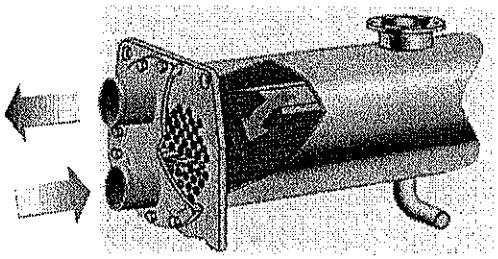
Water Management

Cooling Tower

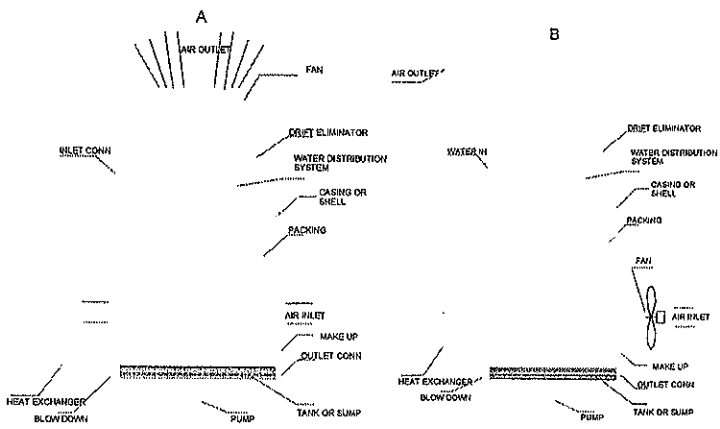
Outline

- Cooling Tower Operations
- Water Management
  - Estimate of Make Up water
  - Regulations
  - Strategies to reduce consumption
- Q & A

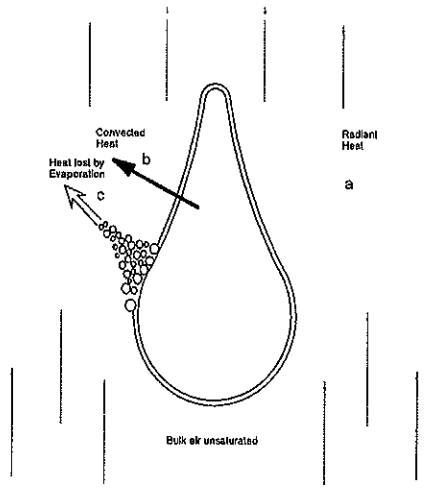
water-cooled condenser



Cooling Towers



Heat Transfer



Water Usage

- Water Loss
  - Evaporation (74.7%)
  - Drift (0.8%)
  - Bleed (24.5%)
- Evaporation
  - water loss as water vapour while performing the cooling function
  - affected by the temperature difference between inlet and outlet of the cooling tower

Water Usage

- Bleed (blow down)
  - to prevent the build up of dissolved and suspended solids
  - normally automatic and controlled via a conductivity sensor
- Drift
  - water lost as droplets in the exhaust air of cooling tower

Water Usage

- Splash
  - water lost due to the splashing action of falling water within the tower, or
  - effect of a strong wind blowing
- Overflow
  - water is lost when the level of water in the basin rises above a pre-determined level
  - normally due to a faulty valve on the incoming pipe

Make Up Water

- Make-up water required

MU = ER + BD + DR + L

MU : make up water
ER : evaporation rate
BD : blowdown
DR : Drift loss
L : system loss
(lost through pumps, gland seal, splash, overflow)

Make Up Water

- **ER = 0.8 x RR x (T_{hw} – T_{cw})° K x 4.2 / 2431 kg/s**

RR : pump recirculation rate (l/s)
0.8 : evaporation factor (typical range 0.75-0.85)
4.2 : specific heat of water (kJ/kgK)
2431 : latent heat of evaporation of water kJ/kgK
T_{cw} : temperature of cold water (leaving cooling tower
T_{hw} : temperature of hot water (entering the cooling tower)

Make Up Water

- Make-up water is normally measured using flow meter
- Otherwise, estimate using

  MU = ER x [COC / (COC-1)]

  COC : cycles of concentration

  the number of times the water circulates within the cooling system before being lost to blow down

Make Up Water

- **$COC = C_{cw} / C_{mu}$**
  - COC is the ratio of ions in the cooling water C_{cw} to that of the make-up water C_{mu}
  - Ions considered are magnesium or silica
  - TDS (total dissolved solids) is commonly used
- **$COC = C_{cw} / C_{mu} = TDS_c / TDS_m$**

- Example
  - Calculate the cycles of concentration , if the TDS of the cooling water is 2150 mg/l and that of the make up water is 390 mg/l
  - COC = 2150 / 390
    = 5.5 cycles

- Bleed (or blow down, BD)
  - can be measured using flow meter
  - otherwise,

MU x C_{mu} = BD x C_{cw}
BD = MU x C_{mu} / C_{cw}
BD = MU / COC
COC = MU / BD = C_{cw} / C_{mu}

- System losses
  - system losses should be minimized
  - If there is a mismatch between cycle of concentration (COC) calculated by MU/BD and by C_{cw} / C_{mu} then it is clear indication that leaks are occuring

Regulations for Cooling Towers

- Environmental Public Health Act (Chapter 95, Section 113)
- Environmental Public Health (Cooling Towers and Water Fountains) Regulations

(1) the owner or occupier of any designated area where a cooling tower is installed shall ensure that the cooling tower which is in use has –

- a standard plate count that does not exceed 100,000 cfu per ml
- a legionella bacteria count that does not exceed 10 cfu per ml

Regulations for Cooling Towers

(2) Without prejudice to the generality of paragraph (1) , the owner or occupier of any designated area where a cooling tower is installed shall ensure that the cooling tower which is in use is –

(a) at all times kept in a good state of repair and free of any sludge, slime, algae, fungi, rust, scale, dust , dirt or any foreign matter

(b) thoroughly cleaned and disinfected at least once every 6 months

Regulations for Cooling Towers

(c) inspected at least once a week for any physical defect, general cleanliness, organic fouling and presence of physical debris

(d) supplied with water only from the PUB water mains or any source as may be approved by the commissioner; and

(e) provided with easy and safe access to allow for the maintenance, inspection, and sampling of water required under these Regulations

Water Management

Minimize or eliminate water use through design

Minimize water use through good operation and maintenance of cooling systems

Minimize water use through effective contractor management

Water Management

Minimize or eliminate water use through design

minimize cooling load

- **Improve design of cooling tower**
- **Alternative heat rejection system**
- **Alternative water source**

Minimize Cooling Load

- reduced cooling load
  =reduced water consumption by cooling tower
- building design
  - passive cooling features
  - energy efficient system
  - best practices in operations

Improve design of Cooling Tower

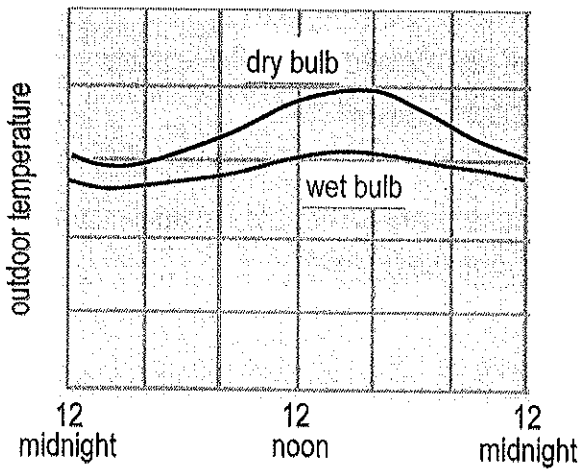
- reduce water flow rates
- increase temperature differences
- variable fan speed
- install drift eliminators, anti splash lourves
- install water meter on the make-up line to monitor consumption

Alternative Heat Rejection System

air-cooled systems	water-cooled systems
• less energy efficient • no cooling tower , no water needed • no risk of legionnaires' disease	• more energy efficient • consumes water • water treatment to control scale, corrosion and legionnaires' disease

air-cooled or water-cooled

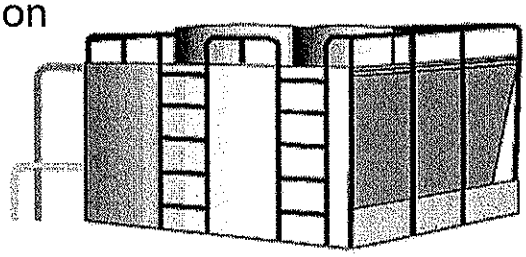
Efficiency



air-cooled or water-cooled

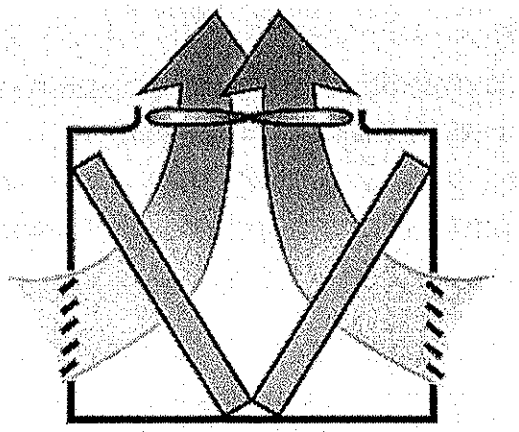
Maintenance

- Water treatment
- Condenser tube brushing
- Tower maintenance
- Freeze protection
- Makeup water



cooling tower

air-cooled condensers



Alternative Water Source

- Sea Water
- NEWater
- Rainwater
- Recycled Water

Alternative Water Source

- NEWater
  - Where applicable, NEWater should be used as make-up water for cooling tower
  - NEWater is cleaner than PUB water, enable a higher concentration cycle and increase water efficiency

Alternative Water Source

- Rain Water
  - It may be possible to harvest rain water for cooling tower use, especially on industrial sites where buildings are covered by large roofs

Alternative Water Source

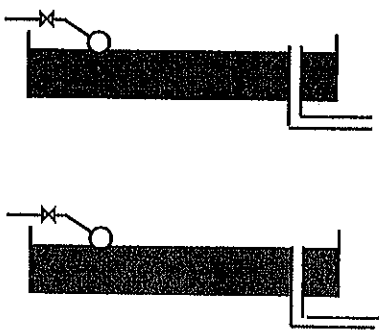
- Recycled water
  - condensate can be collected and used as make-up water, as it is usually clean and cold
  - reverse osmosis membrane unit can be used to treat reject water or bleed off treated water can be a suitable substitute for cooling tower water

Operations

Minimize water use through good operation and maintenance of cooling systems

- reduce uncontrolled water losses
- reduce controlled water losses
- Others – operations & management

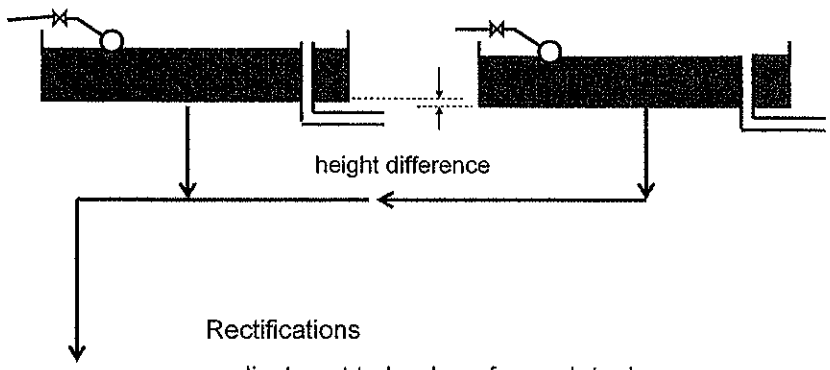
Uncontrolled Losses



Fixing Water Overflows

- Ball float valves need to be checked periodically as the water movement in the tower affects their setting
- Replacing the ball float valve with a solenoid valve linked to electronic level detectors

Uncontrolled Losses

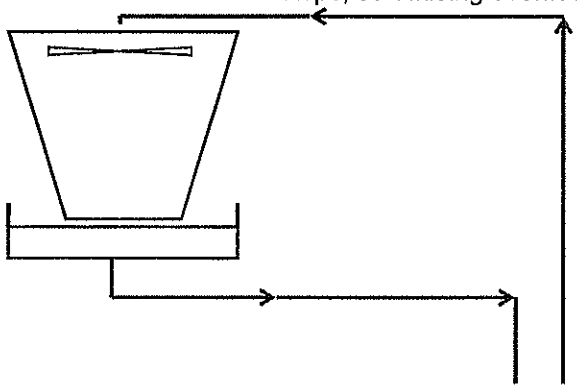


Rectifications

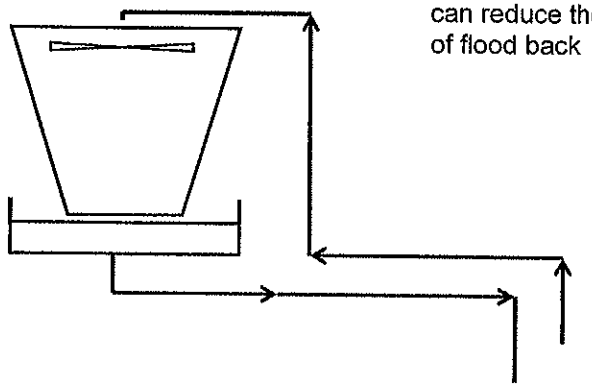
- adjustment to be done for each tank

Uncontrolled Losses

Long section of high level pipework can allow a significant quantity of water to flow back into the tower when the pump stops, so causing overflow



Uncontrolled Losses



Keeping high level pipework to a minimum can reduce the chances of flood back

Uncontrolled Losses

- Reducing Water Splashing
  - Use anti-splash louvres or splash mats
  - Use suitable wind breaks if wind is an issue
- Minimizing drift losses
  - Use drift eliminator (arrestor)
  - Drift loss < 0.002% of condenser water flow rate
- Leakage from pipes, joints, pump glands

Uncontrolled Losses

- Reducing uncontrolled water losses
  - minimize overflow of water from tower basin
  - adjust incorrectly set piping configuration
  - arrest leaks in tower basin, joints, pump seals
  - reduce back flooding
  - reduce excessive drift
  - reduce water splash

Controlled Losses

- Controlling Bleed
  - install conductivity controller to automatically control bleed
  - clean conductivity sensor monthly and re-calibrate it at least once every 6 months
  - have automatic bleed lockout to stop the bleed drain discharging treated water to waste while the biocide injection is in progress

Controlled Losses

- Managing cycles of concentration
  - Consult with water treatment contractor to check the possibility to increase the 'cycles of concentration'
  - A COC of 6 or better shall be achieved (recommended)

Controlled Losses

- The percentage of water saved by increasing COC can be calculated by :

$$= [COC_2 - COC_1] / [COC_1 (COC_2-1)] \times 100\%$$

COC_1 – COC before increasing cycle
COC_2 – COC after increasing cycle

example

Cost of water	$2.12/m^3
Cost of water treatment	$6.00/m^3
Total Cost	$8.12/m^3
Make-Up water flow rate	20 m^3 / d
Operating period	300 d x 24 hr

Annual water savings

COC – increase from 3 to 10 (26% savings)

Water savings	5.2 m^3 / d
Annual water savings	300x5.2 =1560m^3
Annual $ savings	$8.12 x 1560
	= $12,667

Controlled Losses

- Monitoring water use
  - Flow meters
  - Conductivity meters
- Install side-stream filtration
- Operate blow down in continuous mode

Operations

Minimize water use through effective contractor management

Water treatment contract

Monthly Reports

Contracts

- Work closely with your water treatment contractor to reduce bleed off. Reducing bleed off will also reduce your chemical purchasing requirements
- Require water treat contractors to commit to a pre-determined minimum level of water usage and make this a KPI
- Cooling tower shall operate a the highest practical COC. Contract needs to stipulate the desired number of cycles. Use this as a KPI

Contracts

- When purchasing chemicals for treating cooling tower water, have the supplier explain the purpose and action of each chemical
- Include in the service schedule a requirement that the contractor cleans the conductivity probe on a monthly basis and recalibrates the bleed controller at least once every six months

Contracts

- Make up water and blowdown water flow and conductivity should be monitored, logged and charted. The COC should be logged and charted.
- When commissioning new cooling towers, ensure that the condenser water system is pre-treated as per the water treatment contractors recommendations.

Contracts

- Get the water treatment contractor to report or attend to water wastage problems in a timely manner.

Contracts

- Monthly Reports
  - Analysis readings of flow meter for make-up water
  - Analysis of readings of conductivity meter
  - Attention for reports of uncontrolled losses

Q & A

Water Management

Water Efficient Irrigation

Outline

- Design of Landscape
  - Selection / grouping of plants
  - Reduction of turf areas
- Use of water efficient irrigation system
  - Controllers
  - Drip irrigation
  - Rain sensors

- Use of non-potable water
  - Rainwater
  - NEWater
  - condensate

Water Efficient Plants

- Where applicable, use drought resistance plants or plants that fit naturally into the existing climatic conditions including rainfall and temperature pattern and require little irrigation
- The amount of turf area should be limited as most turf grasses need a lot of water and require continual upkeep
- Group plants by their water needs such as plants that need high, moderate or little to no irrigation rather than their appearance

Reference : Handbook on Skyrise Greening in Singapore

Water Efficient System

- Controllers
  - Independent programs, allow differing waterdays, start times, station running times
  - Automatic, semi-automatic
  - Flexible watering day schedules
  - Zoning

Water Efficient System

- Consideration for Selecting Irrigation System
  - Climatic Conditions
    - Potential evaporation / transpiration rate
  - Plant type
    - Tree , shrubs, ground cover, turf etc
  - Soil texture
    - Course, medium or fine

Equation Energy

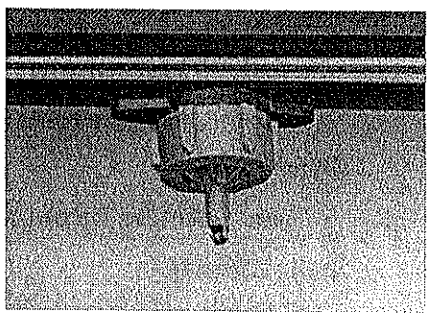
Water Efficient System

- Features
  - Applies water slowly
  - Direct to the roots
  - Small flexible pipes
  - Flow control devices

Equation Energy

Water Efficient System

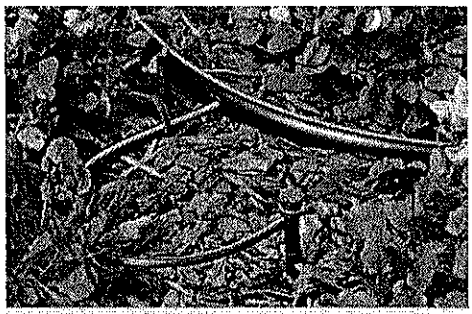
- Drip Irrigation
  - frequent, slow, application of water to the specific root zone area of the plant material



Equation Energy

Water Efficient System

- Drip Irrigation
  - since water is applied directly to the root, evaporation and run-off is minimized



Equation Energy

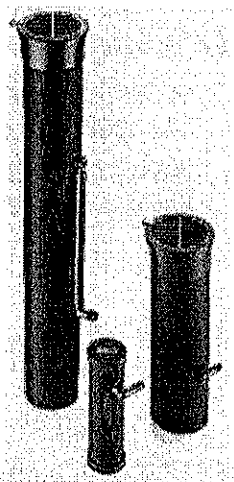
Water Efficient System

- Why use drip irrigation ?
  - prevents over spray and run off
  - conserves water
  - reduce weed growth
  - drip irrigation allow flexibility and will work with both pvc & polyethylene

Equation Energy

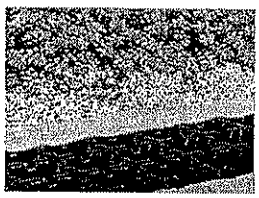
Water Efficient System

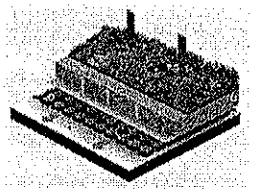
- Roots Watering System (RWS)
- allows water , oxygen, nutrients to bypass compacted soil and reach three and shrub root systems directly encouraging roots to grow deep and remain below the surface

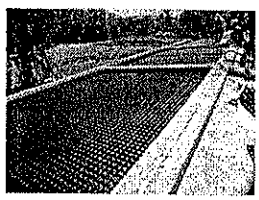


Equation Energy

Water Efficient System



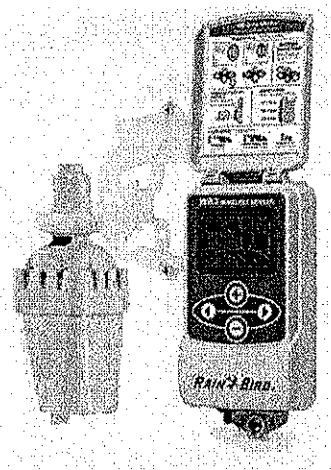






Equation Energy

Water Efficient System



- Rain sensors
  - mounting rain sensor as close to the controller as possible
  - avoid sprinkler spray, exposed to unobstructed rainfall
  - similar sun exposure as the landscape being watered

Equation Energy

Water Efficient System

- Best Practices
  - water landscape at cooler hours of the day
  - water your plants only before 9am or after 5pm to minimize evaporation loss
  - water every third day
  - understand plant , soil, water relationship

Water Efficient System

- water about 4mm/day or 21mm/week
- ground cover / shrubs / small tree
  - 4-8 litres per sqm
- turf
  - 8-12 litres per sqm
- trees (dry weather)
  - 15-40 litres per sqm

Water Supply

- Potable Water
  - Hoses / sprinklers not to be used
  - PUB Regulations disallow any person from using water supplied by PUB to water any garden, lawn or other land including commercial market gardens, commercial nurseries, sports grounds, golf courses, race courses, by means of a hose or a fixed or movable sprinkler

Water Supply

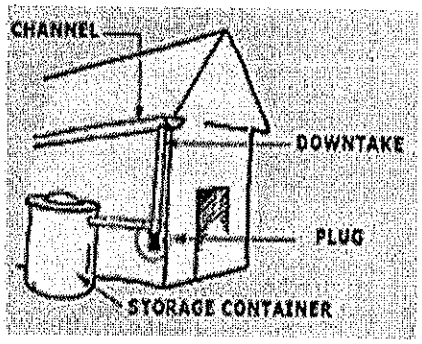
– However, nothing in the regulations prevents such person from using a bucket, can or other similar container or a hose fitted with a controlling device specified by the Board for this purpose.

Water Supply

- NEWater
  - permitted for use
  - backup supply for rain water harvesting

Water Supply

- RainWater Harvesting
  - process of collecting, filtering and storing rain water from roof tops, paved and unpaved areas for multiple uses.
  - about 2500 mm of rainfall per year in Singapore



Q & A