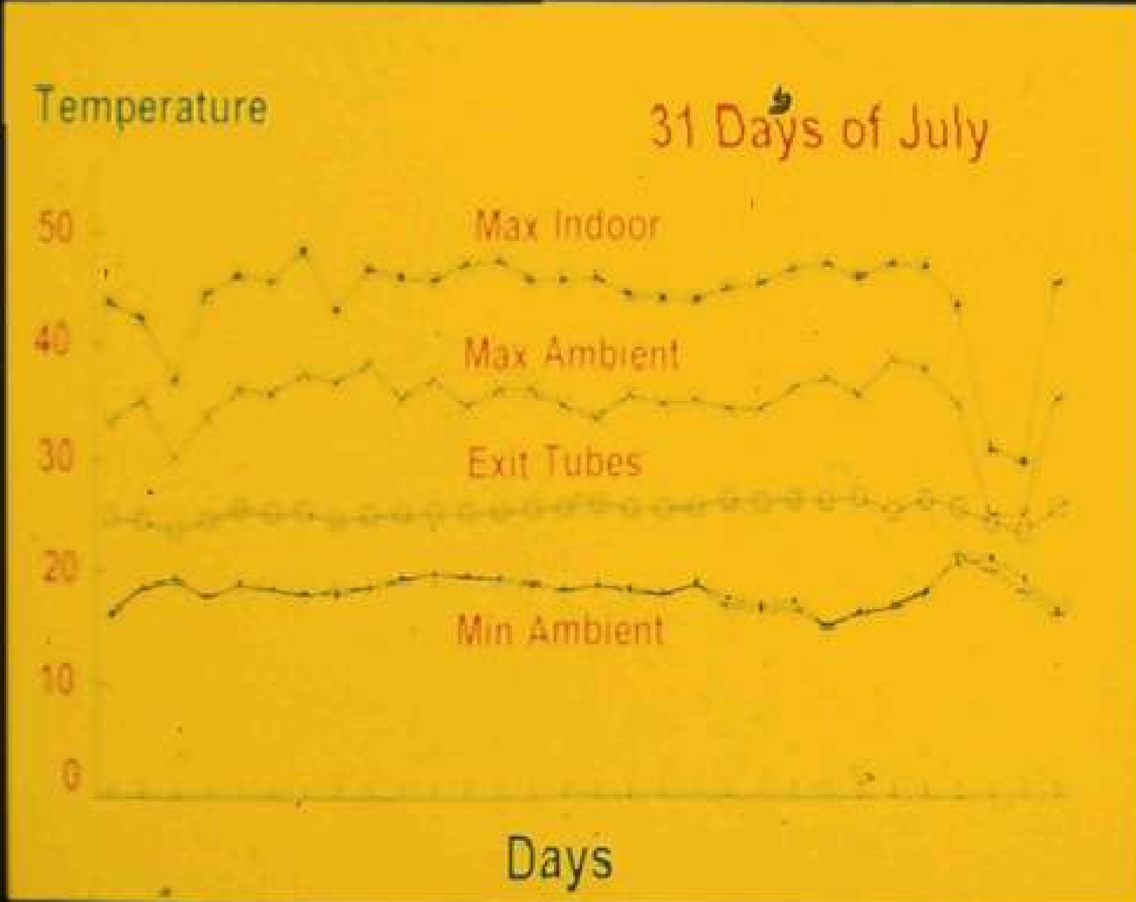


Experimental Results for a month

The performance of the buried pipes is a function of the inlet air temperature, the ground temperature, the thermal characteristics of the pipes and soil as well as of the air velocity, the pipe dimension and the pipes depth.

GROUND COOLING

• PERFORMANCE OF BURIED PIPES



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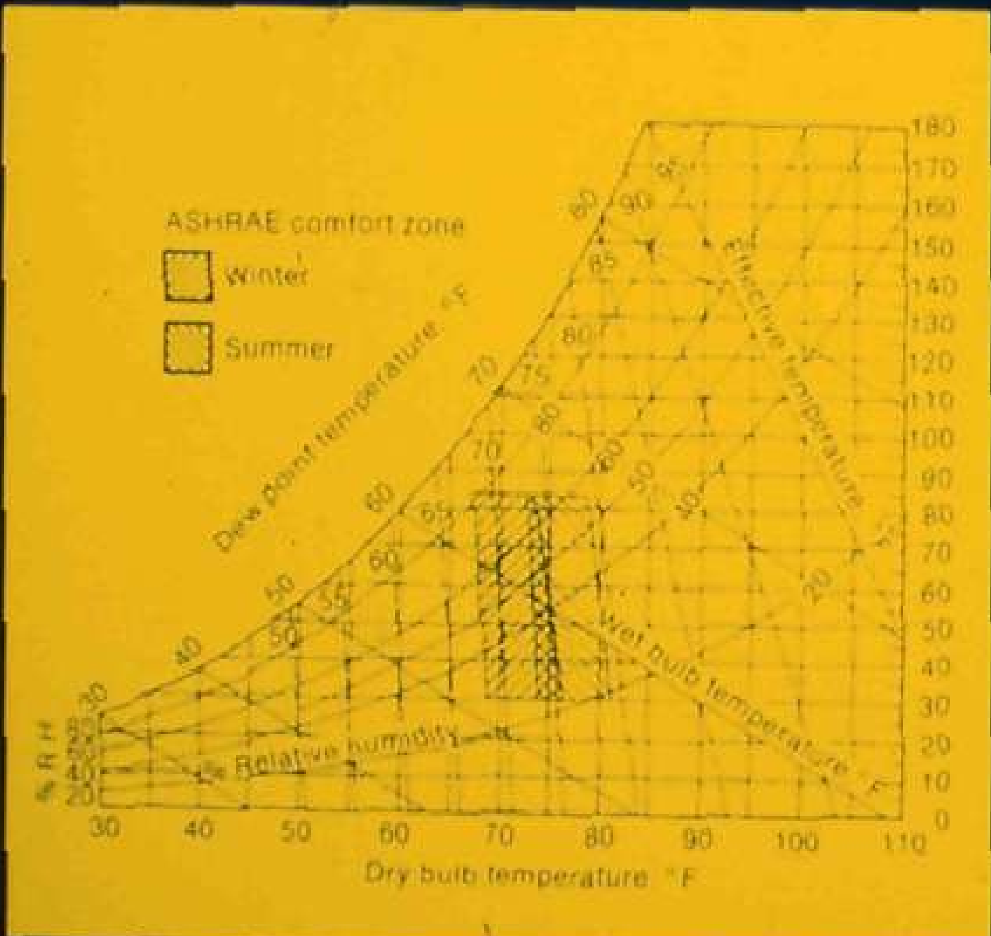
EVAPORATIVE COOLING

• DEFINITIONS



Evaporative Cooling applies to all processes in which the sensible heat in an air stream is exchanged for the latent heat of water droplets or wetted surfaces.

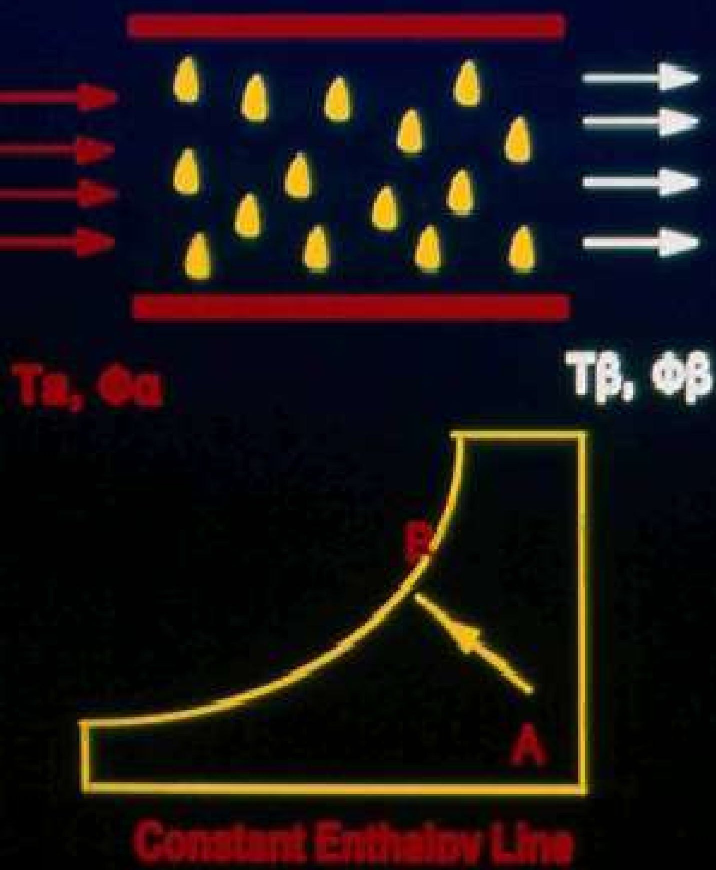
Evaporative Efficiency :

$$e = (t_1 - t_2)/(t_1 - t_1')$$

t_1, t_2 : Dry bulb temp of the entering and leaving air , t_1': wet bulb temperature of the entering air

EVAPORATIVE COOLING

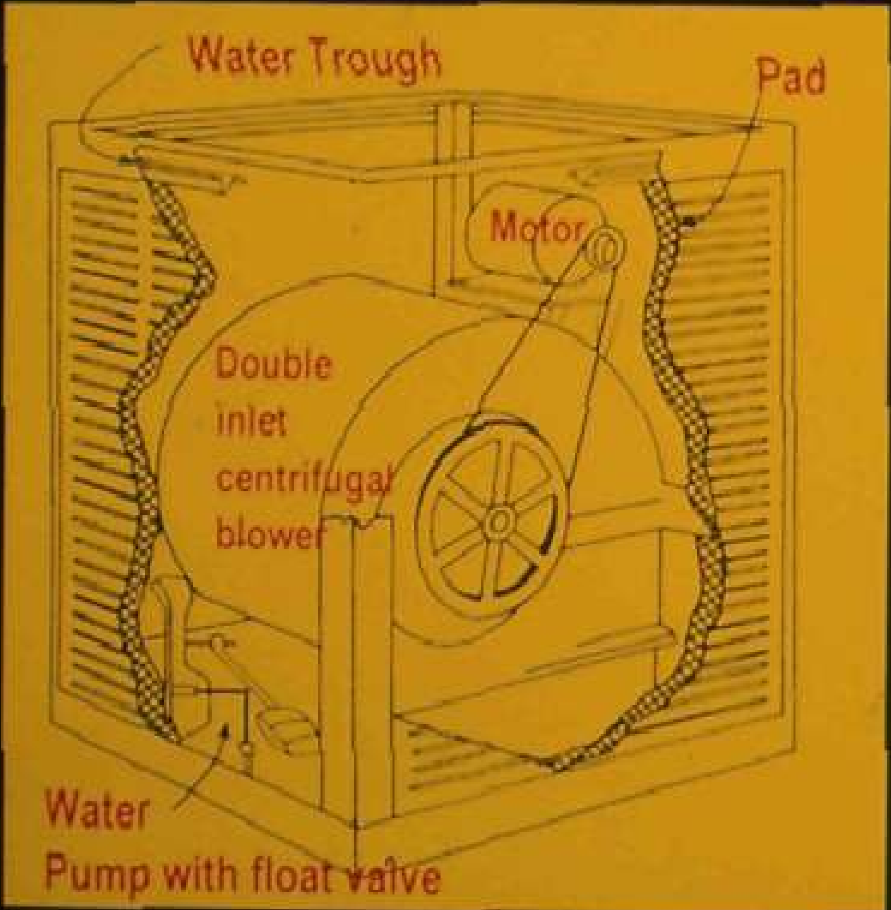
• DIRECT EVAPORATIVE COOLING PROCESSES



When the air stream comes into direct contact with liquid water , the cooling equipment is characterized as DIRECT. Direct Evaporation is characterized by a displacement along a constant wet bulb line AB, . Thus, the decrease in the dry bulb temperature is accompanied by an increase in the moisture content of the air.

EVAPORATIVE COOLING

• DIRECT EVAPORATIVE COOLING , (DEC)



In a direct evaporative cooler water is supplied to a small reservoir and then flows through fibrous pads. The air temperature is reduced by about 70-80 % of the difference between the dry, D.B.T, and the wet bulb, W.B, temperature of the air. The climatic criterion for the applicability of D.E.C is the ambient W.B.T. and a large difference between D.B.T and W.B.T.

EVAPORATIVE COOLING

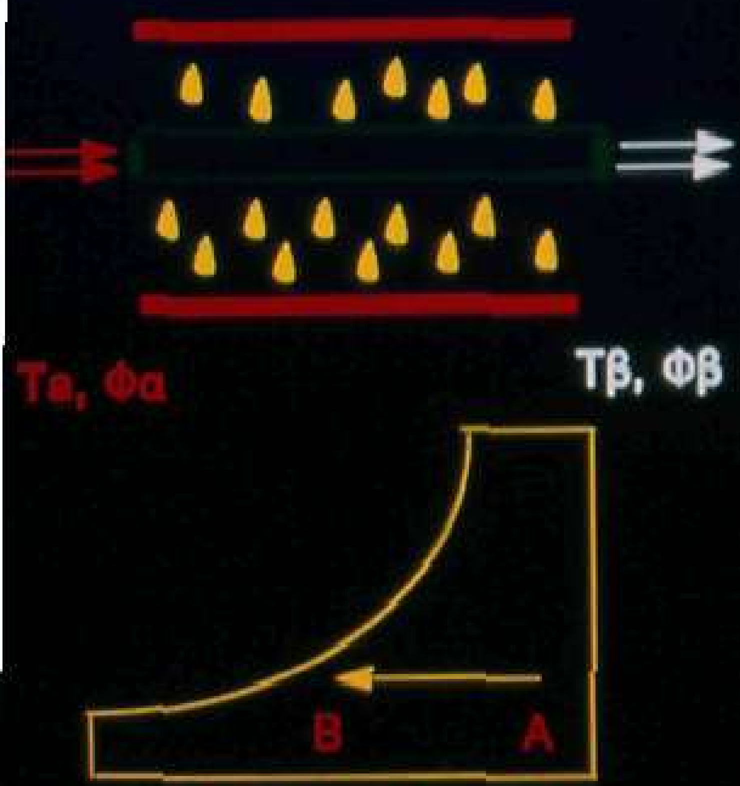
- **CLIMATIC APPLICABILITY LIMITS OF EVAPORATIVE COOLING**

DIRECT : Only Where and When the maximum Wet Bulb Temperature in summer is about 22 C and the maximum dry bulb temperature is about 42 C.

INDIRECT : As the indoor humidity is not elevated by indirect evaporative cooling, it is possible to apply in places where the maximum wet bulb temperature is 24 C and the maximum dry bulb temperature is 44 C.

EVAPORATIVE COOLING

• INDIRECT EVAPORATIVE COOLING PROCESSES

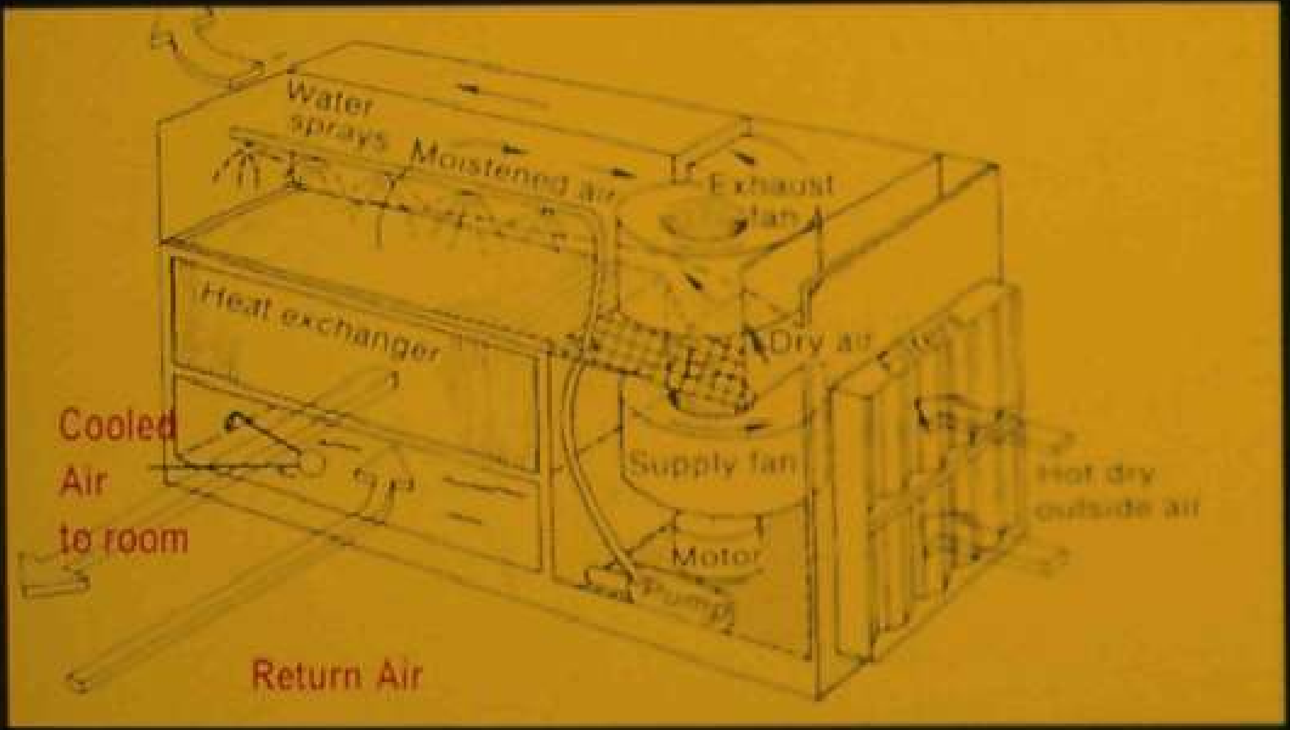


Constant Moisture Content Line

When the air is cooled without addition of moisture by passing through a heat exchanger which uses a secondary stream of air or water , the cooling equipment is characterized as INDIRECT. Indirect Evaporation is characterized by a displacement along a constant moisture content line AB, . Thus, the dry bulb temperature is decreased without increase of the moisture content of the air.

EVAPORATIVE COOLING

• INDIRECT EVAPORATIVE COOLING , (IEC)



It is based on the use of a heat exchanger where the indoor ventilated air passes through the primary circuit where evaporation occurs while the fresh air passes through the secondary circuit

Energy Savings of up to 60 percent compared to A/C may be achieved in hot dry regions


Hollywood