Analysis On Cooling Water Circuit Of A Compressor House – A Case Study

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***Abstract-* This paper is basically a case study of a cooling water circuit of a compressor house of an automotive production line through which compressed air is regularly supplied to the production line. As a result there is heat generation in compressors which are involved in production of compressed air. The case study is done in a compressor house in which there are two compressors and the cooling circuit includes two pumps and two cooling towers. But it was observed that for cooling one compressor, two cooling towers are used due to some technical problem in the system. Several calculations are carried out for solving the issue which includes calculations of head required for cooling water circuit of compressor house and calculation of head due to pressure drop inside heat exchanger of compressor & dryer. Capacity and effecectiveness of cooling towers are also discussed. Finally the compressor house is compared with another compressor house running in proper manner which results in identification of the problem. Annual cost saving of power consumption is also discussed further**

***Keywords*—Compressor, Cooling tower, pressure drop**

I. INTRODUCTION

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers uses the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature. With respect to drawing air through the tower, there are three types of cooling towers. Natural draft utilizes buoyancy via a tall chimney. Warm, moist air naturally rises due to the density differential to the dry, cooler outside air. Warm moist air is less dense than drier air at the same pressure. This moist air buoyancy produces a current of air through the tower. Mechanical draft uses power driven fan motors to force or draw air through the tower. Induced draft is a mechanical draft tower with a fan at the discharge which pulls air through tower. The fan induces hot moist air out the discharge. This produces low entering and high exiting air velocities, reducing the possibility of recirculation in which discharged air flows back into the air intake. This fan/fin arrangement is also known as draw-through. Forced draft is a mechanical draft tower with a blower type fan at the intake. The fan forces air into the tower, creating high entering and low exiting air velocities. The low exiting velocity is much more susceptible to recirculation. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions. Another disadvantage is that a forced draft design typically requires more motor horsepower than an equivalent induced draft design. The forced draft benefit is its ability to work with high static pressure. They can be installed in more confined spaces and even in some indoor situations. This fan/fill geometry is also known as blow-through. [2]

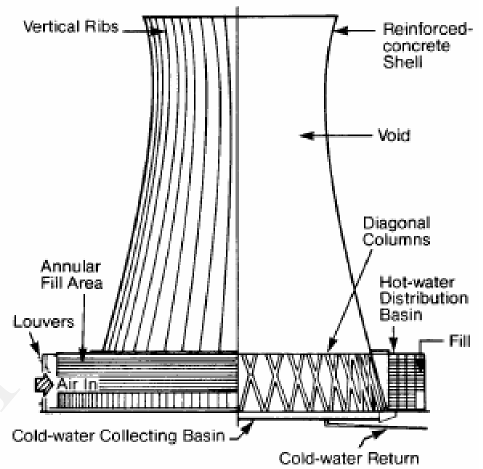

Fig. 1 Natural draft cooling tower [3]

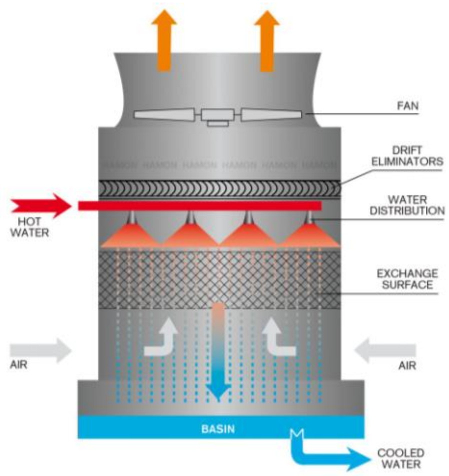

Fig. 2 Induced draft cooling tower [6]

A. *Layout of cooling water circuit of Compressor house*

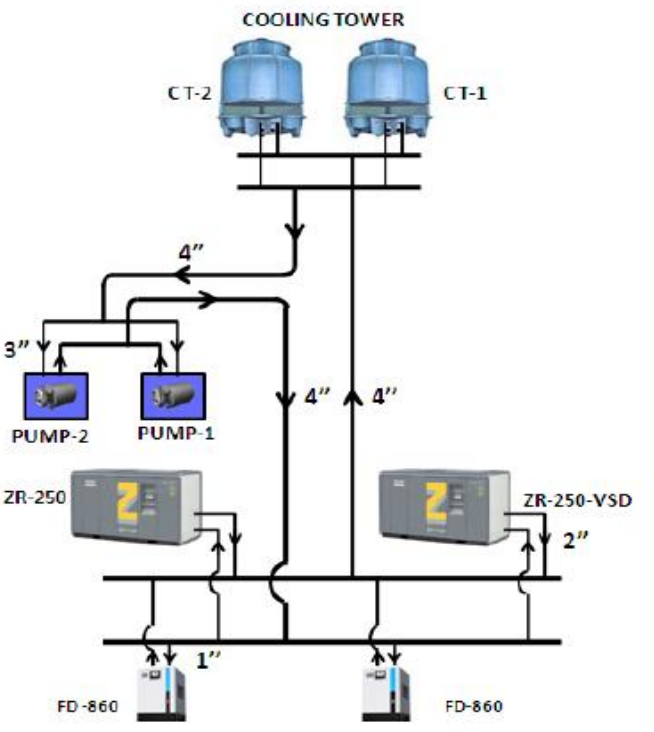

Fig. 3 This figure shows the layout of cooling water circuit of compressor house which includes cooling towers, pumps, compressors and dryers.

II. HEAD REQUIRED FOR COOLING WATER CIRCUIT OF COMPRESSOR HOUSE TOTAL HEAD LOSS [4]

For calculation of head required by pump, several observations were taken which are as follows.

- Pipe size- 1,2,3 and 4 (inches)
- Valve - butterfly and globe
- Tee - line flow and branch flow
- Bend

Frictional head loss in delivery line

<u>4-inches</u>

Bend	T- line flow	T-branch flow
7	2	6

- Straight length=209.08 ft
- Bend (equivalent length) = 7×9=63 ft
- Tee (equivalent length)= (6×22)+(2×7)=146 ft
- Total length=418 ft = *<u>125.4m</u>*

<u>3-inches</u>

- Straight length=2.58 ft
- Total length= 2.58 ft = *<u>0.774m</u>*

<u>2-inches</u>

Bend	T- line flow	T-branch flow
12	--	--

- No. Of bend = 12
- Straight length = 60 ft
- Bend (equivalent length) = (12×4.5) = 54 ft
- Total length=114 ft = *<u>34.20m</u>*

<u>1-inch</u>

Bend	Globe valve
12	2

- Straight length= 52 ft
- bend (equivalent length) = (12×2.3) = 27.6 ft
- Globe valve (equivalent length) = 48 ft
- Total length = 128 ft = *<u>38.40m</u>*

Loss of head due to friction is given as –

$H_f = (4*f*l*v^2)/(2*d*g)$

Where

- F = co-efficient of friction
- L = length (m)
- V = velocity (m/s)
- d = Diameter of Pipe (m)
- g = acceleration due to gravity (m/s^2)

Let loss of head due to friction corresponding to Pipe diameter (4,3,2,1) inches be h_1,h_2,h_3,h_4 respectively.

	L	d	V
1"	38.4	0.025	1.5
2"	34.20	0.05	1.5
3"	0.774	0.075	1.5
4"	125.	0.1	1.5

By using formula and substituting the values, results are-

- h_1 = 2.82m
- h_2 = 1.256m
- h_3 = 0.0189m
- h_4 = 2.303m

Total Head Loss h_f (Delivery) = *<u>6.397m</u>*

III. FRICTIONAL HEAD LOSS OF HEAD IN SUCTION LINE [4]

<u>4-inches</u>

Bend	T- line flow	T-branch flow
5	3	1

- Straight Length=80ft
- Bend (Equivalent Length) = 5×9=45 ft
- Tee (Equivalent Length)= (1×22)+(3×7)=43 ft
- Total Length=168 ft = *<u>50.4m</u>*

<u>3-inches</u>

- Straight Length=4 ft
- Total Length= 4 ft = <u>*1.2m*</u>

Loss of Head due to friction is given as –

$H_f = (4*F*L*V^2)/(2*d*g)$

Where

F = co-efficient of friction
L = Length (m)
V = Velocity (m/s)
D = Diameter of Pipe (m)
G = acceleration due to gravity (m/s^2)

Let loss of head due to friction corresponding to Pipe diameter (4,3,2,1) inches be h_1,h_2,h_3,h_4 respectively

	L	D	V
4	50.4	0.1	0.6
3	1.2	0.075	0.6

By using formula and substituting the values, results are-

- H_3 = 0.0189m
- H_4 = 0.0047m

Total Head Loss h_f (Suction) = <u>*0.1527m*</u>

Loss of Head due to friction in cooling water circuit comes out to be

<u>H_f = 6.549m</u>

IV. HEAD DUE TO PRESSURE DROP INSIDE HEAT EXCHANGER OF COMPRESSOR & DRYER

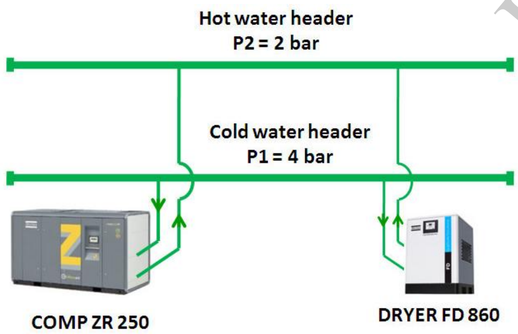

Fig. 4 This figure shows the connection of compressor and dryer with hot and cold water header showing the pressure drop in the header.[1]

As per the information given by Manufacturer (Atlas Copco)
Pressure drop in compressor =2 bar
Pressure drop in Dryer= 2 bar
All Machines (Compressor, Dryer) are connected in parallel
Pressure drop is uniform
Pressure in Cold water header= 4 bar
Pressure in Hot water header = 2 bar
Pressure drop = 2 bar
Head due to pressure drop inside heat exchanger of compressor & dryer = 2 bar = 20 m
Total Head = (H_f) + (Head due to pressure drop)

Therefore Total Head = 6.549+20 = <u>*26.549 m*</u>
For more accuracy we take Head as <u>30 m</u>
According to Manufacturer, Discharge required for Compressor & Dryer is 6.11 lps

Pump is selected by considering 2 parameters (Head, Discharge)

According to the Catalogue of Kirloskar Pumps,
Pump corresponding to Head = 30 m & Discharge = 6.11 lps is of Model 852++ which is installed in TMML compressor house.

Therefore Observations and Calculations are Satisfactory in consideration to Pump.

V. RESULT

A. *Analysis on Cooling Tower*

TABLE I

Location	Cooling Tower	Air Flow Inlet (m^3/Sec)	Motor Rating (KW)	Maximum Rated Current (Amp)	Actual Current (Amp)
TMML	CT-1	1.78	1.1	2.8	1.6
	CT-2	1.647	1.1	2.8	1.5
Eastern Complex	CT-3	2.296	1.1	2.8	2.5
	CT-4	2.096	1.1	2.8	2.4

After analysis of Cooling Towers of TMML & Eastern Complex Compressor House, Result may be concluded as follows-

1. Refer Table-1 , TMML –Compressor House's Cooling Towers have less air flow

2. Cooling Tower of TMML Compressor House is dissipating less heat as compared to Cooling Towers of Eastern Complex resulting increase of Cooling water Temperature.

3. TMML Cooling Tower fan is consuming less Current (Amp), this means that the blade angle of fan should be Readjusted in proportion to its maximum rated Current (Amp) for increasing the air flow.

4. Presently no scale has been found in cooling towers fills but it has to be maintained in future.

B. *Analysis on Pump*

TABLE II

Location	TMML	
Pump	Pump-1	Pump-2
Motor Rating (KW)	5.5	5.5
Rated Discharge(Lps)	7.5	7.5
Required Discharge(Lps)	6.5	6.5
Rated Head(m)	28-42	28-42
Required Head (m)	30	30

From Table-II, Results are concluded as follows:-

1. Both pumps runs simultaneously, that will only increase discharge in circuit however the flow rate of single pump is sufficient as required for compressor & dryer i.e. 6.5 lps.

2. There is no need to run two pumps while one pump is enough sufficient to overcome required head with required flow of water.

VI. CONCLUSION

The case study is done in a compressor house in which there are two compressors and the cooling circuit includes two pumps and two cooling towers. But it was observed that for cooling one compressor, two cooling towers are used due to some technical problem in the system. Several calculations are carried out for solving the issue which includes calculations of head required for cooling water circuit of compressor house and calculation of head due to pressure drop inside heat exchanger of compressor & dryer. Capacity and effectiveness of cooling towers are also discussed. Finally the compressor house is compared with another compressor house running in proper manner which results in identification of the problem. Annual cost saving of power consumption is calculated as follows:

With consideration of result a and b, there is energy saving
Power consumption in cooling tower can be calculated as
= 1.1x16x300 = 5280 units / year

Power consumption of pump can be calculated as
= 5.5x16x300 = 26400 units/year

1 KWh = 4.5 INR

Total Energy Saving = 31680 (KWH/Year)

Total Saving (INR/Year) = 142560.00 /-

REFERENCES

[1] Robert Robertson (1998), Compressor Air Manual, Atlas Copco, Uddvägen-7 S-131 82 Nacka Sweden.

[2] R.S. Khurmi and J.K. Gupta (2009), Refrigeration & Air Conditioning, S Chand & company Limited, New Delhi, PP-325-328.

[3] *Energy Efficiency Guide for Industry in Asia*, Electrical Energy Equipment: Cooling Towers (2006), PP-4-8.

[4] Pipeline Design Manual, Ishrae Institute, New Delhi

[5] C-tower, Marvinsilbert and Associates, Glenelia Avenue, Toronto, Ontario, Canada

[6] The Hamon Website
Available: http://www.hamon.com/en/cooling-systems/wet-cooling-systems/mechanical-draft-cooling-towers/special-application/