KLM Technology Group
#03-12 Block Aronia,
Jalan Sri Perkasa 2
Taman Tampoi Utama
81200 Johor Bahru
Malaysia


# PROCESS DESIGN OF COOLING TOWERS

# (PROJECT STANDARDS AND SPECIFICATIONS)

## TABLE OF CONTENT


SCOPE 3
REFERENCES 3
DEFINITIONS AND TERMINOLOGY 3
UNITS 8
GENERAL 9
TYPES OF COOLING TOWERS 10
Natural Draught Towers 10
Mechanical Draught Towers (see Figs. 1b, c and d) 11
DESIGN CONSIDERATIONS 16
Design Parameters 16
Ambient Air Temperatures 16
Approach 17
Cooling Range and Water Quantity 17
Effect of Altitude 17
Packings 17
Water Loadings 18
Drift Losses 18
Windage Losses 18
Recirculation 19
Hydrocarbon Detection System 19

**WATER QUALITY** **19**
**Make-Up Water** **19**
**Circulating Water** **20**
**COLD CLIMATE DESIGN CONSIDERATIONS** **20**
**General** **20**
**Avoidance of Icing by Air Control** **21**
**Avoidance of Icing by Control of Water Load** **21**
**Effects of Anti-Icing Flow on Tower Capacity** **22**
**SITING, SPACING AND ENVIRONMENTAL CONSIDERATIONS** **23**
**General** **23**
**Siting** **23**
**Spacing** **24**
**Environmental Considerations** **24**
**GUARANTEES** **29**
**APPENDIX A** **30**

## SCOPE

This Project Standards and Specifications covers the minimum process design requirements, field of application, selection of types, design consideration and thermal process design for cooling towers.

## REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. BSI (British Standards Institution)

   BS 4485 "British Standard Specification for Water Cooling Towers"

   - Part 1: 1969, "Glossary of Terms"
   - Part 2: 1988, "Methods for Performance Testing"
   - Part 3: 1988, "Thermal Design Principles"
   - Part 4: 1975, "Structural Design of Cooling Towers"

2. CTI (Cooling Tower Institute, USA)

   CTI Bulletin NCL-109 "Nomenclature for Industrial Water Cooling Tower"

   \- "Acceptance Test Code"

3. ASME (American Society of Mechanical Engineers)

   \- "ASME Test Code Section VIII

## DEFINITIONS AND TERMINOLOGY

In the preparation of this glossary care has been taken to standardize only suitable terms and definitions, dealing with the thermal design as mentioned by the British Standard Glossary and CTI of USA.

**Air Flow -** Air flow is total quantity of air including associated water vapor flowing through the tower

**Ambient Wet Bulb Temperature -** Ambient wet bulb temperature is wet bulb temperature of air measured windward of the tower and free from the influence of the tower.

**Approach -** Approach is difference between recoiled water temperature and nominal inlet air wet bulb temperature.

**Basin Kerb -** Basin kerb is top level of the retaining wall of the cold water basin; usually the datum point from which tower elevation points are measured.

**Cell -** Cell is the smallest subdivision of a cooling tower bounded by exterior walls and partition walls which can function as an independent unit as regards air and water flow.

**Cell Height -** Cell height is the distance from basin kerb to top of fan deck but not including fan stack.

**Cell Length -** Cell length is the dimension parallel to longitudinal axis and the plane where louvres are usually placed.

**Cell Width -** Cell width is the dimension perpendicular to tower longitudinal axis and usually at right angles to the louvre area.

**Circulating Water Flow -** Circulating water flow is the quantity of hot water flowing into the tower.

**Cold Water Basin (Basin Pond) -** Cold water basin is a device underlying the tower to receive the cold water from the tower, and direct its flow to the suction line or sump.

**Column Anchor -** Column anchor is a device for attaching the tower structure to the foundation; it does not include the foundation bolt.

**Concentration -** Concentration is the increase of impurities in the cooling water due to the evaporative process.

**Concentration Ratio -** Concentration ratio is ratio of the impurities in the circulating water and the impurities in the make-up water.

**Cooling Range (Range) -** Cooling range is the difference between the hot water temperature and the recooled water temperature.

**Discharge Stack -** Discharge stack is that part of the shell or casing of a forced draught tower, through which the outlet air is finally discharged. (See "fan stack" for induced draught towers and "shell" for natural draught towers.)

**Distribution Basin -** Distribution basin is the elevated basin used to distribute hot water over the tower packing.

**Distribution Header -** Distribution header is pipe or flume delivering water from inlet connection to lateral headers, troughs, flumes or distribution basins.

**Distribution System -** Distribution system is those parts of a tower beginning with the inlet connection which distribute the hot circulating water within the tower to the point where it contacts the air.

**Down Spout -** Down spout is a short vertical pipe or nozzle used in an open distribution system to discharge water from a flume or lateral on to a splash plate.

**Drift Eliminator -** Drift eliminator is a system of baffles located in the tower designed to reduce the quantity of entrained water in the outlet air.

**Drift Loss -** Drift loss is water lost from the tower as liquid droplets entrained in the outlet air.

**Effective Volume -** Effective volume is the volume within which space the circulating water is in intimate contact with the air flowing through the tower.

**Fan -** Fan is a rotary machine which propels air continuously. This is used for moving air in a mechanical draught tower and is usually of the axial-flow propeller type. The fan may be of induced draught or forced draught application.

**Fan Casing -** Fan casing is those stationary parts of the fan which guide air to and from the impeller. In the case of an induced draught fan, the casing may form the whole or part of the fan stack.

**Fan Deck -** Fan deck is surface enclosing the top of an induced draught tower, exclusive of any distribution system which may also form a part of the enclosure.

**Fan Drive Assembly -** Fan drive assembly is components for providing power to the fan, normally comprising driver, drive shaft and transmission unit, and primary supporting members.

**Fan Duty (Static) -** Fan duty (Static) is the inlet volume dealt with by a fan at a stated fan static pressure.

**Fan Duty (Total) -** Fan duty (total) is the inlet volume dealt with by a fan at a stated fan total pressure.

**Fan Power -** Fan power is the power input to the fan assembly, excluding power losses in the driver.

**Fan Stack -** Fan stack is cylindrical or modified cylindrical structure enclosing the fan in induced draught towers.

**Fan-Stack Height -** Fan-stack height is the distance from the top of the fan deck to top of fan stack.

**Fan Static Pressure -** Fan static pressure is the difference between the fan total pressure and the fan velocity pressure.

**Fan Total Pressure -** Fan total pressure is the algebraic difference between the mean total pressure at the fan outlet and the mean total pressure at the fan inlet.

**Fan Velocity Pressure -** Fan velocity pressure is the velocity pressure corresponding to the average velocity at the fan outlet, based on the total outlet area without any deductions for motors, fairings, or other bodies.

**Film Packing -** Film packing is an arrangement of surfaces over which the water flows in a continuous film throughout the depth of the packing.

**Heat Load -** Heat load is rate of heat removal from the circulating water within the tower.

**Hot Water Temperature -** Hot water temperature is temperature of circulating water entering the distribution system.

**Inlet Air -** Inlet air is air flowing into the tower; it may be a mixture of ambient air and outlet air.

**Inlet Air Wet Bulb Temperature -** Inlet air wet bulb temperature is average wet bulb temperature of the inlet air; including any recirculation effect. This is an essential concept for purposes of design, but is difficult to measure.

**Louvres -** Louvres is members installed in a tower wall, to provide openings through which air enters the tower; usually installed at an angle to the direction of air flow to the tower.

**Make-Up -** Make-up is water added to the circulating water system to replace water loss from the system by evaporation, drift, purge and leakage.

**Motor Rated Power -** Motor rated power is nameplate power rating of the motor driving the fan.

**Nominal Inlet Air Wet Bulb Temperature -** Nominal inlet air wet bulb temperature is the arithmetical average of the measurements taken within 1.5 m of the air inlets and between 1.5 m and 2.0 m above the basin kerb elevation on both sides of the cooling tower.

**Nominal Tower Dimensions -** Nominal tower dimensions is dimensions used to indicate the effective size of cells, or cooling tower. In the horizontal plane, they refer to the approximate width and length of packed areas, and in the vertical plane to the height above basin kerb level.

**Outlet Air -** Outlet air is the mixture of air and its associated water vapor leaving the tower. (See Air flow.)

**Outlet Air Wet Bulb Temperature -** Outlet air wet bulb temperature is average wet bulb temperature of the air discharged from the tower.

**Packing (Filling) -** Packing is material placed within the tower to increase heat and mass transfer between the circulating water and the air flowing through the tower.

**Plenum -** Plenum is the enclosed space between the eliminator and the fan stack in induced draught towers, or the enclosed space between the fan and the packing in forced draught towers.

**Purge (Blow Down) -** Purge is water discharged from the system to control concentration of salts or other impurities in the circulating water.

**Recooled Water Temperature -** Recooled water temperature is average temperature of the circulating water entering the basin.

**Recirculation (Recycle) -** Recirculation is that portion of the outlet air which re-enters the tower.

**Shell -** Shell is that part of a natural draught tower which induces air flow.

**Splash Packing -** Splash packing is an arrangement of horizontal laths or splash bars which promotes droplet formation in water falling through the packing.

**Splash Plate -** Splash plate is used in an open distribution system to receive water from a down spout and to spread water over the wetted area of the tower.

**Spray Nozzle -** Spray nozzle is used in a pressure distribution system to break up the flow of the circulating water into droplets, and effect uniform spreading of the water over the wetted area of the tower.

**Sump (Basin Sump or Pond Sump) -** Sump is a lowered portion of the cold water basin floor for draining down purposes.

**Standard Air -** Dry air having density of 0.0011 kg/L, at 21°C and 0.7 atm (531 mm Hg).

**Tower Pumping Head -** Tower pumping head is the head of water required at the inlet to the tower, measured above the basin kerb to deliver the circulating water through the distribution system.

**Water Loading -** Water loading is circulating water flow expressed in quantity per unit of packed plan area of the tower.

**Wet Bulb Temperature -** Wet bulb temperature is the temperature indicated by an adequately and wetted thermometer in the shade and where applicable protected from strong ground radiation.

**UNITS**

This Standard is based on International System of Units (SI) except where otherwise specified.

## GENERAL

1. A water cooling tower is a heat exchanger in which warm water falls gravitationally through a cooler current of air.

   Heat is transferred from the water to the air in two ways:

   a. by evaporation as latent heat of water vapor;
   b. by sensible heat in warming the air current in its passage through the tower.

   As a general measure, about 80% of the cooling occurs by evaporation and about 20% by sensible heat transfer. The transfer of heat is affected from the water through the boundary film of saturated air in contact with the water surface. This air is saturated at the water temperature. From this saturated air film, heat transfer occurs to the general mass of air flowing through the tower.

2. In the interests of efficiency, it is essential that both the area of water surface in contact with the air and the time of contact be as great as possible. This may be achieved either by forming a large number of water droplets as repetitive splash effects in one basic kind of tower packing, or by leading the water in a thin film over lengthy surfaces.

3. Air flow is achieved either by reliance on wind effects, by thermal draught or by mechanical means. The direction of air travel may be opposed to the direction of water flow giving counterflow conditions, or may be at right angles to the flow of water giving crossflow conditions. Although the methods of analysis may be different for counterflow and crossflow conditions, the fundamental heat transfer process is the same in both cases. In some designs mixed flow conditions exist.

4. The cooling range of the tower corresponds to the difference in temperature of the air-water film between entry to and exit from the tower. Air enters the tower having wet and dry bulb characteristics dependent on the ambient conditions. It is generally in an unsaturated state and achieves near-saturation in passing through the tower. It may be considered saturated at exit in all but very dry climates.

5. Performance Characteristics

   a. The performance characteristics of various types of towers will vary with height, fill configuration and flow arrangement crossflow or counterflow. When accurate characteristics of a specific tower are required the cooling tower manufacturer should be consulted.

b. Performance tests on a cooling tower should be done in accordance with the Cooling Tower Institute (CTI) Acceptance Test Code and the American Society of Mechanical Engineers (ASME) test code.

## TYPES OF COOLING TOWERS

There are many types of tower used in evaporating cooling, generally they tend to be divided into two groups depending upon the method used for moving air through the tower:

a. natural draught;

b. Mechanical draught.

### Natural Draught Towers

1. Atmospheric tower

   a. General

      Air movement through the tower is almost entirely dependent upon natural wind forces. Water falls in a vertical path through a packing while the air moves in a horizontal path, resulting in a crossflow arrangement to achieve a cooling effect. Wind speed is a critical factor in the thermal design and should always be specified. This type of tower is infrequently used in practice.

   b. Advantage

      The advantage is that there is no mechanical or electrical maintenance.

   c. Disadvantages

      The disadvantages are as follows:

      - Narrow construction results in considerable length of tower.
      - There is high capital cost due to low thermal capacity.
      - Unobstructed location broadside on to prevailing wind is required.
      - The recooled water temperature varies widely with changes in the wind speed and direction.
      - The drift loss may be substantial under high wind conditions.

2. Hyperboloidal tower (Commonly known as hyperbolic tower)

   a. General

      Air flow is affected by the reduction in density of the column of warm saturated air within the tower shell. Secondary effects of wind velocity may

influence air flow but are not normally taken into consideration in tower design.

The choice of counterflow, mixed flow or crossflow arrangements is dictated primarily by site and economic considerations.

b. Advantages

The advantages are as follows:

- It is suited to large water flow rates.
- High-level emission of plume virtually eliminates fogging at ground level and recirculation.
- It occupies less ground space than multiple mechanical draught towers for large thermal duty.
- It is independent of wind speed and direction when compared with atmospheric towers.
- There is no fan noise.
- There is no mechanical or electrical maintenance.

c. Disadvantages

The disadvantages are as follows:

- The chimney effect of the shell diminishes as the humidity decreases and this may be a disadvantage in hot dry climates.
- Close approach is not economical.
- The considerable height of shell frequently arranged in multiple installations presents an amenity disadvantage.

**Mechanical Draught Towers (see Figs. 1b, c and d)**

1. General

Fans are used to produce air movement through the tower. This enables the air flow to be determined independently of other process conditions. Correct quantities and velocities of air may be selected to satisfy various design demands.

Several alternative ways of locating the fans in relation to tower structure are used to obtain specific advantages; also there are two basic flow arrangements for air-water flow, the counterflow and the crossflow.