International Journal on Emerging Technologies **11**(5): 623-627(2020)

ISSN No. (Print): 0975-8364
ISSN No. (Online): 2249-3255

Improving Cooling Capacity of HVAC System, A Case Study to Determine Efficient and Cost-Effective Opportunities at Pharma Company

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(Received 06 October 2020, Revised 17 November 2020, Accepted 11 December 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Energy is used for a wide variety of applications within the pharmaceutical industry. There are different process and technologies that are used in Pharmaceuticals for the manufacturing of products under the controlled environment. Pharmaceuticals have extensive business locally in Pakistan and worldwide. Pharma product is a high demanding with the required quality and quantity. The survival of industries in current age is becoming critical due to large consumption of energy especially in industrial sector and because of its effect on environment along with depletion of existing energy resources. The main consumption of Chilled water is required in HVAC System. The requirement of improvement for the efficiency of HVAC System, it is necessary to improve Chiller efficiency by optimizing the performance. It could be done on many ways, which includes by maintaining lower temperature at condenser water, thereby increasing the chilled water delta Temperature, minimizing complexity in distribution network, Energy Utilizes and different equipment and opportunities, generally on whole distribution system is carried out to ascertain potential design problems and resulting energy loss, selection of equipment at the time of design, operation under recommended conditions by OEM, Maintenance regimes, use of technology to improve efficiency and minimize losses.

The key challenge was to identify the changes made over the period of time to fulfil unplanned cooling needs through expansions in existing network, as-built schematics doesn't fully reflect as installed state of distribution network. Therefore, in order to fully map the distribution network, we have worked through physical verification of piping network along with their condition to map actual current state.

Keywords: Cooling system Optimization, Chilled water Distribution, HVAC System.

Abbreviations: HVAC, heating ventilation and air conditioning; AC, air conditioner; PBP, OEM Original Equipment Manufacturer.

I. INTRODUCTION

Cooling System is an integral part of entire HVAC System. Cooling system generation consist of Chilled Water System i.e. Chiller & Cooling Tower and Fuel Sources i.e. Boiler in case of Steam Absorption Chiller, Electricity in case of Electric Chiller and Natural Gas in case of Direct Fired Chillers. Once the chilled water generated in the system. The pump and distribution networks should be capable to transfer the Chilled water to the Air Handling Units without compromising the required flow rate and temperature of water, Key element of an HVAC System is an efficient cooling system that provides Chilled water to the system. Chilled water system contains the generation and continuous flow of Chilled water to the Air Handling Units, any issues in the Chilled water system would directly impact the HVAC System and increase energy demand with less efficiency.

There are several issues can be found in Cooling system that cause huge Energy losses and large Operation Cost in which

— Selection of Chilled Water Distribution Scheme
— Distribution Network
— Pump Sizes (Head Size etc.)
— Pipe Sizing for Correct Flow and Friction Losses
— Insulation & Cladding
— Maintenance Routines.

The survival of industries in current age is becoming critical due to large consumption of energy especially in industrial sector and because of its effect on environment along with depletion of existing energy resources. So, it is necessary to design an ideal system through which energy consumption can be minimized [4].

Aim of this study to study existing Airconditioning System of the Pharmaceutical Plant in which mainly its Chilled Water distribution to explore the opportunities in improvement, to reduce cost of Energy and provide required Quality standard air-conditioning to the manufacturing and packaging areas [5].

II. MATERIALS AND METHODS

Table 1: Mythology and tools used to identify the potential opportunities in the cooling system.

Mythology	Tools
Literature Review & Visual Observation	Literature Study, GEMBA Walk, Work Study Etc.
Data Collection of Technical Design Parameters	Obtain and Review Technical Submittals, Equipment details, Layouts, Schematics
Distributed Network Analysis of Existing System E.g. Cooling system Parameters, Flow etc.	Verify Design parameters and actual installation through SOPs Logs, Layouts, Schematics, Data Sheets etc.
Distributed Network Analysis of Proposed System	Through Worksheet, Data Sheets, Calculations with Formulas, Network design modeling

III. RESULTS AND DISCUSSION

A. Chilled Water Distribution Network

Observation/Analysis

Analysis of Chilled water circuit was performed by taking the actual flow of all Air Handling Units and Pipe sizing and performed analysis to check the existing pipe size are adequate for the flow

Now below Calculations to verify the same.

$$Pipe\ \text{Diameter} = \sqrt{\frac{4*\text{Flow rate}}{\pi*\text{Velocity}}} \quad (1)$$

$$\text{Velocity} = \frac{4*\text{Flow Rate}}{\pi*(\text{Pipe Diameter})^2} \quad (2)$$

$$\text{Flow Rate} = \frac{1}{4} * \pi * (\text{Pipe Diameter})^2 * \text{Velocity} \quad (3)$$

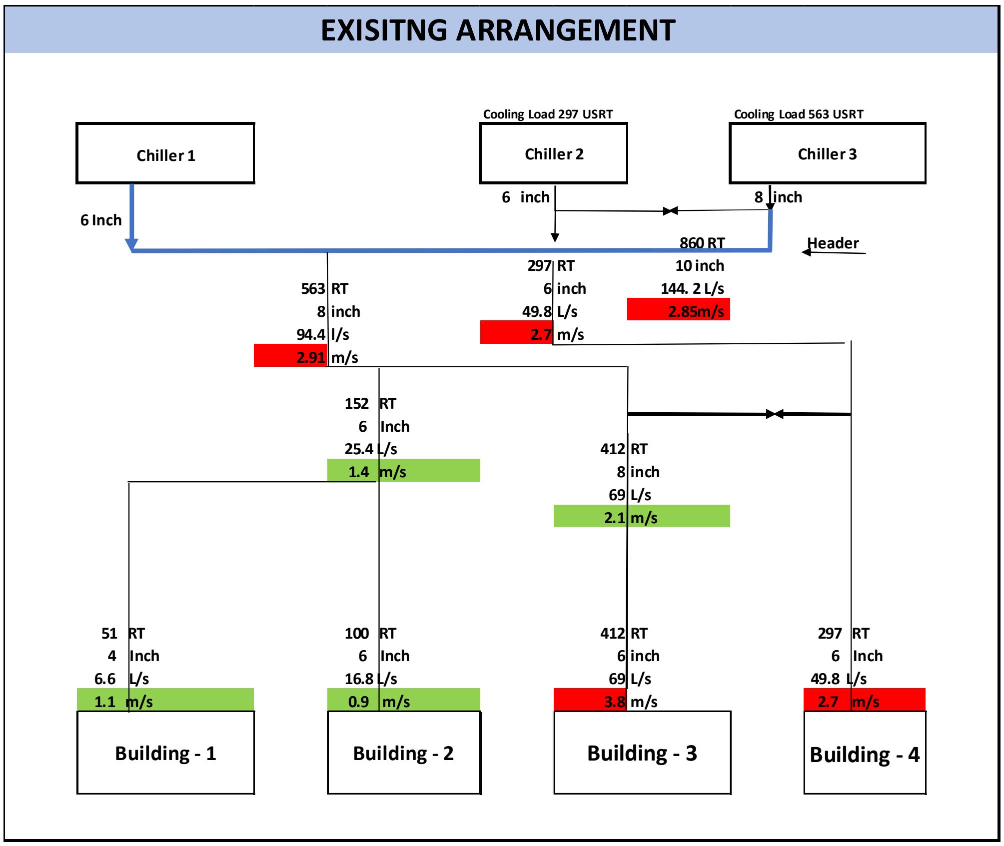

Fig. 1. Existing Distribution System.

Table 2: Existing Velocities on Chilled water distribution.

Equipment	Cooling Capacity kW	Cooling capacity RT	Diversity	Operational Tonnage	Flow	Chilled Water Line Size			Velocity
	KW	RT	%Age	RT	L/s	Inch	Equv. DN	M	m/s
Existing									
Chiller No1 & 2 & 3	3,010.0	860.0	100%	860.0	144.2	10.0	280	0.3	2.85
Chiller No1 & 3	1,970.5	563.0	100%	563.0	94.4	8.0	225	0.2	2.91
Chiller 2	1,039.5	297.0	100%	297.0	49.8	6.0	160	0.2	2.73
Chiller No1 & 3	532.0	152.0	100%	152.0	25.4	6.0	160	0.2	1.39
for Building 3 & 4	1,442.0	412.0	100%	412.0	69.0	8.0	225	0.2	2.13
For Building 3 Only	1,442.0	412.0	100%	412.0	69.0	- 6.0	160	- 0.2	3.78
for Building 4 only	1,039.5	297.0	100%	297.0	49.8	6.0	160	0.2	2.73
for Building 1	178.5	51.0	100%	51.0	6.6	4.0	110	0.1	0.81
for Building 2	350.0	100.0	100%	100.0	16.8	6.0	160	0.2	0.92

— The size of the main header is 8 inches this causes fluid velocity upto 4.4m/s which is on higher side. High velocity in Fluid pipes causes Friction Loss, Vibrations, Erosion & Corrosion and also could become potential cause of Hydraulic Shocks.

— Noise considerations (high velocities and turbulence can cause noise problems in occupied areas)

— The link valve between two chiller causes unbalanced flow which would impact overall requirement of chilled water in the circuit.

— To run both chillers simultaneously, the header is under sized and would not accommodate required flow.

As per ASHREA Standard for pipe sizing Pipe Sizing. All chilled-water and condenser water piping shall be designed such that the design flow rate in each pipe segment shall not exceed the values listed in Table 3 for the appropriate total annual hours of operation. Pipe size selections for systems that operate under variable flow conditions (e.g., modulating two-way control valves at coils) and that contain variable-speed pump motors are allowed to be made from the "Variable Flow/Variable Speed" columns. All others shall be made from the "Other" columns [11].

Table 3: From ASHRAE Standard 90.1-2007, Piping System Design Maximum Flow Rate in Liters/Second (SI)."

Operating hour/ year	**<2000 Hours/year**		**>2000 and 4400 hours/year**		**> 4400 and < 8760 hours/year**	
DN Pipe Size, mm	**Other**	**Variable Flow / Variable Speed**	**Other**	**Variable Flow/ Variable Speed**	**Other**	**Variable Flow /Variable Speed**
75	8	11	5	8	4	4
90	11	17	9	13	7	7
110	22	33	16	25	13	13
140	26	39	20	30	16	16
160	47	69	36	54	28	28
225	53	82	41	61	32	32
280	114	170	82	126	63	63
315	158	240	120	183	95	95
Maximum Velocity for pipes over 315 mm	**2.6m/s**	**4.0 m/s**	**2.0 m/s**	**2.9m/s**	**1.5m/s**	**2.3m/s**

B. Proposed arrangement

Piping system design are installed to work flawlessly over the long period of time to fulfil cooling need of the system with reduce maintenance cost. Impact of high velocity creates not only the disruption in the overall networks also decreased piping infrastructure life and encounter high maintenance cost. In order to maintain the required velocity in the piping system, below are the recommendations. Total hours of operation were calculated as 6000 hrs/year.

— The ideal Main header size for future cooling load of 860USRT would be 12 inches

— Chiller 1 & 3 Header size of the 10 inches. This results in fluid velocity of just under 2m/s which is ideal for reduced hydraulic losses.

— It is recommended to close the link line when two chillers are running even after upgrading the main header to 10 inches.

— Increase Head Size of Building 3 & 4 to 8 inches.

Table 4: Proposed Velocities on Chilled water distribution.

Proposed A - Replace Existing Header Line Size									
Equipment	**Cooling Capacity**	**Cooling capacity**	**Diversity**	**Operational Tonnage**	**Flow**	**Chilled Water Line Size**			**Velocity**
Chiller No. 1 & 2 & 3	3,010.0	860.0	100%	860.0	144.2	12.0	315	0.3	1.98
Chiller No. 1 & 3	1,970.5	563.0	100%	563.0	94.4	10.0	280	0.3	1.86
Chiller 2	1,039.5	297.0	100%	297.0	49.8	8.0	225	0.2	1.54
Chiller No. 1 & 3	532.0	152.0	100%	152.0	25.4	6.0		0.2	1.39
for Building 3 & 4	1,442.0	412.0	100%	412.0	69.0	8.0		0.2	2.13
For Building 3 Only	1,442.0	412.0	100%	412.0	69.0	8.0	225	0.2	2.13
for Building 4 only	1,039.5	297.0	100%	297.0	49.8	8.0	225	0.2	1.54
for Building 1	178.5	51.0	100%	51.0	6.6	4.0		0.1	0.81
for Building 2	350.0	100.0	100%	100.0	16.8	6.0		0.2	0.92

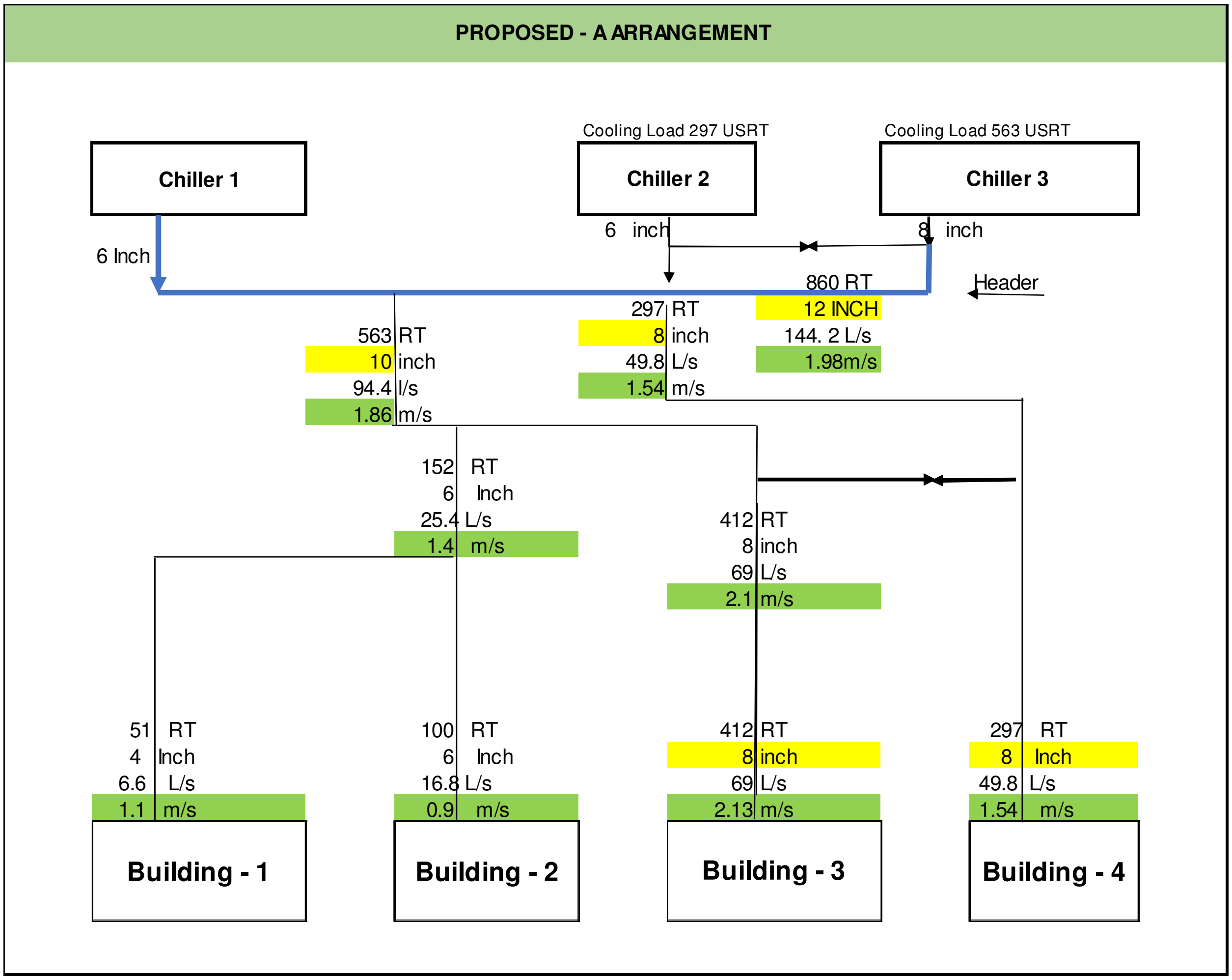

Fig. 2. Proposed arrangement for Distribution network.

IV. CONCLUSION

— Distribution network should be designed to meet the required velocity to minimize Friction Loss, Noise & Vibrations, Erosion & Corrosion. Chilled water system design should be kept by keeping the future provisions so that Pipe sizing at Central plant room will have adequate space to cater the future demand. The low velocity causes losses in flow which directly impact the performance of Chiller water system. In view of data analysis, there are number of opportunities are identified that will help in improving Chilled water system capacity and capability in cost effective manner with low payback.

V. FUTURE SCOPE

Details analysis of pumping system and header sizes along with piping distances from source to user point could be done to further improve the distribution system and identify the losses due to large distance. There could be an opportunity to rather fed the complete system from central plant room, chillers can be placed at nearest location with dedicated fixed loop to get improved efficiency and energy saving.

ACKNOWLEDGEMENTS

This research was supported by Mehran University of Engineering & Technology Jamshoro Pakistan as part of Final year thesis.

Conflict of Interest. There is no Conflict of interest.

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How to cite this article: M. Faisal, Shaikh, S. A., Samo, S. and Harijan, K. (2020). Improving Cooling Capacity of HVAC System, A Case Study to Determine Efficient and Cost-Effective Opportunities at Pharma Company. *International Journal on Emerging Technologies, 11*(5): 623–627.