PROJECT REPORT

INDUCED DRAFT COOLING TOWER

(COOLING CAPACITY EQUIVALENT TO ROOPPUR NUCLEAR POWER PLANT)

ME 310

GROUP MEMBERS:

NAME	STUDENT ID
ENAMUL HASAN ROZIN	1510070
HASIB AHMED PRINCE	1510077
MD. ANIK SARKAR	1510083

2019

Abstract:

Cooling tower are used to remove excess heat that is generated in places such as power station, chemical plants and even domestically in air conditioning units. An induced draft cooling tower is designed with equivalent cooling capacity of Rooppur Nuclear Power Plant here in this project. The structure and parts of one cell of a ten celled cooling tower is presented here. Analysis is done to cool 103341 $\frac{m^3}{hr}$ water from 41.7℃ to 27℃. NTU method is used to determine the size of a single cell of a tower and how many towers needed to fulfill the desired criteria and performance analysis of the proposed model is also done which is satisfactory. Finally, a scaled down model of a single cell is fabricated.

Problem Statement :

An induced draft cooling tower to be designed with equivalent cooling capacity of Rooppur Nuclear Power Plant. Following Specifications will be followed to design this cooling tower –

- Water inlet temp ,T_{1w} : 41.7℃
- Water outlet temp,T_{2w}: 27℃
- Air inlet temp,T_{1a} : 27℃
- Air outlet temp,T_{2a} : 40℃
- $R_H(Relative\ humidity)$ of Bangladesh : 65%
- $R_H(Relative\ humidity)$ of air outlet : 85%

Objectives:

Objective: To design an induced draft cooling tower that can fulfill following criteria:

1)Cool 103341 $\frac{m^3}{hr}$ water from 41.7℃ to 27℃.

2)Expense and performance is optimum.

3)Have reasonable effectiveness, cooling capacity and L/G ratio.

Methods/Cesign Strategy:

Due to large area and height Natural cooling tower is less popular now-a-days. So we choose forced draft cooling tower as our design.
For sizing we use NTU method as described in the literature of H. Jaber and R. L. Webb[1]. A smmary of NTU method (modified for cooling tower) is described below:

NTU=$\frac{KmA}{C_{min}}$,where Km is the mass transfer coefficient.

$C_R = \frac{m_{min}}{m_{max}}$

$\varepsilon = \frac{q_{actual}}{q_{max}}$

$q_{max} = m_{\min}(i_{i1} - i_1)$

Effectiveness and NTU is related by , $\varepsilon = \frac{1-exp[-NTU(1-C_R)]}{1-C_R\exp{(-NTU(1-C_R)]}}$

Cooling tower performance analysis is done using the following factors:
1. Range: is the contrast among the cooling-tower water gulf and vent temperature. A great CT Choice implies that the cooling-tower has possessed the capacity to lessen the water-temperature successfully, and is subsequently presentation admirably.
CT Range (°C) = [CW inlet temp (°C) –CW outlet temp (°C)]
2. "Approach" is the contrast among the coolingtower's outlet icy water temperature and surrounding wet knob temperature. Albeit, together variety and methodology ought to be checked, the Approachfis a superior pointer of cooling-tower's execution.
CT Approach (°C) = [CW outlet temp (°C) – Wet bulb temp (°C)]
3. "Cooling tower effectiveness" (in percentagef) is the proportion of variety, to the perfect variety, i.e., contrast among cooling-water delta temperature and surrounding rainy knob temperature.

$$\text{Effectiveness} = \frac{Range}{Range+approach}$$

4. “Cooling capacity” is the warmth dismissed in kCal/hr or TR, specified as result of mass stream degree of water, particular warmth and temperatured distinction.

5. “Evaporation loss” is the water amount dissipated for cooling obligation and, hypothetically, for each 10,00,000 kCals warm banned, vanishing amount workings out to 1.8 m3. An exact connection utilized regularly is
Evaporation Loss= 0.00085 x 1.8 x circulation rate x (T 1 -T 2)
where T 1 -T 2 = Temp. difference between inlet and outlet water.

6. “Cycles of concentration” (C.O.C) is the proportion of broke down objects in coursing water to the disintegrated objects in cosmetics water.

7. “Blow down” misfortunes rely on series of focus and the dissipation misfortunes and is assumed by connection Blow Down = Evaporation Loss / (C.O.C. – 1)

8. “Liquid/Gas (L/G) ratio” of a cooling-tower’s is the proportion among the water and the air masss stream rates. Against configuration esteems, occasional varieties require alteration and finetuning of water and wind stream charges to get the finest cooling-tower’s adequacy concluded procedures like water box’s stacking variations, sharp edge point modifications.

L (T1-T2) =G (h2-h1)

$$\frac{L}{G} = \frac{h2-h1}{T1-T2}$$

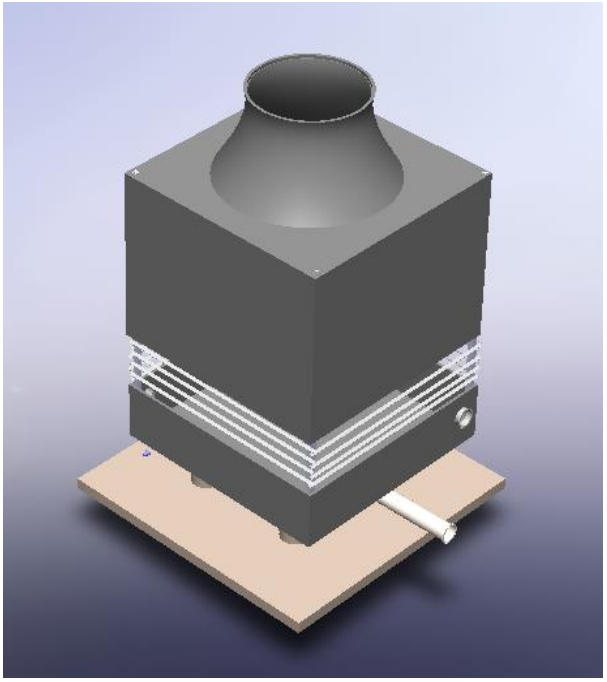
Fill type is being chose based on following table:

	Splash Fill	*Film Fill*	*Low Clog Film Fill*
Possible L/G Ratio	1.1 – 1.5	1.5 – 2.0	1.4 – 1.8
Effective Heat Exchange Area	30 – 45 m^2/m^3	150 m^2/m^3	85 - 100 m^2/m^3
Fill Height Required	5 – 10 m	1.2 – 1.5 m	1.5 – 1.8 m
Pumping Head Requirement	9 – 12 m	5 – 8 m	6 – 9 m
Quantity of Air Required	High	Much Low	Low

(BEE India, 2004; Ramarao; and Shivaraman)

Drawings and models of different parts:

Solid works design :



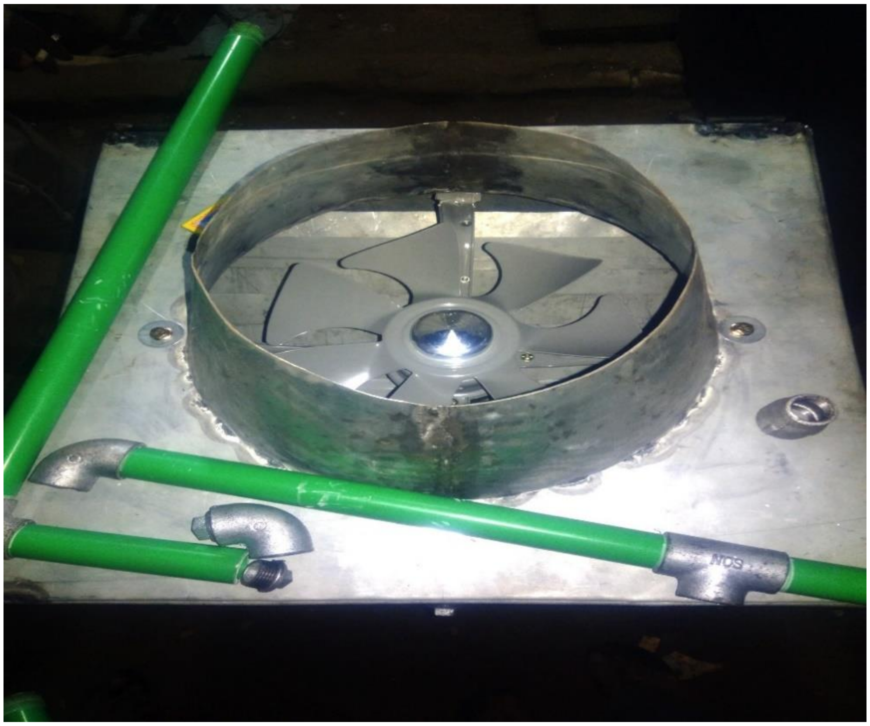
Practical Model:

Model of different parts :

Fills

Drift Eleminator

Piping system



ID Fan

Calculation and results:

FINDINGS :

- Cooling water flow,m : 103341 m^3 / hr
- Drift loss : 0.02%
- Air outlet wet bulb temp,T_{2awb} : 37.5 ℃
- Air inlet wet bulb temp,T_{1awb} : 22 ℃
- Dissolved solidsin circulating water=250 ppm
- Dissolved solids in makeup water = 30 ppm
- Water inlet enthalpy , h_1=174.71 kJ/kg
- Water inlet sat. enthalpy=163.57 kJ/kg
- Water outlet enthalpy, h_2=113.29 kJ/kg
- Air inlet enthalpy, h_3=64.29 kJ/kg
- Air outlet enthalpy, h_4=145.92 kJ/kg
- Abs humidity of air outlet,w_1=0.0411
- Abs humidity of air inlet,w_2=0.0146

Analysis of power plant

❖ Circulating water flow rate = 103341 m^3/hr

✓ **Range**:

CT Range (℃) = [CW inlet temp (℃) – CW outlet temp (℃)]

= [41.7 – 27]

= 14.7 ℃

✓ **Approach**:

CT Approach = [CW outlet temp (℃) – Wet bulb temp (℃)]

= [27 – 22]

= 5 ℃

✓ **Effectiveness**:

CT Effectiveness = {14.7/(14.7+5)}×100=74.61%

✓ **Cooling capacity**:

Cooling capacity (Q) = mass flow rate of water ×specific heat × temperature difference in kcal/hr

= 995.4*103341(kg/hr) ×4.2(kJ/kg)/4.18×16.7/3600

= 479.465 kcal/sec

Evaporaon loss:

= 0.00085 × 1.8 × 103341 ×14.7

= 2324.2424 m^3/hr

Percentage of evaporation =(2324.2424/103341)

= 2.24%

✓ **Cycles of Concentrations (COC) :**

COC =250/30=8.33

✓ **Blow down losses:**

Blow down = 2324.2424/(8.33-1)

= 317.086 m^3/hr

✓ **Make-up water required:**

Total losses in circulating water = Evaporation losses + Blow down losses + Drift losses

= 2324.2424+2.66+317.086

= 2644.7624 m^3/hr

Liquid/Gas (L/G) ratio:
L(T1-T2) = G (h3-h1)
L/G=(34.90-15.38)/14.7
=1.32789

Air flow rate :
$\dot{m}_a$=103341*994*(113.29-174.71)/{(64.29-145.92)+(.0411 - 0.0146)*113.29}
=77314343.07 kg/hr
=21476.20641 kg/s
$\dot{m}_w$=28533.59833 kg/s

NTU method:
f=$\frac{167.57-113.47}{14.7}$
=3.6802
Case 2-
So,Mmax=$\frac{28533.59\times4.179}{3.6802} = 32400.9\frac{kg}{s}$
Mmin=21476.20641 kg/s
Effectiveness=$\frac{32400.9\times(145.92-64.29)}{21476.2\times(174.71-64.29)}$=1.1153
CR=$\frac{Mmin}{Mmax}$ =.6628

NTU=$\frac{1-exp[-NTU(1-CR)]}{1-CR\times\exp(-NTU(1-CR)]}$=.6467=$\frac{kA}{Mmin}$
.$\frac{kA}{\dot{m}_a} = .6467$
KA=13888.66

Assuming k=.37
A=37536.918 m^2
No of towers =10
No of cells in each tower=10
Area of each cell=375.36
L=12m

A=4WL
W=A/ 4L
=7.82m

Pump power: P=$\gamma Qh/\eta$
h=L=12m
Q=103341/(10) m^3/hr (for each tower)
=2.8705 m^3/s
$\gamma = 9810$
$\eta = .80$
P=422 kw

nozzle type: spray nozzle.

Fan power: $\Delta P = \frac{.6\times\gamma\times n^2\times d^2\times\pi}{3600}$
d=diameter of impeller=6m
n=speed of fan =300rpm
$\Delta P = 1953.478\ Pa$

Power required=$\frac{Q\times\ \Delta P}{\eta_p}$=$\frac{(21476.20641/100)\times 1.1515\times 1953.478}{.9}$=536kw (for each cell)

Economic Calculation:

Materials name	Availavality (10)	Cost (40)	Thermal Resistance (30)	Life Expentancy (35)	Corrosion resistance (20)	Wind/Seismic/ Structral integrity (15)	Total(140)
Stainless Steel	8	20	28	22	16	12	106
Galvanized steel	6	30	24	15	14	12	101
Concrete	8	18	29	25	16	9	105
Iron	7	25	20	12	8	9	81
Copper alloys	7	25	18	10	12	8	80

Table 1: Comparison table of different materials that may be used in cooling tower structure.
According to the comparison table stainless stell is more suitable followed by concrete galvanized steel.

Some other considerations also should be considered:

- Compared to other binding materials, the tensile strength of concrete is relatively low
  - Concrete may contains soluble salts. Soluble salts cause efflorescence.
- Galvanized steel requires passivation which may not be practical.
  - When mixed with yellow brass, galvanized steel triggers dezincification, and it results in electrolytic action

when combined with nonferrous metals, such as copper and brass.

- Stainless steel is sussectible to chloride.At industrial area /power plant there’s more chloride in the atmosphere which is problematic if stainless steel is used as construction material.
-

Besides all the advantages and adverse effects we choose stainless steel as the construction material as-

- stainless steel materials has significant strength-to-weight advantage over other material options.
- Resistance to heat damage and corrosion damage.
- Resistance to temperature fluctuation.
- Uneffected by mirco-orgabism and easy to clean.
-

Volume of cooling tower per cell=200m^3

Density of stainless steel=7800 kJ/m^3

Weight of staineless steel used per cell=1560000

Per kg price of stainless steel in Bangladesh = 72 taka/kJ

Total cost for buying Iron =1560000*72=11,2300000 taka.

Fill material:

PVC *(CTI STD-136)*.Because for a cooling tower application, heat deflection temperatures, UV resistance, impact resistance, and flammability of the PVC material are all important .

Fill volume per cell=152 m3.

Price per cubic meter of pvc (CTI STD-126)=100 dollar =8000 tk.

Total price of fill= (152*8000)=1216000 tk/per cell.

Estimated total price of cooling tower=11,35,16,000 tk/cell

Conclusion:

An induced draft cooling tower is more efficient than a natural draft cooling tower. So, performane of cooling of a nuclear power plant increases if we use an induced draft cooling tower in stead of natural draft cooling tower. This is what is done in this project . We have a plan to upgrade the current design by using technological specifications. We will use ultrasonic sensor for water level measurement, pH sensor for solid scale controlling . We will also use the flow rate control system in next upgraded model.

Acknowledgement :

Special thanks to our course teachers –

- Dr. Md. Ashiqur Rahman
  Associate Professor , ME, BUET.
- Md. Rakib Hossain
  Lecturer , ME, BUET.

References:

1) “Design of Cooling Towers by the Effectiveness-NTU Method ”, H. Jaber, B. L. Webb.
2) “STUDY ON INDUCED DRAFT COOLING TOWER PERFORMANCE ANALYSIS IN CAPTIVE POWER PLANT,”UMAKANTA , C.N NATARAJ