Evaporative Cooling (Spinning)

By:

Muhammad Mushtaq Ahmad

Evaporative Cooling (Spinning)

By: Muhammad Mushtaq Ahmad

MTS

Lahore

The ancient thought that man had seven senses, (Animation; Feeling; Hearing; Seeing; Smelling; Speaking; Tasting) but it is no more than coincidence that the principal influences which affect human comfort are also seven in number:

1. Temperature
2. Humidity
3. Radiation
4. Air Volume
5. Air movement
6. Air purity
7. Ionization

Air conditioning is the process of treating air also as to control simultaneously its temperature, humidity, cleanliness and distribution to meet the requirements of "conditioned space". An air conditioning system may use heating, cooling, humidifying, de-humidifying and filtering units of combination of these depending upon the out side weather.

The capacity of an air conditioning system is directly proportional to the heat load in the system. The heat load consists of internal heat which is almost constant for textile mills and transmission heat which varies from time to time and season.

The maximum heat load, which occurs during summer afternoons, determines the capacity of air conditioning re-quired for a department of the maximum heat load, roof heat load accounts 25% to 30%.

Air conditioning plants are installed to maintain correct ambient condition for spinning and weaving process to work smoothly. Norms of temperature and relative humidity for textile mills are established through controlled experiments in laboratories and mills.

The conditioning plants usually operate on the principle of evaporative cooling. The air passes through a spray chamber where it absorbs water, gets saturated and cooled. The cool air is distributed in the department where it gets heated by heat load. When air is heated, its temperature rises and relative humidity falls. Equations (1) give the relation between heat load rate of air circulation and the related temperatures.

$$Q = 3.39H / (DBi\text{-}WBo)\text{-}0.52 \qquad (1)$$

Where
Q is the capacity of conditioning system m3/hr.
H is the heat load, k cal/hr.
DBi is the Dry bulb temperature in side the department °C
WBo is the Wet bulb temperature out side the department, °C.

Once the out side wet bulb temperature is known, the DBi for the desired level of humidity can be found out from the psychometric chart. The difference (DBi-WBo) in equation (1) is fixed by the atmosphere outside and humidity inside. The air circulation rate for a department is directly proportional to the heat load. It is, therefore, desirable to keep down the heat load to reduce the air circulation, which inturn will lower the initial and operational costs of conditioning further, if the heat load is not subjected to gross variations, the frequent adjustment in the air supply rate from time to time could be minimized.

The difference between DBi and WBo is fixed for a level of relative humidity (RH) required in a department, as given in table (1)

Table –1
Relation between RH and (DBi – WBo)
(For evaporative cooling system)

S.NO.	R.H. %	DBi – WBo (°C)
1.	50	12.0
2.	55	10.5
3.	60	9.0
4.	65	7.5
5.	70	6.5
6.	75	5.0
7.	80	4.0
8.	85	3.0

The dry bulb temperature at a particular level of relative humidity inside a department is fixed by the wet bulb temperature of the out side air. The high wet bulb temperature out side will always result in high dry bulb temperature inside. The dry bulb temperature can be lowered by means of refrigerate cooling, which however is quite expensive and is not likely to be widely used in textile mills.

HEAT LOAD

The total heat load for a department is made up of the internal heat load and transmitted heat load.

Internal heat load is the sum of heat generated by machines, workers and lights. Transmitted heat load is the heat flowing into the department, because the outside temperature is higher than that inside the department (summer). The heat Transmission through walls, windows, and roof varies considerably from season to season and even during a day from Morning to evening. The heat transmitted rate for a department is calculated by the following equation.

HT = Uw Aw [To – DBi] + Uwi Awi [To – DBi) + Ur Ar [ts] DBi] (2)

Where:

HT is the transmitted heat load, K cal/hr.
U is the overall heat transmission coefficient K cal/h.m^2°C.
A is the area, m^2
To is the temperature outside °C.
DBi is the dry bulb temperature inside, °C.
ts is the temperature of the roof top.
W, wi and r stand for wall, window and roof respectively.

During summer afternoon the heat from walls and windows together is about 1 to 3% of the total heat load transmitted. While the heat through the roof is about 25 to 30%.

The temperature of the roof starts rising around 9 A.M. and reaches the maximum at about noon and remains almost steady till about 4 p.m. Then it starts dropping gradually.

Against this is the rise in the outside temperature is quite small. The surface temperature of the roof is higher than the temperature of the surrounding air because the roof top receives heat from the sun in the form of radiation.

The rate of heat received by any surface depends upon a number of factors such as the time of day, color of the surface, wind velocity, dust in the atmosphere, materials used, etc.

a) Variation in the outside temperature change the actual heat load from time to time which inturn requires adjustment in the actual supply of air from humidification plants. These adjustments are made by means of dampers in the plants. The degree of adjustments will be minimized if the variable heat loads are reduced by various means such as good insulation or a false roof. Another solution for old mills which is equally effective and less expensive method of reducing the heat load from the roof is by roof cooling.

Some ways of reducing costs, by way of reducing the heat load and consequently the capacity of the humidification plants required. The following methods of reducing heat load are:

(i) Roof cooling
(ii) elimination of north light
(iii) discharge of pneumafil air to the outside
(iv) Minimization or elimination of windows area and
(v) Discharge of motor heat.

HEAT LOAD THROUGH ROOF

Due to radiation from the sun, the temperature of a roof top rises much higher than that of the surrounding atmosphere. The rise in temperature causes a substantial increase in the roof load. The rise in surface temperature due to radiation depends on various factor such as the intensity of radiation, absorbtivity of the roof surface, wind velocity, etc; To estimate the rises is quite complicated because of the complex relationship between these factors. To facilitate the heat load calculation the probable rise in temperature of the surfaces at different locations on the earth receiving, radiated heat from the sun, this depend upon the latitude also.

The atmosphere is presumed to be with out clouds, dust and smoke. The maximum temperature rise of a black horizontal roof, is 38.3°C where as it is 12.8°C if it is white. The heat load caused by radiation from the sun can be reduced if roof are white instead of black. The roof is generally covered with water proofing which is coated with tar, which is black. Heat load due to transmission through the roof is given by equation (3).

$$Hr = Ur\ Ar\ (t_2 - t_1) \qquad (3)$$

Where:

Hr is the roof heat load, K cal/hr.
Ur is the overall heat transmission Coefficient for roof from out side surface to air in the department, K cal/h m2°C.
Ar is the area of roof m2.
t_2 is the temperature of outside surface °C.
t_1 is the dry bulb temperature inside the department °C.

t_1 is almost steady. The outside surface temperature, t2 is quite high and fluctuates from time to time, fluctuation change the heat load, this required frequent adjustments in plant operations. t2 should therefore be kept Constant and as low as possible. Some of the ways to keep t2 low are:

1. The roof should be colored white to reflect radiated heat from the sun back into atmosphere.
2. A false roof.

The same degree of improvement in ambient Conditions can be achieved, if an air conditioning system of adequate capacity is added.

MACHINE HEAT

Amongst various sources of heat in a textile mill, heat from machines is the largest one. The electricity consumed by the motors is converted into heat. The heat of machine is calculated by equation (4)

Hm = Kw-LF/n x 860 (4)

Where

Hm is the heat of the machine, K cal/hr.
Kw is the power of motors installed in a department KW.
LF is the load Factor, dimension less,
n is the efficiency of the motor.

Load factor is defined as the ratio of the delivered power to the rated power of the motors. Hm is the heat load due to the total electrical power consumed by the motors in the department? The motors convert electrical power into mechanical power to drive the production machines. A part of the total power is consumed by the motor itself and the remaining by the machine. Consequently Hm is split in two parts as follows and is calculated by equation (5).

Hm = Heat of Motor + Heat of production machine.
Hm = KW-LF (1-n)/n 860 + KW-LF x 860 (5)

The load factor is generally 0.85. The efficiency of the motor at 0.85 load factor is about 85% to 87%. The factor, 1-n/n in equation (5) therefore works out to 0.18 to 0.25. It indicates that heat of the motor is about 18% to 25% of the total machine heat load and can be reduced if the motors are installed over a perforated top of an underground exhaust duct and enclosed by a perforated cover.

An exhaust Fan at the end of the duct draws air from the department through the perforated cover over the motor.

The heat released by the motor is drawn away along with this air and thrown out. Thus it reduces the heat load of the department. Design the return air duct such that this discharged hot air may be connected to supply air fan of preparatory and winding department to warm these department in cold weather, because in winter due to low temperature, preparatory and winding department performance get effected, with this system these department will get relief in winter. This system will improve the ambient conditions in summer as well as in winter. With this system in summer the temperature in the motor alley will reduce considerably. Cleanliness will also improve due to downward flow of air helping the fluff and dust to settle down.

HEAT OF AIR

Ring frames, Roving frames, etc. are provided with a system for collecting broken ends and dust. This is done by suction arrangement in which air in the conveying medium. The temperature of the air discharged by the suction system is more than that of the department from which the air is drawn. This air adds to the heat load. The heat load from the suction system is worked out by equation (6).

Ha = Kwa 860. LF. (6)

Where:

Ha is the heat of the suction system K cal/hr.
Kwa is the rated power of motor of the suction system, KW.
LF is the load factor, Dimensionless,

Another way of assessing heat load is given by equation (7)

$Ha = 0.295\ Qa\ (t_2 - t_1)$ (7)

Where:

Qa is the rate of Air flow by the suction system m3/hr.
t_2 is the temperature of discharged air °C.
t_1 is the temperature inside the department °C.

Heat transmission through windows and North light

It is better not to provide any window north light, which will improve the efficiency of the air conditioning plant and will be no air draft from outside.

LIGHTING HEAT

All light transmit heat. The heat emitted by light source is directly related to the wattage of the light source. The heat produced by fluorescent lamps is approximately 25% greater than that expected from the ratted wattage. This heat increase is due to the additional electricity required by the ballast (choke)

BODY HEAT GAIN

Peoples are a source of both sensible heat and latent heat. The heat produced by a person depends upon the energy that is being exerted. A person at rest causes less heat than a person being very active. For example a person sitting quietly produces about 1/7 as much heat as person who is bowling.

The effect of different types of physical activity on heat production by the body.

Sleeping	291 Btu/Hour
Sitting at Rest	384 Btu/Hour
Typing Rapidly	558 Btu/Hour
Walking at 2 mph	761 Btu/Hour
Walking at 4 mph	1390 Btu/Hour
Walking up stairs	4365 Btu/Hour

BUILDING ORIENTATION

Since the sun rises in the East, the solar load through the glass in the East wall is greater in the morning. By noon, the solar load in the East is some what reduced and its effects afternoon, the solar heat reaches its greatest intensity, and it is now felt through the glass in the west wall. The north wall, of course is exposed to the less intense late afternoon and early evening sun. Thus the load through the glass on the North side is about 10% of the load on the East or West.

The information is important in its application to practical situation where the effect of the solar load is a factor.

WALLS & ROOFS

Heat from the sun enters a building through the walls and roof at a much lower rate than it does through glass. As the solar heat penetrates the surface sun of the building, some of the heat enters the building material and some is reflected to the atmosphere. The heat absorption process is continuous and the amount of solar heat entering the building material penetrates deeper until it reaches the in side surface.

If the sun were stationary so that it could shine continuously in one location with the same intensity, approximately seven hours would be required for the heat to reach to the interior surface of a 12-inch thick brick wall.

THE AIR MUST BE RENEWED

Where over peoples are engaged in manufacturing operation, satisfactory air conditions must be provided. For this reason the air has to be constantly exchanged and renewed.

The material processed or the manufacturing method call for certain definite air conditions in the rooms. The requirements relate mainly to the temperature and to the relative humidity, but the purity of the air, the number of renewals per unit time and problems connected with movement of the air likewise involved.

When the designed moisture content is within the medium range the problems are least serious. A high relative humidity necessitates a large ventilation plant. For a very low level of relative humidity the correspondingly low dew point in the plant may make it necessary to cool the premises artificially all the year round or to employ special devices to dry the air.

CONTROLLING THE AIR IN AN EXPERT WAY

Ventilation installations will differ widely in appearance and size according to the particular requirements, all of them, however are governed by the golden rule that the best ventilating or air conditioning apparatus is the one that is least noticeable, when blowing air into the room or with drawing it by suction, undesirable air currents and the resulting draughts must be avoided.

The simplest apparatus for the continuous renewal of air is a fan. Ventilation is effected, when the fan takes in air from outside by suction and forces it into the room extraction is effected, when it removes the air from the room by suction and conveys it to the exterior strictly speaking, however, all existing equipment ventilates and extracts, for, in the long run, air can be supplied to a room only if an equivalent quantity emerges from the room at some other point.

According to the DIN standard, no equipment can be termed an air conditioning plant unless it comprises all these devices and its regulation is automatic. Thus air conditioning equipment automatically eats the relative humidity & temperature of the air in a room at predetermined levels through out the year. For this purpose they are fitted with devices for filtering, heating, cooling, moisturizing and humidifying the supply air and for automatic control of temperature and humidity. In practice, however, the term "air conditioning plant" is often used more loosely.

The most important values by which the condition of the air is defined are: dry bulb temperature (°C), wet bulb temperature (°C) dew point (°C), relative humidity of the air (%), heat content (enthalpy) (Kcal/kp) and water content (P/kp dry air).

The relation between these values was illustrated by mollier the well known t-x diagram. When estimating the heat load, indoor heat sources must, be considered also, these source include, people, lights, appliances & motors.

In rooms where considerable moisture forms or a large amount of dust is produced the only basis to be adopted is one of a certain number of air changes, found by experience. The number of Air changes, multiplied by the size of the room, gives the required air delivery.

In most cases, however, the size of a plant will depend on the maximum heat load in summer and on the maximum permissible room temperature and minimum permissible relative humidity. For this purpose the planning Engineer must first of all determine the so-called "cooling load" of the room. This cooling load is a quantity of heat measured in kcal/hr. it consists of the heat supplied to the room from out side and the heat developed in the room itself.

The cost of AC plant is directly related with number of air changes. The cost of plant will increase as the air changes will increase; cost of plant is also related with RH%. If the requirement of RH% will increase plant cost will increase too.

DESIGNING OF EVAPORATING COOLING SYSTEM

$$V = 3.39\, Q/(DBi - WBo) - 0.52$$

Where

V is the capacity of conditioning system m^3/hr.
Q is the heat load K cal/hr.
DBi is the dry bulb temperature in side the department °C.
WBo is the wet bulb temperature outside the department °C.

OR

$$V = Q/rc\triangle t$$

Where

V is the quantity of air in m^3/hr.
Q is the cooling load in K cal/hr.
r is the density of air in KP/m^3.
C is the specific heat in K cal/KP°C.
$\triangle t$ is the temperature difference °C.

- The density of the air depends on the temperature, on the relative humidity and on the height above sea level. It is usually between 1.0 and 1.2 KP/mr.

- The specific heat can be introduced in the equation with a sufficient degree of accuracy and a constant equal to 0.24 K cal/°C.
- By temperature difference mean the difference between the ingoing temperature and that prevailing in the room.

Air changes/hr = volume (m^3/hr)/Volume of shed (m^3).

EXAMPLE-1

The room containing 21 spinning frames. Rated/installed power 690 KW, maximum absorbed power 621 KW, operating factor 90, number of people 40. Surface 1716m^2, height 4.2m, and volume 7207 m^3.

Geographical location	=	Dera Ghazi Khan
Altitude	=	200 m above sea Level
Latitude	=	30.O4Deg N
Longitude	=	70.38Deg E

1. Electric energy consumed. = 621 kW.
2. Heat from fluorescent light Illumination 15 W/m^3
   15 x 1716/1000 = 25.74 kW
3. Body Heat gain 0.2325 x 40 = 9.30 kW
4. Heat by solar Energy = (4.20 kW)
   K-value roof 2.0 K cal/hm^2 k.
   K – value outer walls 1.7 K Cal / hm^2 K.
   K-value floor 1.0 K cal/hm^2k.

Total heat load 621.00 + 25.74 + 9.30 + 4.20 = 660.24 kw.

1 KW = 860 k cal/hr
660.24 x 860 = 567800 k cal/hr
Q = 567800 k cal /hr
V .3.39 x 567800 / 9 - 0.52 = 227000
OR V = 567800/1.158 x 0.249 = 227000
Air changes/hr = 227000/7270 = 31.49 or 32.

EXAMPLE II

The room containing 24 spinning Frames, each required a shaft input of 41.66 H.P. The room has a floor space of 200 ft x 100 ft and average roof height is 14 ft. North wall has 3.75ft x 200ft opening covered with glass. (For north light) There are 286 fluorescent luminaries each have 2 rods of 36 watt each. The number of person working is 40.

Geographical location	= Lahore
Altitude	= 215m above sea level

Latitude = 31.34Deg N
Longitude = 74.22Deg E

Out Door condition 100°F dry bulb and 80°F wet bulb. Inside required R.H. 55%.

Heat gain from spinning machinery.

= Electrical energy consumed
= 24 x 41.66 x 746/1000 x 56.9 x 60 Btu / hr
= 2546436 Btu/hr (1)

One h.p. = 746 Watts
One kw = 56.9 Btu/minute

Heat gain from artificial illumination.
= 286 x 2 x 36/1000 x 56.9 x 60 Btu/hr
= 70301 Btu/hr (2)
= Body heat gain
= 794 x 40
= 31760 Btu/hr. (3)

(Heat emitted by an occupant including sensible and latent heat is 794 Btu/hr during performance of moderate manual Work).

Heat gain from solar radiation in this example will be taken from the north, because other surfaces of the room do not receive rays of the sun at 1.00 p.m. and after.

Heat by solar Energy = Area x solar radiation heat transfer ratio x coefficient of glazing.

= (3.75 x 200) x 46 x 0.8 Btu/hr
= 27600 Btu/hr (4)

Total heat gain = 1 + 2 + 3 + 4

= 2546436 + 70301 + 31760 + 27600
= 2676097
OR 2676000 Btu/hr

The inlet conditions of air are 100°F/80°F.

The enthalpy of air at this condition on psychometric chart is 43.7 Btu/lb of dry air and R.H. is 41%. This air is then passed through the air washer and let us assumes that the water is at wet bulb temperature of incoming air and the condition of air leaving the washer is at 90% R.H. The adiabatic cooling has proceeded and the dry bulb temperature of air is lowered form 100°F to 83°F through adiabatic evaporation within the chamber. The air discharged into the room will being to absorb heat but will not change its moisture content till the R.H. attains its recommended value at 55% Enthalpy at 55% R.H. = 47.5 Btu/lb of air.

Take heating of air by fan = 0.36 Btu/lb of air.

Gain in heat content/lb of air.
= (47.5) – (43.7 + 0.36)
= 3.44 Btu/lb of air.
Let air change coefficient of efficiency.
= 1.12 (for standard air)

Mass of air handled per hour
= 2676000/3.44x1.12 = 694559
Or 694600 Lbs. /hr
Volume of air handled/hour = 694600/0.075
(Air at STP weights 0.075 Lbs/ Cu ft.
= 9261333 cu ft/hr
Or 9261000 cu ft/hr.
Volume of the conditioned area = 200 x 100 x 14
= 28000 cu ft
Air changes per hour = 9261000/280000
= 33 per hour
CFM of fan = 9261000/60 =154350 or 155000

CONTROL OF AMBIENT CONDITIONS

Correct ambient conditions require the following:

a. Provision of an air conditioning plant of suitable type of adequate capacity.
b. Proper control of plant operation.

Table 11 indicates common errors in ambient conditions, possible causes and suggested remedial action. Some general points which are important need to be kept in mind.

1. Warm air discharged from the pneumatic broken end collection system should be discharged out side except in winter when heat is to be conserved.
2. Saturated air from air Washers or wet duct system should show not more than about 1°C difference between dry bulb and wet bulb temperature, otherwise, it indicates that saturation of air is inefficient.
3. In winter the most effective and satisfactory method of heating the department is by re-circulation.

4. Spray Nozzles, elimination plates, air filters dampers diffusers, etc. should be checked at periodical intervals and repaired or replace if necessary.
5. Re-circulation of air hardly helps in raising R.II. But it raises both D.B and W.B temperature and makes it uncomfortable, except in winter.
6. Close all sky lights. It will help in winter as well as in summer.

ERRORS IN AMBIENT CONDITIONS AND CAUSES

AMBIENT Conditions	CAUSES OF ERROR	CORRECTIVE MEASURES
1. Low R.H., high DB,	Low air circulation or low saturation	i- Increase air circulation (check filters, eliminators dampers, and diffusers. ii- Check sprays nozzles. Water pressure.
2.Low R.H., Correct DBi	Low saturation and high air circulation	Check spray nozzles, Water pressure, adjust air circulation. Decrease air circulation
3. Low R.H., and Low DBi	Insufficient heating and insufficient moisture	Decrease air circulation
4. High R.H., Correct DBi or high R.H., High DBi,	Low air circulation and free moisture in shed	Reduce free moisture and increase air circulation
5. Correct R.H., high DBi	Re-circulation adopted	Stop or reduce re-circulation.
6. Correct R.H., high DBi	Low wet bulb temperature of outside atmosphere	Adopt re-circulation, if this is in adequate heat spray Water.

ROOF TREATMENT

Detail of roof insulation treatments is given below:

1) Applying primer coat of solvent base bitumen at 1 liter / square feet.
2) Laying seal coat of mixture of 75% - 10/20 bitumen and 25% 80/100 bitumen @ 12 KG/100 Sft.

3) Applying polythen sheet weighting 100 gms/m2 on top of seal coal of bitumen including sealing of joints and minimum 75mm overlap.
4) Lying of 50 mm thick thermo pore sheet weighing 25 KG/m3 over polythene sheet.
5) Lying of polythene sheet weighing 100 gm/m2 on top of thermo pore sheet including sealing of joints + minimum 75mm overlap.
6) Laying 75mm thick compacted earth over polythene sheet.
7) Lying 38mm burnt clay tiles laid in 25 mm thick mud mortar and grouting with 1:4 cement sand mortar.
8) White washes of roof top burnt clay tiles.

AIR CONDITION SUPPLY OVERDUCTS ROOF TREATMENTS LAYING

1. Applying premier coat of solvent base bitumen at 1 liter /square feet.
2. Laying seal coat of mixture of 75% - 10/20 bitumen and 25%-80/100 bitumen @ 12 KG/100 Sft.
3. Applying Polythene sheet weighing 100 gms/m2 on top of seal coat of bitumen including sealing joint and minimum 75mm overlap.
4. Lying of 50mm thick thermo pore sheet weighing 25 KG/m3 over polythene sheet.
5. Lying of polythen sheet weighing 100 gm/m2 on top of thermo pore sheet including sealing of joints & minimum 75mm overlap.
6. Lying 38 mm burnt clay tiles laid in 25 mm thick mud mortar and grouting with 1:4 cement sand mortar.
7. White wash top of burnt clay tiles.

CONVERSION FACTORS

1 Btu/hr	=	0.25199	k cal/hr
1 K cal/hr	=	3.96832	Btu/hr
1 Watt	=	3.412142	Btu/hr
1 Watt	=	0.8598452	k cal/hr
1 Btu/hr	=	0.2930711	Watt (W)
1 k cal/hr	=	1.163	Watt (W)
1 KW	=	56.9	Btu/minute
1 KW	=	3412.142	Btu/hr
1 K J/S	=	860	k cal/hr=1 KW
1 S	=	0.1KP	
1 BAR	=	1 KP /cm^2=10m WG	
1 KJ/K	=	0.24 k cal/kg.	